

Preliminary and Incomplete: August 23, 2004

PRICING LEGAL OPTIONS:

A BEHAVIORAL PERSPECTIVE

*Oren Bar-Gill**

Abstract

Many legal rules can be interpreted as creating options. Option pricing is thus important for understanding the ex ante effects of these rules. And, recognizing that individuals, whose behavior the law aims to influence, are imperfectly rational, a behavioral option pricing model is a potentially helpful tool for legal policy. This paper develops such a model and applies it to a series of legal problems in tort law, contract law, corporate law and criminal law.

Keywords: Options, behavioral law and economics, optimism, overconfidence.

JEL Classification: K12, K13, K22, K42.

* Harvard University, the Society of Fellows; and Harvard Law School, the John M. Olin Center for Law, Economics and Business.

This paper greatly benefited from comments and criticisms by Ronen Avraham, Michal Barzuza, Lucian Bebchuk, Sharon Hannes, Dotan Oliar, Gideon Parchomovsky and Rip Verkerke. I thank the John M. Olin Center for Law, Economics and Business at Harvard Law School and the William F. Milton Fund of Harvard University for generous financial support.

1. Introduction

Many legal rules provide individuals with choices or options. What is the value of these legal options? How do they influence the ex ante decision to engage in the option-bearing activity? Option pricing theory, initially developed to calculate the value of financial options, and more recently applied to price real options in business contexts, can also be used, and indeed has been used albeit sparingly, to value legal options.¹ Option pricing is important for individuals affected by option-creating rules. And a better understanding of how individuals price options is important for law-makers intent on affecting individual behavior through option-creating rules. In particular, imperfect rationality may significantly affect option pricing and thus individual behavior. This paper hopes to advance our understanding of behavioral option pricing, and to explore its implications for legal policymaking.

Option structure is pervasive in the law. Many legal rules require or allow individuals to choose between two or more options. To quote Ian Ayres: “In Hohfeldian terms, every “privilege” is an option to do some act and every “power” is the option to change some legal relation.” (Ayres, forthcoming, p. 5) Contract law either mandates or facilitates a multitude of option structures, the best known being the promisor’s choice between performing the contract or breaching the contract and paying damages (see, e.g., Katz, 2004). Recent scholarship has emphasized the option structure underlying the broad

¹ See Mahoney (1995). The option-oriented approach in the law and economics literature has largely adopted an ex post perspective which deemphasizes option pricing. See, e.g., Ayres, forthcoming. This is not to say that Ayres ignores ex ante concerns. On the contrary, Ayres emphasizes that his ‘decoupling result’ allows courts to promote ex ante efficiency without compromising ex post efficiency. Moreover, when discussing ‘election of remedies’ put options, Ayres studies how these options deter or facilitate the initial taking (Ayres, forthcoming, pp. 48-52). But Ayres does not option pricing theory to explore the ex ante implications of legal options. Bebchuk (2001) develops an ex ante model comparing the incentive effects of property rules versus liability rules. Bebchuk, however, does not explicitly treat liability rules as options and does not engage in option pricing.

liability rule category (see, e.g., Ayres, forthcoming). Tort law provides the potential tortfeasor with a choice between avoiding (or minimizing) the risk of harm and bearing liability for failure to prevent (or reduce) the risk of harm. Criminal sanctions create a similar choice: obey the law or bear the sanction for breaking the law. In corporate law, the limited liability principle gives the entrepreneur an option not to pay her company's debt. When an entitlement is encroached upon, the law often gives the entitlement owner a choice between injunctive relief and monetary damages. Consumer protection law guarantees, in certain circumstances, an option to return the merchandise. And the list continues.

The law creates many ex post choices. Ex ante, individuals will often be uncertain about the choice that they or others will end up making. Option pricing determines the ex ante value of the legally-created ex post choice, and thus directly affects the ex ante incentives created by legal rules. If option pricing determines the ex ante incentives generated by many legal rules, it is important to develop an accurate account of how individuals price options. Option theory tells us how individuals *should* price options, or how perfectly rational individuals price options (see Brealey and Myers, 2003). But individuals are not perfectly rational. And these irrationalities may have systematic effects on how individuals price options.

In particular, individuals engaged in option pricing are susceptible to two distinct types of bias in perceiving the distribution of asset or liability values that underlies the option: an optimism bias and an overconfidence bias.² Suppose that the actual

² Clearly optimism and overconfidence with respect to the distribution of asset or liability values that underlies the option do not exhaust the range of potential deviations from perfect rationality that might affect option pricing. For example, optimism can also affect the option's exercise price. See Section 3.1. Other behavioral phenomena also affect option pricing. See Section 4.1.

distribution is fully characterized by its mean and variance. An optimistic individual perceives a distribution of asset values with too large a mean (as if the actual distribution is shifted to the right), and a distribution of liability values with too small a mean (as if the actual distribution is shifted to the left).³ An overconfident individual, while possibly perceiving a correct mean, believes that the variance of the distribution is smaller than it actually is (i.e. the perceived distribution is too tight).⁴ Of course, individuals can be both optimistic and overconfident simultaneously.

The analytical distinction between optimism and overconfidence, defined in terms of the first and second moments of a probability distribution, sits well with the treatment of these two biases in the cognitive psychology literature and the terminology employed in this literature.⁵ It should be noted, however, that the behavioral economics literature sometimes adopts a different terminology, using both “optimism” and “overconfidence” to refer to a mean-related bias.⁶

Not surprisingly, optimism increases the perceived value of the option-generating activity. But this overall effect of optimism often occurs *despite* the contrary effect of

³ The prevalence of the optimism bias has been demonstrated in numerous studies. See, e.g., Cyert, Dill and March (1958), Weinstein (1980), Taylor (1989), Kahneman and Lovallo (1993), Babcock and Loewenstein (1997), Langevoort (1997), Camerer and Lovallo (1999), and Bazerman (2002). The exploding behavioral finance literature documents investor optimism. See, e.g., Lamont and Thaler (2003).

⁴ The prevalence of the overconfidence bias is well recognized. See, e.g., Alpert and Raiffa (1969), Lichtenstein et al. (1977), Kahneman and Tversky (1979), Griffin and Tversky (1992), and Bazerman (2002). Lichtenstein et al. (1977) summarize the evidence as follows: “The overwhelming evidence from research on uncertain quantities is that people’s probability distributions tend to be too tight.” (at p. 314). Arrow (1982), summarizing the evidence from an economics perspectives, writes: “there is a tendency to underestimate uncertainties.” Tversky and Kahneman (1974) argue that the overconfidence bias stems from the anchoring and (insufficient) adjustment heuristic. In the financial options context, Stein (1989) found that investors systematically ignore mean reversion in stock price volatility, and thus overestimate long-term volatility. See also Thaler (1993), Part II (collecting articles demonstrating the prevalence of irrational expectations regarding stock price volatility).

⁵ See references cited in notes 3 and 4 above.

⁶ See, e.g., Bazerman and Zajac (1991) and Camerer and Lovallo (1999). Other behavioral economics papers distinguish overconfidence from optimism and define overconfidence in a way similar to the definition proposed in the present study. See, e.g., Kyle and Wang (1997), Rabin and Schrag (1999) and Bernardo and Welch (2001). The optimism and overconfidence biases, as defined here, also relate to the displacement and variability biases, as defined in Spetzler and Stael von Holstein (1975).

optimism on the perceived value of the option. This claim merits some clarification. First, note that framing is critical for understanding the effects of optimism. Optimism increases the perceived value of an asset, while decreasing the perceived cost of a liability. It is therefore important to distinguish between asset-based options and liability-based options according to the distribution—of asset values or of liability values—that underlies the option. Separating asset-based and liability-based options reveals a symmetry between asset-based call options and liability-based put options, and a corresponding symmetry between asset-based put options and liability-based call options. The effects of optimism, however, are asymmetric. Optimism increases the perceived value of an asset-based call option but reduces the perceived value of the equivalent liability-based put option. Similarly, optimism reduces the perceived value of an asset-based put option but increases the perceived value of a liability-based call option.

But when studying the effects of optimism on the perceived value of an option-generating activity, it might be misleading to focus only on the option component. An activity that includes a call option is generally affected by optimism only through its influence on the perceived value of the option. Accordingly, since optimism increases the perceived values of both asset-based and liability-based call options, optimists will overvalue an activity that includes a call option. An activity that includes a put option, on the other hand, is generally affected by optimism in two ways. An activity that includes a put option will often also include the asset or liability underlying the put option. When the activity includes an asset-based put option, optimism reduces the perceived value of the option but increases the perceived value of the underlying asset. Similarly, when the activity includes a liability-based put option, optimism reduces the perceived value of the

option, thus reducing the perceived value of the activity, but optimism also reduces the perceived value of the underlying liability, thus increasing the perceived value of the activity. And, since the effects of optimism on the underlying asset or liability dominate the effects of optimism on the option component, optimism consistently increases the perceived value of the activity.

