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Determinants of corporate borrowing: A behavioral perspective☆

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ABSTRACT

This article integrates an earnings-based capital structure model into a simple real options framework to analyze the effects of managerial optimism and overconfidence on the interaction between financing and investment decisions. Several empirical implications follow from solving the model. Notably, my analysis reveals that managerial traits can ameliorate bondholder–shareholder conflicts, such as the debt overhang problem. While debt delays investment inefficiently, mildly biased managers can overcome this problem, even though they tend to issue more debt. Similar properties and results are discussed for other real options, such as the asset stripping or risk-shifting problems.
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1. Introduction

Since the irrelevance result of Modigliani and Miller (1958), a myriad of possible explanations for the relevance of financial policy has emerged.[1] In a seminal article, Myers (1977) demonstrates that if the firm has risky debt outstanding and managers act to maximize equity value rather than total firm value (i.e., debt plus equity), then managers have an incentive to defer investment inefficiently. The reason for underinvestment is that pre-existing, risky debt creates an overhang problem because it captures some of the investment benefits without bearing investment costs. Rational bondholders can anticipate shareholders' investment incentives. The underinvestment problem therefore makes debt more costly. That is, it forces firms to behave inefficiently *ex post*, as a result of the debt overhang, and it is impounded into corporate debt values *ex ante*, as an agency cost of debt. These agency costs of debt tend to increase with the amount of debt in the firm's capital structure and with the number of growth options in the firm's investment opportunity set. It is thus widely accepted that these agency conflicts between bondholders and shareholders affect a firm's capital structure.

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[1] Excellent surveys of capital structure research are, e.g., Harris and Raviv (1991), Hart (1995), and Myers (2001).

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Modern corporate financial theory has largely ignored common personality traits of managers in modeling the complex decision-making process of corporate executives. At the present time, we have, at best, a hunch of what the economic consequences of well-documented managerial traits, e.g., excessive optimism and overconfidence, are for, e.g., firms' financing and investment decisions. Optimism is defined as the subjective belief that favorable future events are more likely than they actually are, the better-than-average effect. Overconfidence in the sense of miscalibration, on the other hand, means that people's subjective probability distributions over future events are too tight, the narrow-confidence-interval effect.

The main objective of this article is to advance a behavioral perspective for studying bondholder–shareholder conflicts that are due to the endogenous interaction between financing and investment decisions. For this purpose, I integrate a real options model into an earnings-based contingent claims capital structure environment to measure the agency costs of debt. The firm's EBIT (Earnings Before Interest and Taxes) of assets already in place is governed by a lognormal diffusion process with constant growth rate and volatility. In addition to assets in place, the firm holds an investment opportunity to enhance its profitability in exchange for an irreversible capital outlay.

Analytic solutions are derived for arbitrary beliefs, with rational beliefs as a special case, when financing and investment decisions are endogenously linked by optimality (i.e., smooth-pasting) conditions. A lower default and an upper investment boundary obtain. Rational bondholders anticipate that, after debt issuance, rational managers will implement equity rather than firm value-maximizing default and investment boundaries. So, the commitment problem of underinvestment creates a wedge between the equity value-maximizing (later) and the firm value-maximizing (earlier) investment decisions. The model produces quantitative estimates for the agency costs of debt.

Biased beliefs originate from optimism and/or overconfidence, which are characteristics of individuals, not of firms or markets.[2] This paper consequently looks at what happens inside the firm when managers are rational in all respects, except for how they perceive the firm's future. Similar to DeLong, Shleifer, Summers, and Waldmann (1991), optimistic managers overestimate the growth rate of assets in place. Overconfident managers underestimate the riskiness of assets in place. Biased managers are assumed to maximize the perceived (i.e., subjective) value of equity. In contrast, bondholders and shareholders have rational expectations. Investors can therefore fully anticipate the implications of decision-makers' behavioral biases for financing and investment decisions, in particular when setting security prices. Hence prices of corporate securities are efficient.

