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Oren Bar-Gill NYU Law School, bargill@nyu.edu

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Pricing Legal Options: A Behavioral Perspective

OREN BAR-GILL^{*} New York University School of Law

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

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. Option pricing is important for individuals affected by option-creating rules. And a better understanding of how individuals price options is important for lawmakers intent on affecting

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individual behavior through legal options. 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:5). Contract law either mandates or facilitates a multitude of option structures, the best known being the promisor's choice between either performing the contract or breaching the contract and paying damages (e.g., Katz, 2004; Scott and Triantis, 2004). Recent scholarship has emphasized the option structure underlying the broad liability rule category (e.g., Ayres, forthcoming). Tort law provides the potential tortfeasor with a choice between either avoiding (or reducing) the risk of harm, or 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. This ex ante perspective should be distinguished from the ex post perspective that has largely dominated the legal options literature. The focus of this literature has been on the use of options to efficiently allocate entitlements ex post. Hence, option pricing theory with its inherent ex ante perspective has not been invoked.¹

¹ See 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 considers how these options deter or facilitate the initial taking (48-52). But Ayres does not use 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 and liability rules. Bebchuk, however, does not explicitly treat liability rules as options, and does not engage in option pricing.

Two important exceptions should be noted. Ex ante considerations have taken center stage in the options-oriented contracts literature. This literature recognizes that the value of an ex post option provided for in the contract affects the ex ante contract price (e.g., Mahoney, 1995; Katz, 2004; Scott and Triantis, 2004). Similarly, in the litigation context, the value of the options to negotiate a settlement, to acquire information and to abandon the lawsuit have been shown to significantly affect the ex ante value of a legal claim (Cornell, 1990; Bebchuk, 1996, Huang and Grundfest, 2004).

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 options *should* be priced, or how perfectly rational decision-makers price options (Brealey and Myers, 2003). But not everyone is perfectly rational. Specifically, in the domain of legal options, where market forces cannot always be relied upon to weed out any hint of irrationality (Jolls et al., 1998:1473), it is often unrealistic to assume that those affected by legal options engage in rational option pricing. It is thus valuable—both descriptively and from a legal policy perspective—to study the implications of behavioral option pricing.

Imperfect rationality may affect option pricing in many ways. Behavioral finance has only begun to explore the implications of imperfect rationality for the pricing of financial options (e.g., Stein, 1989; Shefrin, 2001, 2005). This paper does not purport to develop a comprehensive behavioral option pricing model. Rather, it focuses on two cognitive biases that seem especially important in the real options context: optimism and overconfidence. Assume that an individual understands the option structure. For example, at T=0 the individual understands that at T=1 she will face an option to buy an asset at a predetermined price (uncertainty regarding the exercise price will be introduced shortly). The ex ante value of this option is determined by the distribution of T=1 values that the asset can take, as perceived at T=0. Accordingly, the distortions created by behavioral option pricing will derive from the individual's potentially biased perception of the distribution of asset values.

Suppose that the actual distribution of asset values that underlies the option 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).² An overconfident individual, while possibly perceiving

² The prevalence of the optimism bias has been demonstrated in numerous studies. See, e.g., Cyert et al. (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).

a correct mean, believes that the variance of the distribution is smaller than it actually is (i.e., the perceived distribution is too tight).³ 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.⁴ 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.⁵ Moreover, while the mean-related bias, optimism, has received more attention in the behavioral economics and the behavioral law and economics literatures, it is the options framework with its focus on volatility that highlights the importance of the variance-related bias, overconfidence.

Not surprisingly, optimism increases the perceived value of the optiongenerating activity. But this overall effect of optimism often occurs *despite* the contrary effect of optimism on the perceived value of the option. This claim merits some clarification. Consider first an activity that includes a call option. Optimism increases the perceived value of the call option, and accordingly increases the perceived value of the activity. No surprises so far. Now consider an activity that includes a put option. Optimism *reduces* the perceived value of the put option by reducing the perceived likelihood that the option will be exercised, as well as the perceived value of the option conditional on exercise.

But when studying the effects of optimism on the perceived value of an activity that includes a put option, it might be misleading to focus only on the

³ 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. summarize the evidence as follows: "The overwhelming evidence from research on uncertain quantities is that people's probability distributions tend to be too tight." (Lichtenstein et al., 1977;314). Arrow (1982), summarizing the evidence from an economics perspective, 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 tend to overweight recent information and underweight long-term tendencies (i.e., systematically ignore mean reversion) in stock price volatility. See also Thaler (1993), Part II (collecting articles demonstrating the prevalence of irrational expectations regarding stock price volatility).