Overconfidence constitutes a countervailing force to optimism. Unlike optimism, overconfidence affects only the option component of an activity's value, leading to systematic underpricing of legal options and a corresponding undervaluation of option-generating activities. Readers familiar with option pricing theory should not find this result surprising. The value of an option is increasing in the volatility of the underlying asset (see Black and Scholes, 1973; Brealey and Myers, 2003). If overconfidence leads to underestimation of volatility, it also leads to undervaluation of the option.

The intuition behind this overconfidence effect is best understood through an example. A seller contracts with a buyer to supply a good for a set price. When signing the contract with the first buyer, the seller expects that a second buyer may come along and bid for the same good. At this *ex ante* stage, however, the seller does not know how high the second buyer's bid will be; she only knows the distribution from which this bid will come. At the *ex post* stage, after the second buyer makes his bid, the seller must choose whether to perform the contract with the first buyer or rather breach and supply the good to the second buyer. If the second buyer's bid is lower than the damages that the seller expects to pay in case of breach, she will choose performance. Otherwise, she will breach and pay damages. (I am abstracting from the possibility of renegotiation.) The value of the option to breach depends on the likelihood that the second buyer's bid will

exceed the threshold value defined by the damage measure. When an overconfident seller perceives an excessively tight distribution of bid values, she will underestimate the likelihood of a valuable breach-inducing bid, and will thus underprice the option.⁷

In many non-legal contexts the option's exercise price is known ex ante with certainty, and hence optimism and overconfidence affect only the perceived distribution of values of the underlying asset or liability. Legal options on the other hand often have a stochastic exercise price. The case where the exercise price is a court-determined sanction or damages award exemplifies the common uncertainty surrounding the exercise price of legal options. With a stochastic exercise price optimism and overconfidence play a dual role. They influence the perceived option value by distorting both the perceived distribution of values of the underlying asset (or liability) and the perceived distribution of values of the exercise price. This added complexity is tackled by demonstrating that the stochastic exercise price can be interpreted as creating a separate option, which can be priced using the basic behavioral option pricing model that assumes a deterministic exercise price.

The behavioral option pricing model bears potentially important implications for legal policy. At the descriptive level the model predicts how actual option pricing will deviate from rational option pricing; and how actual behavior will correspondingly deviate from rational behavior. If the law seeks to influence behavior by creating options, it should benefit from a more complete understanding of how imperfectly rational individuals price options. The actual incentive effects of an option-creating legal rule may be very different from those predicted by a rational option pricing model.

⁷ The explanation provided in the text assumes that the mean of the distribution of bid values is lower than the damage measure. The analysis, but not the result, changes when the mean of the distribution exceeds the damage measure. See the proof of Proposition 1(ii) in the appendix.

If liability for nuisance is aimed at deterring nuisance-generating activities, optimism might circumvent this goal, while overconfidence might lead to overdeterrence. Mispricing of a contract law option might lead to inefficient trade, or to missed opportunities for value-increasing trade. Biased valuation of an entitlement-owner's election of remedies option might distort the option-holder's decision how much to invest in the entitlement or whether to acquire the entitlement in the first place. And, when a potential encroacher suffers from biased valuation of the entitlement-holder's option, the deterrence goals of the election of remedies option might also be compromised.

At the normative level the behavioral option pricing model can help design legal rules to achieve their incentive-creating goals. If, given observed cognitive biases, a certain legal design can be expected to generate insufficient (or excessive) incentives, the model can guide policymakers towards a superior legal design that can provide better incentives while accounting for the observed biases.

It is important, however, to carefully define the proper scope of application of the behavioral option pricing model. From a normative or prescriptive perspective the model will only prove helpful when the relevant cognitive bias is observable, either directly or indirectly. Limited observability of bias levels, as well as heterogeneity in bias levels across the relevant population limit the practical force of the behavioral option pricing model.⁸

But recognizing the limits of the behavioral option pricing model should not undermine its value. In many contexts, cognitive biases are observable or can be readily inferred. In these cases, the model can be used to predict the effects of legal rules and to

⁸ Most behavioral models merit similar skepticism. See, e.g., Hillman, 2000, arguing that while behavioral decision theory is good for identifying problems with rational choice predictions, it is ill-suited as an alternative theory.

prescribe better policy. In other contexts, the model can help explain existing doctrine. For example, contract law's ambivalence towards both legal and contractual options can be at least partially explained by the relative importance of cognitive distortions in different contexts. Behavioral phenomena complicate matters for legal policymakers. But ignoring them won't make them go away. The behavioral option pricing model promises to provide a guide, albeit an admittedly imperfect guide, to the implications of cognitive biases across a broad range of legal questions.

The remainder of the paper is organized as follows. Section 2 develops the behavioral option pricing model. Section 3 explores the implications of behavioral option pricing for a series of legal problems in tort law, contract law, corporate law and criminal law. Section 4 offers concluding remarks.

2. Behavioral Option Pricing

2.1 Basic Calls and Puts

I begin by exploring the implications of imperfect rationality for option pricing in a simple financial options model. Consider a basic European call/put option to buy/sell an asset at $T=1$ for a price, p (the option's exercise price).⁹ At $T=1$, when the options can be exercised, the value of the underlying asset is x . At $T=0$ the option holder knows only the distribution from which the $T=1$ value of the asset will be drawn. This distribution is characterized by the density function $f(x)$ and the cumulative distribution function $F(x)$, where $f(x)=0 \forall x \notin [a,b]$. Let \bar{x} and \mathbf{s}^2 denote the mean and variance of the

⁹ The analysis in this paper focuses on European options. However, the main results apply to American options as well.

distribution, respectively.¹⁰ A rational, unbiased agent would price the call option at

$$P = \Pr(x > p) \cdot E(x - p | x > p), \quad \text{or} \quad P = \int_p^b (x - p) \cdot f(x) \cdot dx,$$

$$P = \Pr(x < p) \cdot E(p - x | x < p), \quad \text{or} \quad P = \int_a^p (p - x) \cdot f(x) \cdot dx.$$

How would an imperfectly rational agent price these options? I consider two types of biases, with respect to the value distribution: (1) a mean bias, i.e., optimism (or pessimism); and (2) a variance bias, i.e., overconfidence (or underconfidence). Optimism is defined as the difference between the mean of the perceived distribution, \hat{x} , and the mean of the actual distribution, \bar{x} : $\Delta^{opt} = \hat{x} - \bar{x}$. Overconfidence is defined as the difference between the variance of the actual distribution, \mathbf{s}^2 , and the variance of the perceived distribution, $\hat{\mathbf{s}}^2$: $\Delta^{conf} = \mathbf{s}^2 - \hat{\mathbf{s}}^2$. Let $\hat{f}(x)$ denote the distribution, as perceived by an imperfectly rational agent, suffering from optimism and overconfidence.

This imperfectly rational agent will price the call option at $\hat{P} = \int_p^b (x - p) \cdot \hat{f}(x) \cdot dx$, and

the put option at $\hat{P} = \int_a^p (p - x) \cdot \hat{f}(x) \cdot dx$.

While the implications of optimism for option pricing are straightforward and independent of the specific shape of the $f(\cdot)$ distribution, the implications of overconfidence are more subtle and can depend on the specific shape of the $f(\cdot)$ distribution. For expositional clarity, I assume that both $f(\cdot)$ and $\hat{f}(\cdot)$ are symmetric and single-peaked. This assumption, while clearly restrictive, captures a broad range of

¹⁰ While the time horizon of the option is not explicitly modeled, it is captured through the variance parameter (since a longer time horizon generally implies a higher variance).

realistic distributions.¹¹ It also allows for a more detailed study of how overconfidence affects option pricing.

The following proposition summarizes the implications of optimism and overconfidence for option pricing.

Proposition 1:

(i) An optimistic individual would overprice the call option and underprice the put option;

(ii) an overconfident individual would underprice the call and put options.

Remark: The intuition for this result, which is proved in the appendix, is as follows:

(i) An optimistic individual places excessive weight on the high-value end of the distribution. Accordingly, the optimist overestimates the likelihood that she will exercise the call option as well as the value of the underlying asset conditional upon the exercise of the option. Therefore, an optimist will overprice the call option. On the other hand, the optimist underestimates the likelihood that she will exercise the put option as well as the ex post value of the sale conditional upon the exercise of the option (the optimist overestimates the value of the asset, and thus underestimates the difference between the exercise price and the value of the asset). Therefore, an optimist will underprice the put option.¹²

¹¹ The assumption that $\hat{f}(\cdot)$ is symmetric is more difficult to defend. Still, in this preliminary attempt to formally model the implications of optimism and overconfidence for option pricing the tractability benefits of the symmetry assumption justify the compromise in descriptive accuracy.