Perhaps surprisingly, managers with biased beliefs can play a positive role. There are two counterbalancing effects. (1) Leverage effect: Biased managers choose higher debt levels than rational managers. Higher debt levels, *ceteris paribus*, exacerbate underinvestment. (2) Timing effect: Biased managers invest, *ceteris paribus*, earlier, than rational managers. This attenuates underinvestment. For mild biases, the timing effect outweighs the leverage effect, which means that the benefits of managerial biases exceed their costs. Debt overhang agency costs decline and thus investor (i.e., initial shareholder) welfare improves.[3]

Although my formal analysis focuses on the underinvestment problem, the trade-off between the leverage effect and the timing effect extends to many other real option exercise decisions. For example, Leland (1998) points out that even if the manager's risk-shifting policy can be committed to at time 0 to maximize joint benefits of bondholders and shareholders, it will nevertheless be optimal to increase investment risk at some sufficiently low cash flow level prior to default. The commitment problem of asset substitution manifests itself in the wedge between the equity value-maximizing (earlier) and the firm value-maximizing (later) switch point. By waiting a bit longer, biased managers can attenuate the asset substitution problem. Similar arguments apply to asset stripping options, contraction options, and mothballing options, just to name a few. As a result, the bottom-line of this paper is the more general, agency-theoretic observation that mildly biased managers can ameliorate bondholder–shareholder conflicts. Intuitively, mild biases act like commitment devices to approaching first-best real option exercise strategies of debt–equity financed firms.

Moreover, I show that managerial optimism about the magnitude of future investment benefits moderates the above-mentioned leverage effect, which results from managerial optimism or overconfidence about assets in place. Managerial biases about assets in place and about gains from investment increase the region in which the timing effect dominates the leverage effect. Hence this extension provides more scope for positive net benefits to a debt–equity-financed firm from hiring biased managers. In addition, this extension helps explaining the debt conservatism puzzle of seemingly too low leverage ratios observed in practice (Graham, 2000).

Employing either direct survey responses or indirect empirical proxies to identify managerial optimism and overconfidence, the major implications of the model are testable and can be summarized as follows.[4] Managers biased in this way (1) invest more, (2) issue more debt, and, as a result, (3) default more often. (4) Notably, mild managerial biases can play a positive role for debt–equity financed firms in that they can increase firm performance by helping to overcome conflicts of interest between bondholders and shareholders.[5] (5) In contrast to unlevered firms, levered firms' shareholders should therefore rationally seek out the labor market of managers for candidates who are mildly optimistic and/or overconfident. (6) Finally, allowing also for optimism about future investment benefits can further strengthen the positive role of biased managers.

The structure of the paper is as follows. The next section reviews some related research. Section 3 studies the timing effect within a real options model of an all-equity firm, which is integrated into a contingent claims capital structure environment in

[2] Managers' biased beliefs may be attributable to cognitive errors (Kahneman et al., 1982).

[3] Similarly, Kyle and Wang (1997) find that overconfidence acts as a commitment device in a Cournot duopoly.

[4] For example, Ben-David, Graham, and Harvey (2006) and Puri and Robinson (2007) use a survey methodology, while Malmendier and Tate (2005) and Malmendier, Tate, and Yan (2007) rely on an empirical identification. Their studies are consistent with the view that these managerial biases affect firms' financing and investment decisions.

[5] For empirical evidence on bondholder–shareholder conflicts, see, e.g., Hennessy (2004) or Eisdorfer (2008).

Section 4, where the leverage and timing effects are present. The main empirical predictions are developed in Section 5. Section 6 concludes. Table 1 provides a summary of the model's notation. Most mathematical developments appear in Appendix A.

2. Related literature

In this section, I survey prior research that is related to my research agenda. I focus in particular on the progress that has recently been made in the field of behavioral corporate finance, but also consider relevant works from behavioral economics and psychology.

2.1. Behavioral corporate finance

A growing literature studies the implications of investor biases on trading behavior and equilibrium asset prices; see, e.g., Hirshleifer's (2001) survey. In contrast, behavioral corporate finance has not yet experienced similar momentum (Shefrin, 2001). As a consequence, Thaler (1999) concludes he "would like to see more behavioral finance research in the field of corporate finance."

Survey evidence compiled recently by Graham and Harvey (2001) indicates that most executives typically believe that their common equity is undervalued by the market. In addition, only 3% of the CFOs included in their study think their stock is overvalued. These authors' findings can only be reconciled by a very skewed distribution of asymmetric information or, alternatively, by means of a behavioral perspective to corporate finance.