⁴ See references cited in notes 2 and 3 above.

⁵ 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).

option component. Such an activity will often also include the asset underlying the put option. And optimism will affect the perceived values of both the option component and the non-option component of the activity. While optimism reduces the perceived value of the option component, it increases the perceived value of the non-option component. An optimist will overvalue the underlying asset and will also overestimate the likelihood of retaining the overvalued asset (recall that the optimist underestimates the likelihood of exercising the option to sell the asset). And since the effects of optimism on the non-option component dominate the effects of optimism on the option component, optimism increases the perceived value of the activity.

Unlike financial options to buy or sell positive-value assets, legal options are often best characterized as having an underlying liability, rather than an underlying asset. Consider, for example, the option to unload an obligation to compensate a potential victim for harm that the injurer's activity might cause, at the price of exercising due care (the cost of due care can be interpreted as the option's exercise price). The definition of optimism is sensitive to the asset versus liability framing. In the preceding example, an optimistic injurer will underestimate the harm-generating potential of her activity, and accordingly will underestimate the liability underlying the legal option.

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.

Luckily, the aggregate effect of optimism on the perceived value of the option-generating activity is not sensitive to the asset versus liability framing. While optimism reduces the perceived value of a liability-based put option, it increases the perceived value of the non-option component of the activity. And since this latter effect is dominant, optimism increases the overall perceived value of the activity. Similarly, optimism reduces the perceived value of asset-based put options, but nevertheless increases the perceived value of the option-generating activity. To sum up, for all the four types of options identified above—asset-based calls, asset-based puts, liability-based calls and liability-based puts—optimism increases the perceived value of the option-generating activity.

Overconfidence constitutes a countervailing force to optimism, 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 increases with the volatility of the underlying asset (Black and Scholes, 1973; Brealey and Myers, 2003). If overconfidence leads to underestimation of volatility, it also leads to undervaluation of the option. This intuition also explains why, unlike optimism, overconfidence affects only the option component of an activity's value, and is not sensitive to the asset versus liability framing of the distribution of values that underlies the option.

The overconfidence effect is best understood through an example. An entrepreneur considers building a factory at a certain location. At this ex ante stage the entrepreneur does not know how much revenue the factory will produce; she only knows the distribution of possible revenues. The entrepreneur also knows that the factory will produce some level of pollution; and if the entrepreneur at the ex post stage decides to operate the factory, rather than shut down, she will have to compensate residents living in proximity to the factory for damages caused by this pollution. Assume for now that the amount of damages is known ex ante (further assume that the mean revenue is larger than the amount of damages). Put differently, if she decides to build the factory, the entrepreneur will have an option either to operate the factory and pay the legally-determined price in damages, or to shut-down. The entrepreneur will decide to operate and pay damages, namely to purchase the right to pollute, if and only if the revenue generated by the factory turns out to be higher than the legal price.

The value of the option to pollute depends on the likelihood that the revenue generated by the factory will exceed the threshold value defined by the damage measure. When an overconfident entrepreneur perceives an excessively tight distribution of revenue values, she will underestimate the likelihood of high revenues and she will also underestimate the likelihood of low revenues. The former underestimation leads the overconfident entrepreneur to underestimate the value of building the factory; the latter underestimation leads her to overestimate this value. Absent an option to shut down, these two effects cancel out. But given the option to shut down and avoid paying damages, the former effect dominates, implying an overall underestimation of the value of building the factory.

Another layer of complexity is added to the behavioral option pricing model when the deterministic exercise price assumption is relaxed. 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 courtdetermined 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 second option, which can then be priced using the basic behavioral option pricing model developed for the deterministic exercise price case. Consider again the pollution example, now allowing for uncertainty with respect to the damage award. To focus on the option created by the stochastic exercise price, assume, for a moment, that the revenue generated by the factory is known with certainty ex ante. This new option is characterized by an underlying stochastic liability, the damages that the entrepreneur will be forced to pay, and an exercise price equal to the revenues that will have to be forgone if the entrepreneur, faced with a high liability realization, decides to shut down the factory. Applying the behavioral option pricing model, the option-generating activity will be overvalued by an optimistic entrepreneur and undervalued by an overconfident entrepreneur.

The behavioral option pricing model bears potentially important implications for legal policy. 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.

If liability for nuisance is aimed at deterring nuisance-generating activities, optimism might circumvent this goal, while overconfidence might lead to overdeterrence. But which is it—underdeterrence or overdeterrence? Is optimism the dominant bias, or rather overconfidence, or perhaps a third bias outside the scope of the basic model? In certain cases a dominant bias can be identified. Cognitive psychology provides some guidance as to the contextual characteristics of situations that are more likely to trigger different biases. Moreover, for any combination of bias levels, the behavioral option pricing model can be used to identify the dominant bias. And even when the specific bias levels are not observable and the analyst or policymaker has only a rough

estimate of the relative magnitudes of the two biases, still in many cases the model can identify the dominant bias.