¹² That optimism can lead to *undervaluation* of an option is counterintuitive, as optimism is closely associated with overvaluation. As long as the option holder understands what a put option is, however, overvaluation of the option can only arise from optimism regarding the option's exercise price, which is

(ii) The value of both call and put options increases with the volatility of the value of the underlying asset (see Black and Scholes, 1973; Brealey and Myers, 2003, p. 581). An overconfident individual will underestimate volatility and thus underprice the options.¹³

2.2 Assets-Based versus Liability-Based Options

The basic financial call and put options both have an underlying asset that can be bought (in the case of a call option) or sold (in the case of a put option) at a positive exercise price. While some legal options share this characteristic, others are best characterized as having an underlying liability, rather than an underlying asset. Before delving into specific legal applications of the behavioral option pricing model, it is useful to provide a general account of asset-based versus liability-based options, and to explicate the implications of behavioral option pricing for each class of options.

The liability-based options can be perceived as the mirror-image of the asset-based options. An asset-based call option to buy an asset $x > 0$ for $p > 0$ corresponds to a liability-based put option to sell a liability $x < 0$ for $p < 0$, i.e., the option-holder pays $|p| > 0$ when exercising the option. Specifically, the value of a liability-based put option is $\Pr(|x| > |p|) \cdot E(|x| - |p| \mid |x| > |p|)$, precisely the value of the corresponding asset-based call option. And an asset-based put option to sell an asset $x > 0$ for $p > 0$ corresponds to a liability-based call option to purchase a liability $x < 0$ for $p < 0$, i.e., the option-holder gets $|p| > 0$ when exercising the option. Specifically, the value of a liability-based call

only plausible when the exercise price is not known with certainty. (Overvaluation can also arise from undervaluation of the underlying asset, but such undervaluation seems inconsistent with an intuitive notion of optimism, especially since the option holder may end up keeping the asset.)

¹³ The reasoning underlying this result is a bit more subtle, especially when allowing for the possibility that $\hat{x} > p$. See the proof of Proposition 1 in the appendix.

option is $\Pr(|x| < |p|) \cdot E(p - |x| \mid |x| < |p|)$, precisely the value of the corresponding asset-based put option. The symmetry between the asset-based options and the liability-based options is depicted in figure 1.

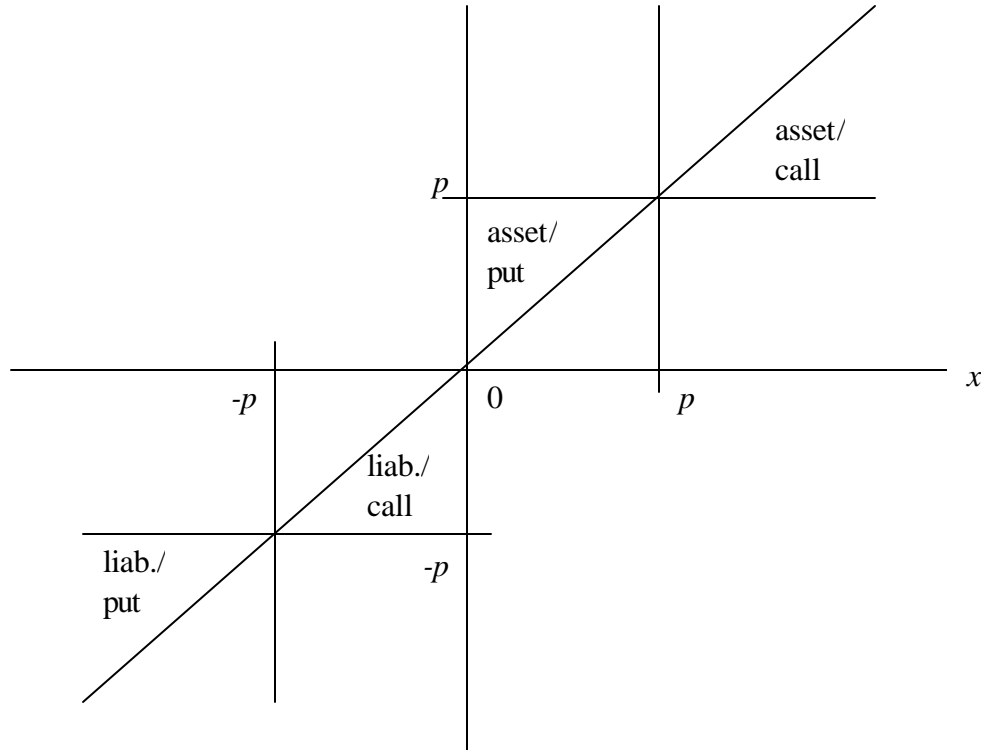


Figure 1: The symmetry between asset-based and liability-based options

The implications of optimism and overconfidence for asset-based options were summarized in Proposition 1. How do these implications translate to liability-based options? The overconfidence bias has an identical effect on asset-based and liability-based options. In both cases, the lower perceived volatility reduces the perceived value of the option. The optimism bias, however, operates differently on asset-based versus liability based options. Since optimism is sensitive to the benefit/cost framing of an asset/liability, the implications of the optimism bias for option pricing are sensitive to such framing effects.

Compare an asset-based call option to the equivalent liability-based put option. For the asset-based call option, optimism implies a greater perceived likelihood of high value realizations, which in turn implies a greater perceived likelihood that the option will be exercised as well as a higher perceived ex post value conditional upon exercise of the option. Accordingly, optimism increases the perceived value of asset-based call options. The opposite is true for the corresponding liability-based put option, where optimism implies a *lower* perceived likelihood of high (absolute) value realizations, which in turn implies a lower perceived likelihood that the option will be exercised as well as a lower perceived ex post value conditional upon exercise of the option. Optimism thus reduces the perceived value of liability-based put options. A similar comparison between an asset-based put option and the equivalent liability-based call option reveals that while optimism reduces the perceived value of the former it increases the perceived value of the latter.

Corollary 1 summarizes the implications of behavioral option pricing for the four identified categories of options: asset-based calls, asset-based puts, liability-based calls and liability-based puts.

Corollary 1:

(i) An optimistic individual would overprice both the asset-based and the liability-based call options and would underprice both the asset-based and the liability-based put options;

(ii) an overconfident individual would underprice all four option types.

2.3 Cognitive Biases Regarding Underlying Assets or Liabilities

The ultimate goal of the present analysis is to expose the implications of behavioral option pricing for ex ante decisions, specifically for the decision whether to engage in the option-bearing activity. But the effect of cognitive biases on the perceived value of an activity is not limited to their effect on the option component. Specifically, when the activity includes an asset or liability plus a put option to unload the asset or liability, the effect of the cognitive bias on the perceived value of the underlying asset or liability may dominate the option-pricing effect.

The effects of cognitive biases on the underlying asset or liability are confined to the optimism bias. Overconfidence affects only the option component of an activity's valuation; hence the overall effect of overconfidence on the value of the activity equals the effect of overconfidence on the option component. Optimism, on the other hand, affects both the option and non-option components.

Consider first an activity that includes an asset plus an asset-based put option. While optimism leads to underpricing of the option component (see Corollary 1), thus reducing the perceived value of the activity, it also leads to overestimation of the underlying asset, the non-option component, thus increasing the perceived value of the activity. And, since the non-option effect operates on the entire domain of the underlying distribution, while the option effect operates only on the low-value end of the distribution (where the legal option is relevant), the non-option effect is dominant. Optimism increases the perceived value of the activity.

Next consider an activity that includes a liability plus a liability-based put option. Again, optimism leads to underpricing of the option component (see Corollary 1), thus

reducing the perceived value of the activity, but it also leads to underestimation of the underlying liability, thus increasing the perceived value of the activity. And, again the non-option effect is dominant, implying that optimism increases the perceived value of the activity.

These results, which are formally proved in the appendix, are summarized in Corollary 2.

Corollary 2: With respect to an activity that includes an asset plus a put option to sell the asset or a liability plus a put option to unload the liability-

(i) an optimistic individual would overestimate the value of the activity; while

(ii) an overconfident individual would underestimate the value of the activity.

3. Behavioral Pricing of Legal Options

Many legal rules can be described as creating options. Section 3 studies a series of legal options and explores the policy implications of behavioral option pricing in each legal context.

3.1 Liability Rules: The Nuisance Law Example

At least since Morris (1993), it has been recognized that liability rules can be characterized as call options. The standard example in this option-oriented literature has been the nuisance example. I too begin with a generalized nuisance/conflicting uses example. Nuisance law is clearly important in its own right, and thus it is valuable to demonstrate the implications of behavioral option pricing in this context. But beyond the

consideration of the nuisance/conflicting uses example the following analysis also expounds the more general policy implications for asset-based legal call options.