Shefrin and Statman (1984) provide a rationale for why firms may pay cash dividends based upon investors' lack of self-control and prospect theory. Roll (1986) amalgamates overconfidence and the winner's curse into his hubris hypothesis for takeovers to explain why acquiring firms tend to overpay for their targets. Later on, Kahnemann and Lovallo (1993) argue that managerial optimism stems from managers' inside view of prospective projects, which anchors predictions and plans on favorable scenarios. Goel and Thakor (2000) argue that overconfident managers have a higher probability to excel in tournaments and thus may get promoted to top executive positions more often, though all managers choose riskier investments when faced by internal competition for leadership. On the other hand, Stein (1996) assumes market inefficiencies and studies a rational manager's capital budgeting strategy for different time horizons and shareholder clienteles.

Three recent papers by Gervais, Heaton, and Odean (2003), Heaton (2002), and Hackbarth (2008) analyze manager–shareholder conflicts, while the present paper is the first to examine bondholder–shareholder conflicts. Gervais, Heaton, and Odean (2003) provide various reasons for why especially managers are likely to be optimistic and overconfident and study these traits within the capital budgeting process of an all-equity financed firm. In their two-state model, manager–shareholder conflicts result from sub-optimal risk-taking of risk-averse managers. By contrast, this article investigates the underinvestment problem of a debt–equity financed firm, using a contingent claims approach that is closer in spirit to the classic real options models (Dixit and

Table 1
Notation Index.

X	Earnings before interest and taxes (EBIT) — $X(0)\equiv X_0$ at $t=0$ and $X\equiv X(t)$ for $t>0$
μ	Growth rate of EBIT per unit of time — rational investor's beliefs.
μ'	Optimistic manager's beliefs: $\mu'\geq\mu$.
σ	Riskiness of EBIT per unit of time — rational investor's beliefs.
σ'	Overconfident manager's beliefs: $\sigma'\leq\sigma$.
$E_\mathbf{t}[\cdot]$	Expectations operator given rational investor's information at time t.
α	Proportional loss due to financial distress — bankruptcy costs $BC(X, C)$.
τ	Corporate taxes paid on EBIT less debt service — tax shield value $TB(X, C)$.
r	Risk-free rate, e.g., on Treasury bonds.
$V_\mathrm{A}(X)$	Value of assets in place.
$V_\mathrm{G}(X)$	Value of investment opportunities.
$V(X)$	Unlevered (all-equity) firm value: $V(X)=V_\mathrm{A}(X)+V_\mathrm{G}(X)$.
$L(X)$	Value of the reorganized firm: $L(X)=(1-\alpha)(1-\tau)X/(r-\mu)$
$X_{d\mathrm{L}}$	Default-triggering EBIT level prior to investment.
$X_{d\mathrm{H}}$	Default-triggering EBIT level after investment.
X_s	Investment-triggering EBIT level
C	Coupon (in \$) — promised debt service flow to bondholders up until default.
$D(X, C)$	Debt value — before (D_L) and after (D_H) exercise of real option.
$E(X, C)$	Equity value — before (E_L) and after (E_H) exercise of real option.
$\upsilon(X, C)$	Levered firm value — before (υ_L) and after (υ_H) exercise of real option.
ℓ	Leverage (in %) — debt value in percent of firm value, $\ell\equiv D(X, C)/\upsilon(X, C)$.
Π	Investment opportunity: EBIT scaling factor at the investment threshold X_s.
I	Investment cost of growth (or risk-shifting) option paid at the threshold X_s.
$A(X)$	Agency costs.
$(X/\underline{X})^a$	Value of a one-sided hitting claim paying \$1 when X touches $\underline{X}$ from above the first time. Example: default option after investment.
$(X/\overline{X})^z$	Value of a one-sided hitting claim paying \$1 when X touches $\overline{X}$ from below the first time. Example: Investment option
$\Delta(X;\underline{X},\overline{X})$	Value of a two-sided hitting claim paying \$1 when X reaches first $\underline{X}$ from above. Example: Default option before investment
$\Sigma(X;\underline{X},\overline{X})$	Value of a two-sided hitting claim paying \$1 when X reaches first $\overline{X}$ from below. Example: investment option.