But even when the model can identify the dominant bias, it is not clear that policymakers can. Even when the information necessary to identify the dominant bias exists, imperfectly rational policymakers might incorrectly interpret this information and might fail to identify the appropriate policy response even if they correctly interpret the information.⁶ Moreover, if one considers the information necessary to apply the behavioral option pricing model more malleable than the information necessary to apply the standard rational choice model, then perhaps policymakers who cannot be trusted to pursue the public interest should not be granted this additional degree of freedom to manipulate policy to their private ends.

When the dominant bias can be identified, the behavioral option pricing model yields concrete policy prescriptions. And when policymakers are sufficiently rational and sufficiently honest, they may be able to effectively use the model to design better policy. In many situations, however, the dominant bias cannot be identified (or the dominant bias is not constant across a heterogeneous population). Even in these situations, analysts and policymakers cannot ignore behavioral option pricing. At the very least, the behavioral option pricing model reveals the uncertainty surrounding the incentive effects of legal options.⁷

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, criminal law and litigation. 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).⁸ At T=1,

⁶ On the imperfect rationality of government officials—see, e.g., Rachlinski and Farina (2002).

⁷ Compare: Hillman (2000), who argues that behavioral decision theory is useful for identifying problems with rational choice predictions, but often cannot provide sufficiently robust alternative predictions.

⁸ The analysis in this paper focuses on European options. However, the main results apply to American options as well.

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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 \overline{x} and σ^2 denote the mean and variance of the distribution, respectively.⁹ A rational, unbiased agent would price the call option at $P = \Pr(x > p) \cdot E(x - p|x > p)$, or $P = \int_{p}^{b} (x - p) \cdot f(x) \cdot dx$, and the put option at $P = \Pr(x < p) \cdot E(p - x|x < p)$, or $P = \int_{a}^{b} (p - x) \cdot f(x) \cdot dx$.

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, σ^2 , and the variance of the perceived distribution, $\hat{\sigma}^2$: $\Delta^{conf} = \sigma^2 - \hat{\sigma}^2$.¹⁰ 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 $\hat{P} = \int_{a}^{b} (x-p) \cdot \hat{f}(x) \cdot dx$, and the put option at $\hat{P} = \int_{a}^{p} (p-x) \cdot \hat{f}(x) \cdot dx$.

⁹ While the time horizon of the option is not explicitly modeled, it is captured though the variance parameter (since a longer time horizon generally implies a higher variance).

¹⁰ Although theoretically individuals can be pessimistic as well as optimistic, and underconfident as well as overconfident, the analysis focuses on optimism and overconfidence as defined by $\Delta^{opt} > 0$ and $\Delta^{conf} > 0$. While in the financial options context this constraint would probably be excessively restrictive, it seems rather innocuous in the context of real, and specifically legal, options.

For expositional clarity, I assume that both $f(\cdot)$ and $\hat{f}(\cdot)$ are symmetric and single-peaked.¹¹

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 ex post 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 This assumption, while clearly restrictive, captures a broad range of realistic distributions.

The assumption that $f(\cdot)$ 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. Moreover, the main results, and specifically the result that overconfidence reduces the perceived value of the option (see Proposition 1 below), can be obtained without the symmetry assumption.

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 only plausible when the exercise price is not known with certainty. See Section 2.4 below. (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.) Alternatively, overvaluation will result if optimism operates directly on the overall value of the option. In the legal options context, however, it is less likely that the option itself will be the object of the optimism bias. See Section 4.1 below.

(ii) The value of both call and put options increases with the volatility of the value of the underlying asset (Black and Scholes, 1973; Brealey and Myers, 2003:581). 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.

Liability-based options can be perceived as the mirror image of 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 $\Pr(|x| > |p|) \cdot E(|x| - |p|||x| > |p|)$, 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, i.e., the option holder pays |p| > 0 for p > 0 corresponds to a liability-based put option. And an asset-based call 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 option is $\Pr(|x| < |p|) \cdot E(|p| - |x|||x| < |p|)$, precisely the value of a liability-based call option is $\Pr(|x| < |p|) \cdot E(|p| - |x|||x| < |p|)$, precisely the value of a liability-based call option is $\Pr(|x| < |p|) \cdot E(|p| - |x|||x| < |p|)$, precisely the value of a liability-based call option is $\Pr(|x| < |p|) \cdot E(|p| - |x|||x| < |p|)$, 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.