Consider the following stylized conflicting uses scenario. At $T=0$ individual X chooses whether to participate in a certain activity. At $T=1$, if X proceeds with the activity, the activity will generate a stochastic return x (to X) and a harm y to individual Y. If X chooses to proceed with the activity, she will have to pay damages that are a function of the harm caused, $L(y)$. Put differently, X faces an option: proceed with the activity and pay $L(y)$, or abort the activity and lose x .¹⁴

If X decides to participate in the activity, then at $T=1$ she learns the realization of x and must choose between abandoning the activity or proceeding with the activity and paying damages. X will proceed with the activity if and only if $x > L(y)$. X has an option to buy the right to proceed with the activity for a price of $L(y)$ (Y has the initial entitlement). The $T=0$ value of this option is $P = \Pr(x > L(y)) \cdot E(x - L(y) | x > L(y))$. When the liability cost is known ex ante, this is a standard call option, with an exercise price equal to the liability cost, $L(y)$ (the case where y and/or $L(y)$ is stochastic is considered below).

This call option interpretation of liability rules is by now well understood. But, subject to a few important exceptions (Ayres, 2001, forthcoming; Bebchuk, 2001), the option-oriented analysis of liability rules has largely taken an ex post perspective, focusing on the effects of such rules on the ex post allocation of the entitlement. The

¹⁴ More generally, y measures the difference between the values of Y's use with and without X's activity. (In the specific case where Y's use is valueless given X's activity, y measures the value of Y's use without X's activity.) And, x measures the cost to X of adjusting her activity to avoid the harm to Y. (Only if the only option is total abandonment of the activity does x equal the total returns from the activity.) Thus, the scenario described in the text captures both Rule 2 and Rule 4 in the classic Calabresi and Melamed (1972) framework.

focus of the current analysis is on the ex ante perspective. The legal call option increases the value of the option-generating activity. The magnitude of this increase is determined by the value of the option; and, when the option-holder is imperfectly rational, by the perceived value of the option, as determined by the behavioral option pricing model.

At $T=0$ when an individual considers whether to engage in a certain activity, she will weigh the costs and benefits of the activity. If the activity includes a legal option, the perceived value of this option will play a role in this cost-benefit calculation. To the extent that legal rules are concerned with encouraging or to deterring participation in various activities, an assessment of the efficacy of these rules could benefit from a more realistic account of how individuals value the options that the law attaches to the regulated activities.

The implications of behavioral option pricing (and specifically of optimism and overconfidence) for the perceived value of the legal option and for the perceived value of the activity follow immediately from Corollary 1, once the liability rule in the conflicting uses scenario is identified as creating an asset-based call option. Specifically, an optimistic individual would overestimate the value of the legal option and thus overestimate the value of the activity, and an overconfident individual would underestimate the value of the legal option and thus underestimate the value of the activity.

From a legal policy perspective, these results suggest that if individuals are expected to suffer from an optimism bias, they will engage in the activity too often. Accordingly, it may be desirable to increase liability, beyond the level that would be optimal in a world without cognitive biases. This is hardly surprising. The policy

implications of overconfidence are less obvious. The preceding results suggest that if individuals are expected to suffer from an overconfidence bias, they will engage in the activity at a suboptimal rate. Accordingly, it may be desirable to reduce liability below the level that would be optimal in a world without cognitive biases.

These results can be extended as follows:

1. *Uncertainty Regarding the Exercise Price*: I have thus far assumed that the liability cost is known ex ante. But generally not only x , but also y , and thus also $L(y)$, will be stochastic variables. Moreover, even when y is deterministic judicial error can make $L(y)$ stochastic (uncertainty with respect to $L(y)$ is a product of both uncertainty with respect to the magnitude of the legal sanction and with respect to the likelihood of its imposition). Accordingly, the resulting option is a call option with an uncertain exercise price. And when the exercise price is no longer deterministic, optimism and overconfidence will affect not only the perceived distribution of values of the underlying asset but also the perceived distribution of values of the exercise price.

The implications of a stochastic exercise price on the value of the option can best be understood by positing, for a moment, a deterministic return x . With a deterministic x and a stochastic $L(y)$, the value of the call option is equivalent to the value of a liability-based put option to unload the liability $L(y)$ for an exercise price of $-x$ (the injurer pays x , i.e., she forgoes her activity). A call option with a stochastic exercise price is therefore really a combination of both an asset-based call option and a liability-based put option (See Fischer, 1978 for the general formula for pricing options with an uncertain exercise price.)

Accordingly, the aforementioned implications of optimism and overconfidence must be supplemented by the implications of the two cognitive biases on the perceived value of the put component. From Corollary 1, we know that optimism with respect to $L(y)$ reduces the value of the liability-based put option. But optimism also reduces the perceived value of the underlying liability $L(y)$. And the overall effect of optimism is to increase the perceived value of the activity (see Corollary 2). Overconfidence with respect to $L(y)$ reduces the value of the put option, and thus reduces the perceived value of the activity.

2. *Ex Ante Investments*: The preceding analysis explored the ramifications of behavioral option pricing for the ex ante value of an activity. In some sense these implications are too crude. In many cases, the question is not whether to engage in an activity, but rather how much to invest in the activity after an initial decision to engage in the activity (see Bebchuk, 2001).¹⁵ Fortunately, the preceding analysis can be adapted to study the more refined implications of optimism and overconfidence for ex ante investments.

In the conflicting uses scenario, X's incentive to invest in the activity directly depends on the likelihood that X will choose to exercise her option to proceed with the activity while harming Y (at the price of bearing tort liability), rather than abandon the activity. For instance, if optimism increases the perceived likelihood that the option would be exercised, X would have a greater incentive to invest. On the other hand, if

¹⁵ Technically, I am now relaxing the assumption that the distribution of benefits or costs underlying the option, i.e., the $f(x)$ distribution, is exogenous. While this is the standard and uncontroversial assumption with respect to most financial options, it misses an important dimension of legal options and real options more generally.

overconfidence reduces the perceived likelihood that the option would be exercised, X would have a lesser incentive to invest.

3. *Option Pricing by the Non-Option-Holder*: The preceding analysis has focused on behavioral option pricing by the option-holder. In some cases, however, behavioral option pricing might also distort ex ante decisions made by the non-option-holder. As Coase (1960) taught us, the conflicting uses scenario is inherently symmetric, in the sense that both uses are required to generate the conflict. Accordingly, in addition to analyzing X's decision whether to engage in a conflicting activity, it is also important to study Y's decision whether to engage in a conflicting activity. And Y's decision will clearly be influenced by X's option. The expected value of Y's activity (to Y) is $y - \Pr(x > L(y)) \cdot (y - L(y))$. Thus the value of Y's activity, as perceived by Y, depends on Y's estimate of the probability that X will exercise her option, an estimate that will be affected by Y's possibly biased perception of the distribution of x values.

As noted above, the nuisance/conflicting uses example is but one example of a legal rule that creates an asset-based call option. The preceding analysis is directly applicable to other legal contexts that share the same structure. For example, a seller, who signs a contract to sell a good to a buyer but expects to receive a higher bid from a second buyer, holds a call option to breach the contract and sell the good to the second buyer. The exercise price of this option is the damages that the seller will need to pay the first buyer for breach of contract. (See also Subsection 3.3). Common criminal law scenarios also share the same structure. An individual, who considers whether to engage in an activity that might lead to a criminal prospect with a return x and an expected sanction L , faces a

call option to “buy” x at an exercise price of L . (The baseline activity can be either legal or illegal. At $T=0$ an individual can establish a perfectly legal business that may provide a $T=1$ opportunity to engage in criminal tax evasion. On the other hand, at $T=0$ an individual can decide to rob a bank, knowing that he might be forced to choose between abandoning the robbery (or making do with a smaller loot) or shooting a heroic bank teller (the exercise price of the option would be the additional sanction for shooting the teller).)

3.2 Tort and Criminal Liability

While the nuisance example illustrates a tort law asset-based call option, tort law also creates many liability-based put options. Consider the following stylized model. Individual X , a potential injurer, can prevent the risk of harm of magnitude y to a potential victim, Y , at a cost, x . And, X has an option to buy the “right” to harm Y , and to avoid the precaution cost x , at the legally-determined price of $L(y)$, the tort damage measure. Put differently, X has an option to unload a liability, the duty to expend x on precautionary measures, by paying $L(y)$. Criminal law creates similar liability-based put options. A criminal, X , facing an expected sanction x , can avoid this liability by tampering with or fabricating evidence, by committing perjury, or by killing a witness—all bearing the price of additional sanctions in case the evasion tactics fail.

As stated in Corollary 1, both optimism and overconfidence lead to the underpricing of these liability-based put options. But in the tort law and criminal law scenarios described above, the option value is not the only relevant value component for the activity. The individual “owns” the underlying liability as well as the put option to unload

the liability. Accordingly, as stated in Corollary 2, optimism increases the perceived value of the activity, while overconfidence reduces the perceived value of the activity.