Pindyck, 1994). Heaton (2002) focuses on optimism in a corporate setting. In particular, he discusses lucidly why the arbitrage and the learning objection are weaker in corporate settings. Biased managers in his two-date model perceive risky corporate securities to be undervalued by the market, may reject positive net present value project if (seemingly costly) external funds are needed to finance them, and may invest in negative net present value projects because of biased cash flow forecasts. Hackbarth (2008) finds that optimism and overconfidence have offsetting effects on the perceived mispricing of equity. He studies market timing of capital structure decisions and provides quantitative estimates for the impact of optimism and overconfidence on financial policy. Furthermore, biased managers' predisposition to debt finance, in his dynamic framework, endogenously reduces manager–shareholder conflicts stemming from diversion of internal funds.

Bertrand and Schoar (2003) identify cross-sectional patterns of corporate performance due to managerial decision-making (financial, investment, and organizational strategy). These authors find that managerial differences are systematically related to corporate performance. For instance, older managers or managers without an MBA degree implement more conservative investment and financial policies. Malmendier and Tate (2005) report that optimistic managers exhibit a higher investment–cash flow sensitivity and Malmendier, Tate, and Yan (2007) find that optimistic managers use leverage more aggressively. Combining empirical and survey data, Ben-David, Graham, and Harvey (2006) document a significant association between managerial overconfidence and various corporate policies. Similarly, Puri and Robinson (2007) provide survey evidence that mild optimism is associated with better decision-making.

2.2. Psychology and economics

Economists have traditionally assumed that, when faced with uncertainty, people correctly form subjective probabilistic assessments according to the laws of probability. But studies in psychology and economics have identified many systematic departures of human decision-making from the rational utility maximization ideal of standard neoclassical agents.[6] Frame-dependent and heuristic-driven biases embrace anchoring, ambiguity aversion, availability bias, confirmatory bias, loss aversion, mental accounting, naïveté, procrastination, regret, representativeness, self-control, statistical inference, and systematically incorrect expectations such as optimism and overconfidence. Though psychologists still do not agree about the underlying causes and sources of these self-serving biases, e.g., motivation or cognition,[7] the existence of positive self-illusions is rarely questioned. Miller and Ross (1975) review the abundant psychology literature on self-serving biases.

A well-established stylized fact in the psychology literature is the better-than-average effect: when people compare their skills to the skills of their peers, they tend to overstate their acumen relative to the average (Larwood and Whittaker, 1977; Weinstein, 1980; Alicke, 1985). Camerer (1997) writes “dozens of studies show that people generally overrate the chance of good events, underrate the chance of bad events.” To this end, Babcock and Loewenstein (1997) summarize: “well over half of survey respondents rate themselves in the top 50% of drivers, ethics, managerial prowess, productivity, health, and a variety of desirable skills.” In this paper, optimistic managers overestimate the growth rate (μ) of future cash flows (EBIT).

Another well-documented stylized phenomenon is the narrow-confidence-interval effect: when people make assessments about the possible range of likely future outcomes they typically underestimate the width of this range. Oskamp (1965), Alpert and Raiffa (1982), Brenner, Koehler, Liberman, and Tversky (1996), and other calibration studies find people overestimate the accuracy of their knowledge. Fischoff, Slovic, and Lichtenstein (1977) make this observation and in addition test affirmatively the robustness of overconfidence with monetary stakes rather than reported judgments. Grifin and Tversky (1992) conclude: “The significance of overconfidence to the conduct of human affairs can hardly be overstated.” In this paper, overconfident managers underestimate the riskiness (σ) of future cash flows (EBIT).

A vast literature suggests that individuals exhibit these behavioral biases in their decision-making and, in particular, show that people tend to be optimistic and overconfident.[8] In fact, Taylor and Brown (1988) portray self-serving biases as necessary ingredients of mental health. They allude to evidence that most well-adjusted people estimate that they are more likely than others to experience positive life events and less likely than others to experience negative life events. These authors further reason that since roughly 50% of the population could be above average, a significant portion of the population displays unwarranted optimism. Moreover, research in psychology finds a strong correlation between the absence of positive self-illusions and subjective distress, the ‘depressive realism’ hypothesis: “are the sadder wiser when predicting future actions and events?” (Allow and Abramson, 1979; McFarland and Ross, 1982; Dunning and Story, 1991). Realistic perceptions do not necessarily equal optimal perceptions; or, put differently, realists appear to be almost clinically depressed. Therefore, Taylor and Brown (1988) propose that the benefits may outweigh the potential costs associated with self-serving biases; i.e., positive distortions cause positive affect. Positive affect provides the crucial link in a psychological chain through which positive illusions produce beneficial consequences: greater ability to care for others, elevated motivation and task performance, greater happiness, more creative problem-solving, and bolstered immune system functioning. The present paper examines financing and investment decisions.