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.

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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 liabilitybased 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 liabilitybased 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 behavioral valuation of this activity can be decomposed into a behavioral valuation of the stand-alone asset or liability, and a behavioral pricing of the put option. Note that with a call option, the option is to buy an asset or liability, so there is no stand-alone asset or liability that needs to be evaluated in addition to the option component.

The effects of cognitive biases on the stand-alone asset or liability are confined to the optimism bias. Overconfidence affects only the option component of an activity's valuation (assuming risk-neutrality); 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 stand-alone asset, thus increasing the perceived value of the activity. To see which effect dominates, it is helpful to exploit put-call parity (Brealey and Myers, 2003). Specifically, note that the value of a stand-alone asset plus a put option to sell the asset is equal to the value of a call option on the asset plus the exercise price:

$$\overline{x} + \int_{a}^{p} (p-x) \cdot f(x) \cdot dx = \int_{p}^{b} (x-p) \cdot f(x) \cdot dx + p$$

The overall effect of optimism on the value of the activity is therefore equal to the effect of optimism on the pricing of a call option. Namely, optimism increases the overall 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 stand-alone 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.

2.4. OPTIONS WITH A STOCHASTIC EXERCISE PRICE

I have thus far focused on options with a deterministic exercise price. The exercise price of standard financial options is generally known with certainty ex ante. But the same is not true for legal options. On the contrary, most legal options have a stochastic exercise price. The polluting factory example, where the exercise price equals a court-determined damages amount, is illustrative. In this example, uncertainty about the magnitude of the harm caused by the

pollution, as well as uncertainty about the court's assessment of this harm, contributes to the overall uncertainty surrounding the option's exercise price.¹⁴

What is the value of an option with a stochastic exercise price? Consider first an asset-based call option with a stochastic 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 exercise price, p, the value of the call option is equivalent to the value of a liability-based put option to unload the "obligation" to pay p for an exercise price of -x (the option-holder pays x, i.e., she forgoes the asset). 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.¹⁵

How do optimism and overconfidence affect the perceived value of an assetbased call option with a stochastic exercise price? When the exercise price is stochastic, 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. Since an option with a stochastic exercise price can be viewed as a double option, I consider the behavioral pricing of each option component in turn. Starting with the asset-based call option, Proposition 1 has shown that optimism increases the perceived value of the option, while overconfidence reduces the perceived value of the option. Moving on to the liability-based put option, Corollary 2 has shown that here too optimism increases the perceived value of the option-generating activity, while overconfidence reduces the perceived value of the activity.

Similar results can be derived for the three other option types—asset-based puts, liability-based calls and liability-based puts—when the exercise price is stochastic. To sum up, recognizing that legal options commonly have a stochastic exercise price does not change the qualitative results stated in Proposition 1 and its corollaries—that optimism increases the perceived value of the option-generating activity, and overconfidence reduces the perceived value of the activity. The added option created by the stochastic exercise price can, however, change the direction of the overall distortion in the perceived value of the activity. For example, ignoring the added option, optimism may be the dominant bias leading to overvaluation of the activity, but when the added

¹⁴ Clearly not all of this uncertainty will be resolved at the time when the option matures, namely when the factory owner needs to choose whether to exercise the option (specifically, some uncertainty regarding the court's assessment of the harm will generally persist at this stage). From an option pricing perspective, however, only the uncertainty that is resolved between the ex ante pricing stage and the ex post exercise stage is relevant.

¹⁵ See Fischer (1978) for the general formula for pricing options with an uncertain exercise price.

option is considered, overconfidence may turn out to be the dominant bias leading to undervaluation of the activity. See Section 2.5 below for a discussion of the factors that determine the dominant bias.

2.5. Identifying the Dominant Bias

Proposition 1 and its corollaries have shown that optimism and overconfidence pull the perceived value of the option-generating activity in opposite directions. Will an option-holder suffering from both biases overvalue or undervalue the activity? Unfortunately, a general answer cannot be provided. However, for a non-negligible subgroup of cases, the dominant bias can be identified.

Cognitive psychology provides some guidance as to the contextual characteristics of situations that are more likely to trigger different biases. For example, Tversky and Kahneman (1974) argue that overconfidence is a product of the anchoring and (insufficient) adjustment heuristic. Accordingly, the overconfidence bias can be expected to be more pronounced in situations where a salient anchor controls the option-holder's perception of the value of the underlying asset or liability. In the polluting factory example, information on revenues generated by a similar factory can provide such an anchor. And regarding the second option created by the stochastic exercise price, an especially relevant precedent where a similar factory was forced to pay damages for pollution-related harm can provide a dominating anchor.