The implications of the behavioral option pricing model for legal policy in tort law and criminal law are similar to those outlined for the nuisance/conflicting uses example. If individuals are expected to suffer from an optimism bias, they will engage in the activity too often. Accordingly, it may be desirable to increase liability, beyond the level that would be optimal in a world without cognitive biases. Conversely, if individuals are expected to suffer from an overconfidence bias, they will engage in the activity at a suboptimal rate. Accordingly, it may be desirable to reduce liability, below the level that would be optimal in a world without cognitive biases.¹⁶

3.3 Contract Law

Contract law is option rich (see, e.g., Katz, 2004; Scott and Triantis, 2004). The most famous contractual option is the promisor's choice between performance and breach under a money damages rule. The Section 3.1 model can be readily adjusted to capture this contract law option. Let y denote the value of performance to the promisee (Y), or equivalently the harm to the promisee in case of breach. And let x denote the value to the promisor (X) of the right to withhold performance. The value to the promisor of the right

¹⁶ An alternative model yields similar policy implications: If the cost of care, x , is known ex ante and the harm, and hence the liability is stochastic, then the potential injurer X has, in addition to an underlying liability x , a liability-based put option with an uncertain exercise price. If the cost of care, x , is deterministic, then X's activity can be described as including an underlying (stochastic) liability $L(y)$ plus a liability-based put option to unload $L(y)$ at an exercise price of $-x$. From Corollary 2, we know that optimism increases the perceived value of this activity, and overconfidence reduces the perceived value of the activity. From a policy perspective, these results suggest that if individuals are expected to suffer from an optimism bias, it may be desirable to increase liability, beyond the level that would be optimal in a world without cognitive biases. And, conversely, if individuals are expected to suffer from an overconfidence bias, it may be desirable to reduce liability, below the level that would be optimal in a world without cognitive biases.

to withhold performance is the result of either an increase in the actual cost of performance, or an increase in the alternative cost of performance caused by the appearance of a competing bid. The law provides the promisor with an option to buy back his promise to perform at the legally-determined price of $L(y)$, the damage measure for breach of contract. If the reason for breach is an increase in the actual cost of performance, then the initial contract can be interpreted as including a liability—the obligation to perform—plus a put option to unload this liability (and Corollary 2 applies). If the reason for breach is the appearance of a higher bid, the initial contract can be interpreted as including an asset-based call option (and Corollary 1 applies).¹⁷

Behavioral option pricing determines the perceived value of the contract to the option-holder, the promisor, and accordingly affects the terms of the initial contract, specifically the price term (on the rational pricing of this option and its ex ante implications, see Mahoney, 1995). If an optimistic promisor overestimates the value of the option, she may be willing to accept a lower price. Conversely, if an overconfident promisor underestimates the value of the option, she may demand a higher price.

At first glance, behavioral option pricing while raising some distributive concerns, through the aforementioned price effects, does not compromise efficiency. However, a deeper examination reveals several efficiency concerns. First, in borderline cases, an optimistic promisor, who overestimates the value of the option, might enter into an

¹⁷ This description abstracts from the possibility of T=1 renegotiation. When $L(y)$ is defined by the expectation measure, then there will be no renegotiation anyway. When damages for breach deviate from the expectation measure, however, absent high transaction costs the parties will renegotiate the contract. Still, the option to breach will affect the outcome of the renegotiations. Accordingly, misperception regarding the likelihood and outcome of the renegotiation process will affect the perceived ex ante value of the option.

inefficient contract. And conversely, the higher price demanded by an overconfident promisor might prevent the parties from reaching a mutually-beneficial agreement.

Second, and related, sophisticated parties might take advantage of less sophisticated parties by structuring contracts to include an option-component that will be inaccurately valued by the less sophisticated party. In other words, sophisticated parties might deviate from the efficient contract design in order to benefit from option mispricing by the less sophisticated parties. Thus, the overall size of the contractual pie might be compromised, as long as the sophisticated party receives a bigger slice.

For example, an optimistic or overconfident promisor, thinking that she will never need to breach the contract, might attribute a zero value to the option to breach and disregard the stipulated damages provision altogether. Recognizing this misperception, a sophisticated promisee would be able to insert a high liquidated damages clause without any increase in the contract price. Ex post efficiency would thus be compromised. This is merely an option pricing reformulation of a long recognized problem with liquidated damages. The option reformulation, however, reveals that the problem is not unique to the liquidated damages context.

When one or both parties misconceive the true value of the contract, mutual consent no longer guarantees that the transaction is Pareto efficient. From a legal policy perspective, it may thus be desirable to restrict certain types of option-based contractual designs that are especially susceptible to cognitive biases. Alternatively, it may be desirable to require that sophisticated parties disclose (and warrant) their valuation of the option price.

Contract law appears to have an ambivalent attitude towards options. On the one hand, it creates many options; on the other hand it is often skeptical of option contracts. The option to breach, inherent in the law's preference for money damages, is the best-known contract law option, but by no means the only one. The doctrine of promissory estoppel grants an option to the relying party to enforce the promise. Similarly, in the context of unilateral contracts, the law interprets the beginning of performance by the offeree as creating an option to bind the offeror by completing performance. Moreover, contractual doctrines, such as the mistake doctrine, that render a contract voidable (but not void) grant an option to enforce. And the list continues (see Katz, 2004; Scott and Triantis, 2004).¹⁸

Despite creating this battery of options, contract law has traditionally been skeptical of option contracts. The illusory promise doctrine, as applied to requirements (or output) contracts for instance, exemplifies the common law's aversion to such contracts. A requirements contract is simply an option to purchase a stochastic quantity for a fixed price, the contract price. Yet contract law is reluctant to enforce such contracts (see Restatement, Sec. 77 – retaining the illusory promises rule), and when courts do enforce requirements contracts they tend to restrict the option-holder's discretion (see UCC 2-306; see also Restatement, Sec. 87(1) and UCC 2-205 for restrictions on the ability to make “firm offers”). Contract law is even skeptical with respect to its favorite option, the option to breach. When parties try to tinker with the default exercise price, as determined by the expectations measure, by setting higher liquidated damages, the penalty doctrine exposes the contract to strict scrutiny (see Restatement, Sec. 356; UCC 2-718(1)).

¹⁸ Employment law similarly creates options. For example, the employment-at-will contract provides the employer with an option to buy back her promise for a zero price.

Without claiming to explain contract law's complex relationship with options and option contracts, the behavioral option pricing model can rationalize some of the law's ambivalence towards options. Contractual options, whether supplied by legal doctrine or privately designed, can serve both ex post and ex ante goals. The relative importance of these two sets of goals varies from one context to the other. For instance, the option created by the mistake doctrine or even the option to breach and pay damages, are largely driven by ex post efficiency concerns and are designed to prevent inefficient trade (when renegotiation is imperfect). The ex ante effects of these legal options take a secondary status, when the parties at the ex ante contracting stage do not consider the possibility of mistake or underestimate the likelihood of breach. And, if parties do not price the option when negotiating the contract, behavioral option pricing need not concern contract law. Of course, contract law may well be concerned with the parties' failure to adequately consider the possibilities of mistake or breach, but this concern cannot be addressed by eliminating the option to rescind or breach the contract.¹⁹ Contract law is justified in creating options that promote ex post efficiency when the potentially adverse ex ante effects of the option are of lesser significance.

Contract law becomes more skeptical of options when their ex ante objectives are brought to the fore. This does not mean that contract law should or does avoid options in these cases.²⁰ It does mean, however, that behavioral option pricing can no longer be ignored. For example, if the parties did not contemplate the possibility of breach, the law is justified in imposing the expectation damages rule to ensure ex post efficiency. But

¹⁹ A qualification is in order. If "punishing" parties ex post by eliminating the option (and thus allowing inefficient trade) can be expected to increase contracting parties' awareness of the mistake and breach possibilities, then it may be desirable to eliminate the option.

²⁰ Scott and Triantis (2004) highlight the importance of the ex ante risk allocation role of contractual options.

when the contract includes a stipulated damages provision, indicating that the parties were aware of the option at the contracting stage, the potential adverse implications of behavioral option pricing must be taken into account. The law's endorsement of the 'perform or breach' option thus makes way to strict scrutiny of stipulated damages (see Restatement, Sec. 356; UCC 2-718(1); restrictions on non-refundable deposits (see UCC 2-718(1)) can be similarly justified; see also Eisenberg, 1995).