Moving on to optimism, the cognitive psychology literature provides some guidance as to when optimism is more likely to pose a serious problem. Specifically, when the object of the optimism bias appears controllable by the decision-maker, a stronger manifestation of the bias can be expected (e.g., Weinstein, 1980). In the polluting factory example, the revenues generated by the factory will likely appear controllable to the factory owner, suggesting a significant optimism bias.

When the characteristics of a scenario suggest a strong optimism bias but a relatively weak overconfidence bias, overvaluation of the option-generating activity is likely. And, conversely, when the characteristics of a scenario suggest a strong overconfidence bias but a relatively weak optimism bias, undervaluation of the option-generating activity is likely. The remaining question is quantitative: how much optimism is needed to overcome a given level of overconfidence, and vice versa?

The answer to this question is also context dependent. Still, important generalizations can be drawn. Consider the basic asset-based call option. Assume that the possible values of the underlying asset are normally distributed with a mean of \bar{x} and a standard deviation of σ . An imperfectly rational

option-holder perceives a distribution of asset values with a mean of \hat{x} and a standard deviation of $\hat{\sigma}$.¹⁶ For different values of the exercise price, p, of \bar{x} and of σ , it is possible to derive the threshold level of optimism that is needed to overcome any level of overconfidence, and vice versa. These threshold values can be calculated by numerically solving the following equation:

$$\hat{P} = \int_{p}^{\hat{b}} (x-p) \cdot \hat{f}(x) \cdot dx = \int_{p}^{b} (x-p) \cdot f(x) \cdot dx = P.$$

Figure 2 presents the results of a series of numeric calculations using the parameter values $\overline{x} = 5$ and $\sigma = 2$. Each curve in Figure 2 presents the threshold values of optimism and overconfidence for a different exercise price: p = 3 in the lowest curve, p = 5 in the intermediate curve, and p = 7 in the highest curve. For any curve, bias combinations above the curve lead to overvaluation of the option, while bias combinations below the curve lead to undervaluation of the option.

¹⁶ I assume that the perceived distribution is still a normal distribution – see footnote 11 above.



Figure 2: Optimism versus overconfidence - identifying the dominant bias

Figure 2 illustrates several results. First, it emphasizes the significant effect of an option's exercise price on the relative importance of the optimism and overconfidence biases. A lower exercise price translates into a broader range of bias combinations where optimism dominates and overvaluation ensues. Second, optimism enjoys an increasing marginal impact, while overconfidence suffers from a decreasing marginal impact. This "advantage" of the optimism bias is especially pronounced for lower exercise prices. Finally, while Figure 2 may appear to suggest that optimism is more likely to be the dominant bias, a closer look reveals that this is not necessarily the case. Tversky and Kahneman (1974) report evidence of an overconfidence bias characterized by a perceived standard deviation equal to half the actual standard deviation. In Figure 2 this translates into a perceived standard deviation of 1. Accordingly, when p = 7, an optimism level of approximately 30%, or 1.5 times the perceived standard

deviation, would be required to offset the underestimation effect of the overconfidence bias.

The preceding analysis provides general guidelines for identifying the dominant bias. The proposed framework is mainly descriptive, rather than prescriptive, since the characteristics of a situation that determine which bias is dominant in that situation are often unobservable to policymakers, and even when they are observable their value may vary across situations that cannot be separately regulated. Moreover, even the descriptive value of the proposed framework is limited by the possibility that other biases not modeled here dominate the effects of both optimism and overconfidence (see Section 4.1 below).

There is, however, a class of cases where the dominant bias can be identified with greater confidence. When market forces interact with behavioral tendencies, readily observable market outcomes can reliably indicate which bias is dominant (or at least indicate the direction of the overall deviation from the rational choice prediction). For example, if market contracts leave out a cost-effective warranty provision which obviously would benefit a majority of consumers, this implies that consumers systematically underestimate the value of the option created by such a warranty. Overconfidence regarding the future value of the purchased product (stemming perhaps from optimism regarding the likelihood of a defect) is thus revealed to be the dominant bias.¹⁷

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 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.

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

¹⁷ For another example where market outcomes are used to infer behavioral biases, see Bar-Gill (2004).

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.¹⁸

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, 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 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, the perceived increase is determined 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 costbenefit calculation. To the extent that legal rules are concerned with encouraging or 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 of the

¹⁸ 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.

option-generating activity follow immediately from Corollary 1, once the liability rule in the conflicting uses scenario is identified as creating an assetbased call option. Specifically, an optimistic individual would overestimate the value of the legal option, and thus overestimate the value of the activity. An overconfident individual would underestimate the value of the legal option and thus underestimate the value of the activity. These results are strengthened when the additional option created by a stochastic exercise price is considered (see Section 2.4 above).¹⁹

If the dominant bias can be identified, then these results suggest the following policy implications: If the optimism bias is dominant, then individuals will engage in the activity too often, and it may be desirable to increase liability beyond the level that would be optimal in a world without cognitive biases. Conversely, if the overconfidence bias is dominant, then individuals will engage in the activity at a suboptimal rate, and it may be desirable to reduce liability below the level that would be optimal in a world without cognitive biases.²⁰

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)

¹⁹ Generally, not only x but also L(y) are stochastic variables. Uncertainty with respect to

L(y) is a product of uncertainty with respect to the value of *y*, uncertainty with respect to the likelihood that harm caused will be translated into a legally-imposed damages award, and uncertainty with respect to the relationship between the actual harm and the magnitude of the damages award.

²⁰ The focus of the analysis has been on the ramifications of behavioral option pricing for the ex ante value of an activity and on the corresponding propensity to engage in the activity. In some sense this perspective is 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 has been made. (Technically, this more refined perspective relaxes the assumption that the distribution of asset values 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.) This question has been thoroughly explored by Bebchuk (2001) in a rational choice framework. Optimism and overconfidence clearly influence an option-holder's incentives to invest in the option-generating activity. 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 overconfidence reduces the perceived likelihood that the option would be exercised, X would have a lesser incentive to invest. These implications require some qualification, however, if a higher/lower perceived x, due to optimism/overconfidence, may lead the option-holder to believe that the marginal return from an investment is lower/higher than it really is.

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 beliefs about the distribution of x values. As suggested in Section 2.5, however, in the present case cognitive biases should pose a lesser concern for the nonoption-holder. The optimism bias can be expected to be relatively weak, since generally Y will not think that she has control over the distribution of x values. And overconfidence should not present a significant concern, since Y is less likely to have a strong anchor regarding the level of the factory's revenues. (Cognitive biases may pose a problem, if y and L(y) are stochastic.)

The nuisance/conflicting uses case 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 LAW AND LIABILITY-BASED PUTS

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).

As stated in Corollary 1, both optimism and overconfidence lead to the underpricing of these liability-based put options. But in the tort law scenario 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.

Again, these results are magnified when the exercise price, L(y), is stochastic. In fact, in many tort law scenarios it is reasonable to assume that the cost of care, x, is known ex ante and that only the harm and the liability for harm caused are stochastic. As noted above, the results under this alternative assumption would be qualitatively similar.

As in the nuisance/conflicting uses example, if the dominant bias can be identified, then these results suggest concrete policy implications, very similar to those outlined in the preceding subsection: If the optimism bias is dominant, then individuals will engage in the activity too often, and it may be desirable to increase liability beyond the level that would be optimal in a world without cognitive biases. Conversely, if the overconfidence bias is dominant, then individuals will engage in the activity at a suboptimal rate, and it may be desirable to reduce liability below the level that would be optimal in a world without cognitive biases.

3.3. CONTRACT LAW

Contract law is option rich (e.g., Katz, 2004; Scott and Triantis, 2004). The most famous contractual option is the promisor's choice between performance and breach under a monetary 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 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.²¹

²¹ This description abstracts from the possibility of renegotiation at T=1. 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

When the promisor is a seller, the value to the promisor of the right 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. 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 assetbased call option (and Corollary 1 applies).²²

When the promisor is a buyer, the value to the promisor of the right to withhold payment is the result of a possible decline in the value of the good or service to the buyer. The initial contract can thus be interpreted as including a liability-the obligation to pay the contract price-plus a put option to unload this liability (and Corollary 2 applies). Alternatively, the initial contract can be interpreted as creating a call option to secure performance by the seller, with an exercise price equal to the portion of the contract price not paid ex ante as a non-refundable deposit.²³ 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.²⁴ If an optimistic seller overestimates the value of the option, she may be willing to accept a lower price. Conversely, if an overconfident seller underestimates the value of the option, she may demand a higher price. If an optimistic buyer overestimates the value of the option, she may be willing to pay a higher contract price. Conversely, if an overconfident buyer underestimates the value of the option, she may demand a lower contract price. Importantly, these implications of optimism and overconfidence are not sensitive to the framing of the contractual option as either a put option or a call option.²⁵

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.

²² The different reasons for breach may also affect the relative importance of the two cognitive biases. As explained in Section 2.5 above, overconfidence can be expected to create a more significant distortion when a salient anchor exists. When the likely cause of breach is an increase in the technological cost of performance, the normal cost presents a very powerful anchor. On the other hand, when the likely cause of breach is the appearance of a higher bid, no obvious anchor exists.