Contract law is justified in its concern with liquidated damages clauses. This does not mean that such clauses should never be enforced. The risks should be measured against the benefits (Edlin and Schwartz, 2002 summarize the different economic rationales supporting liquidated damages). Indeed, when the parties indicate that the option is important to them, courts will afford greater deference to the contract. For instance, rather than writing a contract with a stipulated damages clause, the parties could write an economically equivalent contract that includes an up-front (or unconditional) payment for the purchase of an explicit option, which can then be exercised by the tendering of an additional sum (see also Masten and Crocker, 1985 and Goldberg, 1998 – discussing take-or-pay and pay-or-play contracts, which are an extreme example of this contractual design where the additional sum is zero). Courts will not scrutinize this contract even though it is economically equivalent to a standard contract with a stipulated damages clause (see Katz, 2004).²¹

Requirements contracts provide another example of the legal balancing between the costs and benefits of contractual options. Ex ante objectives are clearly central in the

²¹ Katz (2004) presents the different legal treatment of these two economically equivalent contracts as a puzzle (Katz also notes a related puzzle regarding the inapplicability of the duty to mitigate damages in take-or-pay and play-or-pay contracts). The preceding discussion can be read as an attempt to solve this puzzle.

design of the option embodied in a requirements contract. Contracting parties will surely try to evaluate this option at the contracting stage, but will often misprice the option due to their cognitive biases. Refusing to enforce these contracts would avoid the risks of behavioral option pricing, but only at the greater cost of eliminating a valuable risk allocation device. Contract law thus found a middle ground: enforce a mellowed version of the option—one that restricts the range of permissible decisions that the option-holder can make in exercising the option. Restricting the option-holder's discretion clearly reduces the value of the option, but it also reduces the magnitude of the behavioral distortions. A similar balance was struck in the context of "firm offers." Contract law has evolved to allow these option contracts, but only after restricting the magnitude of the option component by imposing a time limit on the duration of the offer (see Restatement Sec. 87(1) and UCC 2-205; see also Katz, 2004, pp. 6-8).²²

3.4 The Limited Liability Company

The limited liability company allows individuals to engage in risky activities without bearing the full downside risk of these activities. Consider the following stylized model. At $T=0$ an entrepreneur invests initial capital, K , in the company and undertakes a project that at $T=1$ will yield a (net) stochastic return x . As long as the project yields a (net) return of $x \geq -K$, the entrepreneur bears the entire gain or loss from the project. But what happens when $x < -K$? Absent limited liability, and assuming she has sufficient additional capital from personal sources, the entrepreneur would bear the entire loss x . With limited liability, however, an entrepreneur facing a $x < -K$ realization can liquidate

²² An alternative explanation is that the parties in fact wanted to limit the option holder's discretion and the law is simply enforcing the parties' true intent. In some cases it may well be the case that limited discretion is optimal. In other cases, however, limited discretion will only reduce the ex ante value of the contract.

the company, losing only her initial capital investment K .²³ The entrepreneur has an option not to pay.

In other words, the entrepreneur, in addition to owning the return from the project x , also owns a put option to “sell” x , if it turns out to be a liability, for the price of $-K$ (the value of this option is $P = \Pr(x < -K) \cdot E(|x| - K | x < -K)$). Therefore, cognitive biases affect the ex ante value of the project, as follows: optimism leads to overestimation of the project’s value, while overconfidence leads to underestimation of the project’s value (see Corollary 2).

From a legal policy perspective, these results add to the debate over the desirability of limited liability (see, e.g., Hansmann and Kraakman, 1992). Limited liability induces excessive business activity. Optimism aggravates the excessive activity concern. Accordingly, if optimism among entrepreneurs is a problem (and there is evidence suggesting that this is the case, see, e.g., Pinfeld, 2001), this may provide a reason to limit limited liability.²⁴

More fundamentally, however, both optimism and overconfidence limit the adverse effects of limited liability. These cognitive biases will lead the entrepreneur to underestimate the likelihood that the project would ever produce $x < -K$. In fact, given

²³ In practice, often the entrepreneur will simply stop paying her creditors, and the creditors will force liquidation.

²⁴ One way to limit the effects of limited liability is through the imposition of a minimum capital requirement (i.e. a minimum K) on an entrepreneur who wishes to establish a limited liability company (compare: Shavell, 2004). A minimum capital requirement exists in the Netherlands for example. In the U.S. there is no general minimum capital requirement. Yet, in practice such a requirement is often imposed by lenders or rating agencies. The veil piercing doctrine also limits the effects of limited liability and thus can serve to counter the excessive activity problem created by the optimism bias. One branch of the veil piercing doctrine is based explicitly on the insufficient funding of the firm (rather than on fraud) (see Clark, 1986, p. [PINCITE]). The risk of veil piercing will likely induce the entrepreneur to increase her capital investment in the company. But even absent such an increase, the entrepreneur would have to consider the possibility that the veil will be pierced and her option—to pay only K —dissolved. (The related doctrine of equitable subordination has similar effects. See Clark, 1986, p. [PINCITE].)

sufficiently high levels of optimism and overconfidence, the entrepreneur's ex ante decisions will not be affected by limited liability. And, accordingly, legal policies and doctrines aimed at limiting the effects of limited liability would be of little consequence.

3.5 Election of Remedies as Put Options

An entitlement-holder's option to choose between different remedies after her entitlement has been initially encroached upon can be characterized as a legal put option.

The following examples from Ayres (forthcoming, pp. 24-25) are illustrative:

“Contrary to accepted wisdom, the common law does use "put options"—the right to force a nonconsensual purchase—as a mechanism for protecting entitlements: (1) if Calabresi steals Melamed's watch, Melamed has the option of suing to recover the watch (replevin) or suing to receive the watch's value (trover); (2) if Calabresi is a holdover tenant in Melamed's apartment, Melamed has the option of suing to enjoin Calabresi's continuing trespass or (at least in some jurisdictions) suing to force Calabresi to rent for up to an entire additional year; and (3) if Calabresi builds an encroaching wall on Melamed's land, Melamed has the option of suing to force Calabresi to remove the wall or suing to force Calabresi to permanently buy the encroached land. In each of these examples, after Calabresi takes Melamed's entitlement, the common law gives Melamed a put option—the option to choose court-determined damages (for permanently ceding the entitlement to the defendant) or injunctive relief (to require the entitlement).”

Consider the following stylized “election of remedies” model. At $T=0$ individual X chooses whether to purchase a certain entitlement. At $T=1$ the entitlement will generate a stochastic utility x (to X), unless the entitlement is encroached upon by Y (in which case X enjoys zero utility from the entitlement). If Y encroaches upon X 's entitlement, X faces a choice between: (a) obtaining an injunction against Y that would end the encroachment and allow X to enjoy x , and (b) suing Y for money damages equal to a court-determined amount L . X has an option to force Y to purchase the entitlement for a price of L .

At $T=1$ X already knows the realization of x , and thus will choose the injunction remedy if and only if $x > L$. The $T=0$ value of this option is $P = \Pr(L > x) \cdot E(L - x | L > x)$ (discounted by the probability of encroachment). When the court-determined damage award, L , is known ex ante, this is a standard asset-based put option, with an exercise price of L .

The $T=0$ value of the entitlement is influenced by the value of the election of remedies put option. Accordingly, the perceived option value, as determined by the behavioral option pricing model, will affect an individual's decision whether to acquire a certain entitlement or how much to invest in the underlying asset. Note, however, that since the individual owns the entitlement, as well as the put option to sell the entitlement, cognitive biases will also affect the non-option value component. Specifically, an optimistic individual would underestimate the value of the legal option, but would nevertheless overestimate the overall value of the entitlement plus the option. And, an overconfident individual would underestimate the value of the legal option and thus underestimate the value of the entitlement plus the option. (See Corollary 2)

As argued above, behavioral option pricing affects the perceived value of the entitlement, and thus influences the ex ante decisions of the option-holder how much to invest in the entitlement and whether to acquire the entitlement in the first place. But cognitive biases also affect the decision of the non-option-holder Y, whether to encroach on X's entitlement (on the deterrence effects of the election of remedies option, see Ayres, forthcoming, pp. 48-52). From Y's perspective, the expected value of encroachment is $\Pr(x < L) \cdot (y - L)$, where y is the value of the entitlement to Y.

Y's perception or misperception of this value will directly affect the efficacy of the law's attempt to protect entitlements by deterring encroachments. Specifically, if Y's possibly biased perception of the distribution of x values leads Y to overestimate $\Pr(x < L)$ and consequently to overestimate the value (to Y) of the encroachment, it may be desirable to try and boost deterrence. Conversely, if Y underestimates $\Pr(x < L)$ and consequently underestimates the value (to Y) of the encroachment, overdeterrence may result.²⁵ Unfortunately, it is not obvious how to calibrate the damages amount L to achieve optimal deterrence. Interestingly, and counterintuitively, raising the damages amount L will not necessarily increase deterrence (and lowering L will not necessarily reduce deterrence). While higher damages reduce the value of encroachment in the event that X exercises her option to sell, higher damages also increase the likelihood that Y will be able to purchase the entitlement ($\Pr(x < L)$), thus increasing the value of the encroachment to Y.