²³ See Scott and Triantis (2004), stressing the call option interpretation.

 $^{^{24}}$ On the rational pricing of the option to breach and its ex ante implications, see Mahoney (1995).

²⁵ The contracts literature, while recognizing the option value created by the right to breach and pay damages, has not recognized the additional option created by the stochastic exercise

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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 inefficient contract. On the other hand, undervaluation of the option by an overconfident promisor might prevent the parties from reaching a mutually-beneficial agreement.

Second, and related, sophisticated parties (who price options rationally) might take advantage of less sophisticated parties (who are more susceptible to cognitive biases) 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.

These results should not be surprising. When one or both parties misconceive the true value of the contract, mutual consent no longer guarantees that the transaction is Pareto efficient. Still, framing the problem in terms of behavioral (mis)pricing of options provides a common framework to study the (potentially adverse) implications of a broad array of contractual options.²⁶ Moreover, option framing highlights the role of the overconfidence bias, which has received little attention in the behaviorally-informed contracting literature.

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 $x \ge -K$, the entrepreneur bears the entire gain or loss from the project. But what happens

price of this basic option, namely by the uncertainty surrounding the damages award. Specifically, this additional option affects the choice between stipulated damages and court-determined damages. A rational promisor would prefer the added uncertainty, and thus increased option value, of court-determined damages, even when stipulated damages lower than the average court-determined award can be negotiated. An overconfident promisor might have the opposite preference. Conversely, a rational promisee may well prefer stipulated damages, while an overconfident promisee might have the opposite preference. A similar analysis applies to arbitration clauses, which are often included as a lower-uncertainty substitute for the jury verdict. ²⁶ See Katz (2004) and Scott & Triantis (2004) for a comprehensive account of the multitude of contractual options.

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 an x < -K realization can liquidate the company, losing only her initial capital investment K^{27} . 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 (e.g., Hansmann and Kraakman, 1992). Limited liability induces excessive business activity. Optimism aggravates the excessive activity concern, while overconfidence lessens this concern. Accordingly, if optimism is the dominant bias among entrepreneurs,²⁸ this may provide a reason to put limits on limited liability.²⁹

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 sufficiently high levels of optimism and

 $^{^{\}rm 27}$ In practice, often the entrepreneur will simply stop paying her creditors, and the creditors will force liquidation.

²⁸ There is evidence suggesting that optimism is in fact a problem in this context (see, e.g., Pinfold, 2001); this is not to say that overconfidence is not a problem.

²⁹ 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, 2005). 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: §2.4). 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: §2.3.)

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 (from an ex ante perspective).

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: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 pay 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 optionthe 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 monetary 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 $P = \Pr(x < L) \cdot E(L - x | x < L)$ (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 entitlement plus the 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 on how much to invest in the entitlement and whether to acquire the entitlement in the first place. Cognitive biases also affect the decision of the non-option-holder Y, on whether to encroach on X's entitlement.³⁰ 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, assuming y > L, 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.³¹ Unfortunately, even if the direction of the distortion is known, 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

³⁰ On the deterrence effects of the election of remedies option in a rational choice framework, see Ayres (forthcoming:48-52).

 $^{^{31}}$ 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:49-50).

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 monetary 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 law.³² The exercise price of the put option created by the right to return 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" (e.g., Clark, 1986: §10.6).

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. To the extent that the appraisal remedy is designed to deter inefficient corporate changes that undermine shareholder value, the efficacy of the remedy depends on the cognitive biases that the non-option-holder suffers 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.³³

³² See, e.g., 16 CFR §429.1, specifying rescission rights in door-to-door sales.

³³ One important difference, as compared to the election-of-remedies case, is that here the non-option-holder has substantial control over the post-change share value, which can be expected to affect her ex ante beliefs regarding the distribution of post-change share values.

If the direction of the distortion is known, 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 by raising the "fair value" standard, while overdeterrence can be cured by relaxing the "fair value" standard.

3.7. LITIGATION OPTIONS

"Filing a suit is analogous to purchasing an option" (Cornell, 1990). The plaintiff has an option to proceed all the way to trial, to settle, or to drop the case. In fact, the plaintiff has many more options: to invest in discovery, to file different pre-trial motions, to present evidence and witnesses, to challenge the defendant's evidence and witnesses, to appeal unfavorable decisions, etc. These options increase the ex ante value of a lawsuit, and may even render an otherwise negative present value (NPV) suit a profitable prospect (Cornell, 1990; Bebchuk, 1996; Grundfest and Huang, 2004).

How will an imperfectly rational plaintiff value these litigation options? Generally, optimism will increase the perceived value of a lawsuit, while overconfidence will reduce the perceived value of the lawsuit. However, the implications of behavioral option pricing in the litigation context are complicated by the strategic nature of the interaction between plaintiff and defendant. For example, as shown by Grundfest and Huang (2004), while the value of litigation options is increasing in the variance of the underlying asset for a broad range of parameters, the litigation and settlement game may produce regions where a higher variance *reduces* the ex ante value of the option. Accordingly, an overconfident plaintiff may theoretically overestimate the value of an option-bearing lawsuit.

This ambiguity further complicates any attempt to deduce the descriptive implications of the behavioral option pricing model in the litigation context. From a normative perspective, imperfect rationality adds another dimension to "the fundamental divergence between the private and the social motive to use the legal system" (Shavell, 1997).

4. CONCLUDING REMARKS

4.1. EXTENDING THE BEHAVIORAL OPTION PRICING MODEL

The behavioral option pricing model studied in this paper focuses on the optimism and overconfidence biases. These two biases, which correspond to the two fundamental moments of the distribution of an option's 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 the preference reversals caused by hyperbolic discounting.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 phenomena that can be expected to have a significant effect on option pricing falls under the alternate titles of "endowment effects," "loss aversion" and "WTP-WTA disparity" (or "bid-ask spread"). Individuals tend to demand more for selling an asset than 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.35 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.³⁶ Going back to the optimism bias, this paper focuses on optimism with respect to the value of the asset or liability underlying the option, and with respect to the option's exercise price. Arguably, however, optimism can operate directly on the overall value of the option. In other words, given the option framing of the legal choice, an option-holder might be optimistic about the value of the option as a whole, without even considering the underlying asset or liability and the exercise

 ³⁴ See generally Loewenstein and Thaler (1992) and Laibson (1997); see also Katz (2004:33-34).
 ³⁵ But see Zeiler and Plott (2005) for recent evidence questioning the existence of an endowment effect.

³⁶ See also Ayres (forthcoming:191-194).

price—the building blocks that determine an option's value. While plausible, this type of optimism assumes a greater departure from perfect rationality compared to the type of optimism incorporated into the proposed behavioral option pricing model. For optimism to operate on the value of the option as a whole, it is necessary to assume that the option-holder does not understand the basic structure of the option.

Moreover, it seems unlikely in the legal options context that the option framing is so powerful that it obscures the basic choice that underlies the option. The perception of the option as an asset in its own right, subject to optimism, would be more plausible in the financial options context, but not so much so in the context of real options and specifically legal options. Most likely, individuals holding legal options do not think of the legal choice as a distinct asset.

Finally, it should be recognized that, while optimism and overconfidence are probably more common in the real options and specifically the legal options context, in some cases the opposite biases, namely pessimism and underconfidence, may be observed. Specifically, such contrary biases seem plausible when considering the added option created by a stochastic exercise price. For example, a potential injurer might be pessimistic about the likelihood and/or extent of liability.³⁷ A potential injurer might also overestimate the variance of jury-determined punitive damages awards (which can be described as underconfidence).

4.2. LEGAL RULES AND ENDOGENOUS BIASES

I have thus far assumed that the levels of 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 or in the population (e.g., Waldman, 1994; Kyle and Wang, 1997; Heifetz and Spiegel, 1999; and Bar-Gill, 2002). If accurate option pricing is advantageous,³⁸ these dynamic processes can be expected to produce bias combinations that lead to accurate option pricing.

³⁷ Arguably, pessimism regarding the likelihood of liability explains why the IRS does not advertise the (very low) audit rates.

³⁸ 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.

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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.

Another implication of the endogeneity of cognitive biases is that legal rules can be designed to minimize, or even eliminate, biases. When such a debiasing policy is effective, we can justifiably revert back to the rational option pricing model. Debiasing, however, is not always feasible; and even when feasible might be normatively problematic.³⁹

³⁹ See generally, Jolls and Sunstein (2004).

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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:
$$f(x) = f(x - \Delta^{opt})$$

 $\hat{P} = \int_{p}^{b + \Delta^{opt}} (x - p) \cdot f(x - \Delta^{opt}) \cdot dx$. 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) into 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 $\left[p - E[x|x < p] \right]$ (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 Accordingly, the effect of

y, the effect
$$((p-\hat{x})+\int_{p}^{b}(x-p)f(x)dx = \int_{a}^{p}(p-x)f(x)dx).$$

overconfidence on p^{p} the valuation of the put option follows 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:

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

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

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

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