3.6 A Right to Return

The election of remedies option involves a choice between two distinct legal remedies: injunction and money damages. In some consumer contexts a similar put option is created simply by giving the buyer a right to return the merchandise. This right, while often the product of contractual design or maybe even business practice, is also in some cases required by the law (see, e.g., 16 CFR §429.1, specifying rescission rights in door-to-door sales). The exercise price of the put option created by the right to return

²⁵ I assume for simplicity that the value of the entitlement to Y (y) does not change over time. If y is stochastic and might fall below L , the deterrence effect of X's option to force a sale (in terms of deterring the initial encroachment) increases. See Ayres (forthcoming, pp. 49-50).

merchandise is generally equal to the purchase price (although it can be smaller, for example when the seller gives less-fungible store credit, rather than money back).

As in the election of remedies case, when a right to return attaches to a product, an optimistic individual would overestimate the value of the product, and an overconfident individual would underestimate the value of the product. A right to return encourages the purchase of goods with uncertain value to the consumer. From this perspective optimism can serve as a substitute for the right to return, while overconfidence dilutes the value of the option and may warrant an enhanced right to return.

In the corporate context, a put option very similar to the one created by the right to return is created by the appraisal rights granted to shareholders. After a fundamental corporate change encroaches upon the shareholders' entitlement, these shareholders are given a choice between retaining their shares and selling those shares back to the company for "fair value" (see, e.g., Clark, 1986, p. [PINCITE]).

From an ex ante perspective, appraisal rights increase the value of the shares. Optimism similarly increases the perceived value of the shares, while overconfidence dilutes the value of the appraisal option and thus reduces the perceived value of the shares. But, as in the election of remedies case, from an efficiency perspective the main concern of the appraisal remedy is probably the deterrence of inefficient corporate changes that undermine shareholder value.

As elaborated in the preceding subsection, the efficacy of the law's attempt to deter inefficient behavior by the non-option-holder depends on the cognitive biases that this party may suffer from. Specifically, the non-option-holder's estimate of the probability

that shareholders will exercise their appraisal option will be affected by this party's possibly biased perception of the distribution of the post-change share values.

The "fair value" exercise price may be used as a policy lever to correct for an excessive, or alternatively for an inadequate, level of corporate changes. Raising the "fair value" exercise price will increase deterrence by (1) raising the likelihood that shareholders will choose to exercise the appraisal option, and (2) reducing the value of the corporate change conditional upon exercise of the option. Accordingly, underdeterrence can be cured raising the "fair value" standard, while overdeterrence can be cured by relaxing the "fair value" standard.

4. Concluding Remarks

4.1 Extending the Behavioral Option Pricing Model

The behavioral option pricing model studied in this paper focused on the optimism and overconfidence biases. These two biases, which correspond to the two fundamental moments of the distribution of the underlying asset or liability, seem to be the natural starting point for an attempt to incorporate behavioral insights into option pricing theory. But option pricing can also be influenced by other behavioral phenomenon. This paper does not purport to offer a comprehensive behavioral option pricing model.

Still it is prudent to at least mention a few additional behavioral forces that could potentially have a significant effect on option pricing. First, options involve multi-period decision-making. Hence, option pricing might be affected by temporal inconsistencies, such as those falling under the alternate titles of hyperbolic discounting and preference reversals (see, generally, Loewenstein and Thaler, 1992, and Laibson, 1997; see also

Katz, 2004, pp. 33-34). For example, an option-holder might believe at $T=0$ that she will exercise the option at $T=1$, but nevertheless decide not to exercise the option at $T=1$.

Another set of behavioral phenomenon that can be expected to have a significant effect on option pricing falls under the alternate titles of ‘endowment effect,’ ‘loss aversion’ and ‘WTP-WTA disparity’ (or ‘bid-ask spread’). People tend to demand more for selling an asset than what they would be willing to pay to acquire the same asset. The reduction in utility following a loss is greater than the utility increase from a gain of the same objective magnitude. These behavioral regularities directly affect option pricing. Specifically, put options will not be exercised as often as predicted by standard models. Moreover, the framing of an option may significantly affect the price of the option. An option to avoid a loss might be priced above an option to enjoy a gain of equal magnitude, even though these two options are identical from the perspective of rational option pricing theory. (See also Ayres, forthcoming, pp. 191-194.)

4.2 Legal Rules and Endogenous Biases

I have thus far assumed that the levels of the cognitive biases are exogenously given and fixed. This assumption is helpful for understanding the short-run effects of option-creating rules. It is also helpful when changes in the level of the biases are likely independent of the legal rule. But cognitive biases are not necessarily fixed or exogenous. Market selection forces or cultural transmission mechanisms can alter the distribution of biases in the market and in the population (see, e.g., Waldman, 1994; Kyle and Wang, 1997; Heifetz and Spiegel, 1999; and Bar-Gill, 2002). If accurate option pricing is

advantageous,²⁶ these dynamic processes can be expected to produce bias combinations that lead to accurate option pricing. Interestingly, since the two biases often lead to countervailing distortions, individuals with positive levels of optimism and overconfidence can price options accurately. Thus, the positive bias levels that we observe in the real world do not necessarily imply inaccurate option pricing and suboptimal behavior. Moreover, if the dynamic, bias-molding forces are sufficiently powerful, then accurate option pricing will always occur, and policymakers might as well rely on the simpler rational pricing model. The problem, of course, is that the dynamic processes leading to these optimal bias combinations will often be slow and inaccurate.

²⁶ In some cases, inaccurate pricing can be advantageous. See, generally, Schelling (1960) and Frank (1988) – demonstrating the potential advantage of imperfect rationality in strategic interactions.

References

- Alpert W. and Raiffa H. (1969), "A Progress Report on the Training of Probability Assessors", unpublished manuscript.
- Arrow, Kenneth J. (1982), "Risk Perception in Psychology and Economics," *Economic Inquiry*, 20, 1-9.
- Ayres, Ian (forthcoming), *Optional Law: Real Options in the Structure of Legal Entitlements* (University of Chicago Press, Chicago, IL).
- Babcock, L. and Loewenstein, G. (1997), "Explaining Bargaining Impasse: The Role of Self-Serving Biases", *Journal of Economic Perspectives*, 11(1), 109-126.
- Bar-Gill, Oren. 2002. The Evolution and Persistence of Optimism in Litigation. Discussion Paper #373, John M. Olin Center for Law, Economics, and Business, Harvard Law School.
- Bazerman, M. H. (2002), *Judgment in Managerial Decision Making* (5th edition, New York, NY, John Wiley & Sons).
- Bazerman, M. H. and Zajac, E. J. (1991), "Blind Spots in Industry and Competitor Analysis: Implications of Interfirm (Mis)perceptions for Strategic Decisions", *Academy of Management Review*, 16, 37-56.
- Bernardo, A. and Welch, I. (2001), "On the Evolution of Overconfidence and Entrepreneurs", *Yale Cowles Foundation Discussion Paper No. 1307*.
- Black, Fisher and Myron Scholes (1973), "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy*, 81, 637-659.
- Brealey, Richard A. and Stewart C. Myers (2003), *Principles of Corporate Finance* (7th Ed., McGraw-Hill Higher Education, New York, NY).
- Calabresi, Guido and Douglas Melamed (1972), "Property Rules, Liability Rules, and Inalienability: One View of the Cathedral," *Harvard Law Review*, 85, 1089-???
- Camerer, C. and Lovallo, D. (1999), "Overconfidence and Excess Entry: An Experimental Approach", *American Economic Review*, 89, 306-318.
- Clark, Robert C. (1986), *Corporate Law* (Little, Brown & Co., Boston, MA).
- Coase, Ronald H. (1960), "The Problem of Social Cost," *Journal of Law and Economics*, 3, 1-???
- Cyert, R. M., Dill, W. R. and March, J. G. (1958), "The Role of Expectations in Business Decision Making", *Administrative Science Quarterly*, 3, 307-340.
- Edlin, Aaron S. and Alan Schwartz (2002), "Optimal Penalties in Contracts," *Chicago-Kent Law Review*, 78, 33-???
- Eisenberg, Melvin Aron (1995), "The Limits of Cognition and the Limits of Contract," *Stanford Law Review*, 47, 211-259.
- Fischer, S. (1978), "Call Option Pricing When the Exercise Price Is Uncertain, and the Valuation of Index Bonds," *Journal of Finance*, 33, 169-176.
- Frank, R. H. (1988), *Passion with Reason - The Strategic Role of the Emotions* (New York, NY, W.W. Norton & Company).
- Goldberg, Victor (1998), "Bloomer Girl Revisited, or How to Frame an Unmade Picture," *Wisconsin Law Review*, 1998, 1051-???
- Griffin, D. and Tversky, A. (1992), "The Weighting of Evidence and the Determinants of Confidence", *Cognitive Psychology*, 24, 411-435.

- Hansmann, Henry and Reinier Kraakman (1991), "Toward Unlimited Shareholder Liability for Corporate Torts," *Yale Law Journal*, 100, 1879-???
- Heifetz, A. and Spiegel, Y. (1999), "On the Evolutionary Emergence of Optimism", mimeo, Tel-Aviv University, Tel-Aviv.
- Hillman, Robert A. (2000), "The Limits of Behavioral Decision Theory in Legal Analysis: The Case of Liquidated Damages," *Cornell Law Review*, 85, 717-738.
- Kahneman, D. and Lovallo, D. (1993), "Timid Choices and Bold Forecasts: A Cognitive Perspective on Risk Taking", *Management Science*, 39, 17-31.
- Kahneman, D. and Tversky, A. (1979), "Intuitive Prediction: Biases and Corrective Procedures", in Makridakis, S. and Wheelwright, S. C. (Eds.), *Forecasting*, TIMS Studies in the Management Sciences, Vol. 12, 313-327.
- Kyle, A. S. and Wang, F. A. (1997), "Speculation Duopoly with Agreement to Disagree: Can Overconfidence Survive the Market Test?", *Journal of Finance*, 52, 2073-2090.
- Laibson, David (1997), "Golden Eggs and Hyperbolic Discounting," *Quarterly Journal of Economics*, 112, 443-???
- Lamont, Owen A. and Richard H. Thaler (2003), "Can the Market Add and Subtract? Mispricing in Tech Stock Carve-outs," *Journal of Political Economy*, 111, 227-268.
- Langevoort, D. C. (1997), "Organized Illusions: A Behavioral Theory of Why Corporations Mislead Stock Market Investors (and Cause Other Social Harm)", *University of Pennsylvania Law Review*, 146, 101-172.
- Lichtenstein, S., Fischhoff, B. and Phillips, L. D. (1977), "Calibration of Probabilities: The State of the Art" in Jungermann, H. and de Zeeuw, G. (Eds.), *Decision Making and Change in Human Affairs* (Amsterdam, Holland, Reidel).
- Loewenstein, George and Richard H. Thaler (1992), "Intertemporal Choice," in Richard H. Thaler, *The Winner's Curse: Paradoxes and Anomalies of Economic Life*, ch. 8 (Princeton University Press, Princeton, NJ).
- Mahoney, Paul G. (1995), "Contract Remedies and Options Pricing," *Journal of Legal Studies*, 24, 139-163.
- Masten, Scott E. and Keith J. Crocker (1985), "Efficient Adaptation in Long-Term Contracts: Take-or-Pay Provisions for Natural Gas," *American Economic Review*, 75, 1083-???
- Morris, Madeline (1993), "The Structure of Entitlements," *Cornell Law Review*, 78, 822-???
- Pinfold, John (2001), "The Expectations of New Business Founders," *Journal of Small Business Management*, 39(3), 279-285.
- Rabin, Matthew, and Joel S. Schrag (1999), "First Impressions Matter: A Model of Confirmatory Bias," *Quarterly Journal of Economics*, 114, 37-82.
- Schelling, T. C. (1960), *The Strategy of Conflict* (Cambridge, MA, Harvard University Press).
- Schwartz, Alan (1998), "A Contract Theory Approach to Business Bankruptcy," *Yale Law Journal*, 107, 1807-???
- Scott, Robert E., and George G. Triantis (2004), "Embedded Options and the Case Against Compensation in Contract Law," *Columbia Law Review*, 104, ???-???

- Shavell, Steven (2004), "Minimum Asset Requirements and Compulsory Liability Insurance as Solutions to the Judgment-Proof Problem," Harvard Olin discussion Paper No. 456.
- Spetzler, C. S., and Stael von Holstein, C. A. S. (1975), "Probability Encoding in Decision Analysis", *Management Science*, 22, 340-358.
- Stein, Jeremy (1989), "Overreactions in the Options Market," *Journal of Finance*, 44, 1011-1023.
- Thaler, Richard H. (1993), *Advances in Behavioral Finance* (Russell Sage Foundation, New York, NY).
- Taylor, S. E. (1989), *Positive Illusions* (New York, NY, Basic Books).
- Tversky, A. and Kahneman, D. (1974), "Judgment under Uncertainty: Heuristics and Biases", *Science*, 185, 1124-1131.
- Waldman, M. (1994), "Systematic Errors and the Theory of Natural Selection", *American Economic Review*, 84, 482-497.
- Weinstein, N. D. (1980), "Unrealistic Optimism about Future Life Events", *Journal of Personality and Social Psychology*, 39, 806-820.

Appendix

The Appendix collects the proofs of Proposition 1 and Corollary 2.

Proof of Proposition 1:

I begin by proving both parts of the proposition for the call option.

(i) Optimism implies: $\hat{f}(x) = f(x - \Delta^{opt})$. $\hat{P} = \int_p^{b+\Delta^{opt}} (x-p) \cdot f(x - \Delta^{opt}) \cdot dx$. And

$\partial \hat{P} / \partial \Delta^{opt} = (b + \Delta^{opt} - p) \cdot f(b) - \int_p^{b+\Delta^{opt}} (x-p) \cdot f'(x - \Delta^{opt}) \cdot dx$, or, after some simplification,

$\partial \hat{P} / \partial \Delta^{opt} = 1 - F(p - \Delta^{opt}) > 0$.

(ii) Consider first the case where $\hat{x} \leq p$. $P = \Pr[x \in (p, b)] \cdot [E[x|x \in (p, b)] - p]$. An overconfident individual would underestimate both $\Pr[x \in (p, b)]$ and $E[x|x \in (p, b)]$, and would thus underprice the option. Next consider the case where $\hat{x} > p$. Divide the domain (a, b) to the following four regions: (1) (a, p) , (2) (p, \hat{x}) , (3) $(\hat{x}, \tilde{x} = \hat{x} + (\hat{x} - p))$, and (4) (\tilde{x}, b) , such that $\Pr[x \in (p, \hat{x})] = \Pr[x \in (\hat{x}, \tilde{x})] \equiv q_1$ and $\Pr[x \in (a, p)] = \Pr[x \in (\tilde{x}, b)] \equiv q_2$. $P = 2q_1 \cdot E[x - p|x \in (p, \tilde{x})] + q_2 \cdot E[x - p|x > \tilde{x}]$, or, $P = \hat{x} - p - q_2 \cdot E[x - p|x < p]$ (since $E[x|x \in (p, \tilde{x})] = E[x|x \notin (p, \tilde{x})] = \hat{x}$). The truncating effect created by the option increases P above $\hat{x} - p$ by $q_2 \cdot [p - E[x|x < p]]$. Overconfidence reduces both q_2 and $[p - E[x|x < p]]$ (since it increases $E[x|x < p]$), leading to undervaluation of the option, i.e., $\hat{P} < P$.

Next consider the put option. The value of the put option equals $p - \hat{x}$ plus the value of

the call option $((p - \hat{x}) + \int_p^b (x - p)f(x)dx = \int_a^p (p - x)f(x)dx)$. Accordingly, the effect of

overconfidence on the valuation of the put option follow immediately from the effect

derived for the call option. The effect of optimism can also be derived using the results

obtained for the call option:

$$\partial \hat{P}^{Put} / \partial \Delta^{opt} = -1 + \partial \hat{P}^{Call} / \partial \Delta^{opt} = -1 + [1 - F(p - \Delta^{opt})] = -F(p - \Delta^{opt}) < 0.$$

QED

Proof of Corollary 2

(i) The perceived value of the activity is $\hat{V} = \hat{x} + \hat{P}$, where \hat{P} is the perceived value of the option. Consider first an activity including an asset plus a put option to sell the asset.

Since $\partial \hat{P}^{Put} / \partial \Delta^{opt} = -F(p - \Delta^{opt})$ (see proof of Proposition 1), I obtain:

$$\partial \hat{V} / \partial \Delta^{opt} = 1 - F(p - \Delta^{opt}) > 0.$$

Next consider an activity including a liability plus a put option to unload the liability.

Recall that the value of a liability-based put is equal to the value of an asset-based call.

Therefore, I can use the derivative $\partial \hat{P} / \partial \Delta^{opt} = 1 - F(p - \Delta^{opt})$ (from the proof of Proposition 1), subject to the redefinition of optimism with respect to a cost/liability

distribution as $\Delta^{optC} = -\Delta^{opt}$, to obtain:

$$\partial \hat{V} / \partial \Delta^{optC} = 1 + (\partial \hat{P} / \partial \Delta^{opt}) \cdot (\partial \Delta^{opt} / \partial \Delta^{optC}) = 1 + [-(1 - F(p + \Delta^{optC}))] = F(p + \Delta^{optC}) > 0.$$

(ii) Since overconfidence reduces \hat{P} (see Corollary 1(ii)) and since \hat{x} is not affected by overconfidence, overconfidence leads to underestimation of the value of the activity,

$$\hat{V} = \hat{x} + \hat{P}.$$

QED