Optimism, in the form of the better-than-average effect and overconfidence, in the form of the narrow-confidence-interval effect, can be dispositional or situated. In the former case, the bias represents a rather permanent personality trait, while in the latter case it is

[6] See especially Slovic (1972), Kahnemann and Tversky (1974), and the influential volume by Kahneman, Slovic, and Tversky (1982) on cognitive errors in judgment under uncertainty. More recently, Rabin (1998) reviews important facts about how humans differ from the traditional assumptions concerning the *homo oeconomicus*.

[7] See, e.g., Dunning (1999), and the references therein. Hirshleifer (2001) argues that the occurrence of many self-serving biases can be explained by heuristic simplification, self-deception, or emotion-based judgments.

[8] Odean (1998), Hirshleifer (2001), and Shefrin (2000, 2001) provide surveys from a financial economics perspective.

to a large extent the individual's current environment (i.e., situation) that causes a perceptional distortion. In the managerial context of this article, the dispositional form of self-serving biases is likely to be the appropriate one given the special characteristics of managers.

More specifically, managers, like people, err the most about their ability when faced by complex tasks (Alpert and Raiffa, 1982). Experts (e.g., CFOs) tend to be more prone to optimism and overconfidence than novices (Grifin and Tversky, 1992). Moreover, the diffuse tasks of decision-makers I study are not well suited for quick learning because they only take place infrequently and feedback is typically delayed and rather vague (Einhorn, 1980).

In addition, these personality traits can affect the attribution of causality in multi-period settings. The psychology literature documents that as individuals learn about the outcomes of their decisions, they revise their beliefs in a biased fashion, implying a (dynamic) self-attribution bias. Because individuals expect in general their behavior to produce success, they are more likely to attribute outcomes to their actions (and not to luck) when they succeed rather than when they fail (Bem, 1965; Langer and Roth, 1975; Nisbett and Ross, 1980). This biased self-attribution may temporarily magnify individuals' optimism and overconfidence, especially for successful managers.

3. Investment decisions

This section presents a simple real options model for investment.[9] Managerial optimism and overconfidence impact investment option exercise strategies. The intuition behind the timing effect for an unlevered firm provides the foundations for the paper's central results in the subsequent sections.

3.1. Setting

Table 1 contains a notation index. The owners of an all-equity financed firm delegate its operations to a manager. The manager makes investment decisions to maximize equity value; i.e., shareholders have aligned the manager's interests with their own.

Following Myers (1977), the firm is composed of assets in place and investment opportunities. The firm's assets in place generate a random stream of EBIT, Earnings Before Interest and Taxes, $X=(X(t))_{t\geq 0}$, which is governed by a geometric Brownian motion process:

$$\mathrm{d}X(t) = \mu X(t)\mathrm{d}t + \sigma X(t)\mathrm{d}Z(t), \quad X_0 > 0, \tag{1}$$

where $Z=(Z(t))_{t\geq 0}$ is a standard Wiener process. The constant μ denotes the expected growth rate of EBIT; that is, the drift per unit of time under the risk-neutral measure.[10] The constant σ denotes the volatility (standard deviation) per unit of time. A risk-free security yields a constant rate of return r with $\mu<r$. Corporate taxes are paid at a rate τ on EBIT.

In addition to assets in place, the firm has an investment opportunity. Investing yields an EBIT scaling benefit of $\Pi-1>0$ and requires an irreversible capital expenditure of $I>0$. Similar to Zwiebel (1996), I assume that the manager has full discretion over the decision when to invest as shareholders provide the manager access to financial resources in the amount of I.[11] Notice that deciding how much to invest in a two-period model is a compressed version of when to invest in a multi-period model; i.e., earlier investment corresponds to, in expectation, more investment.

Investors have rational expectations and therefore, in setting security prices, can anticipate the implications of managerial biases. Rational managers and investors believe everybody has the same vector of beliefs **b**, which comprises the correct growth rate of EBIT and the correct volatility of EBIT, i.e., $\mathbf{b}=(\mu,\sigma)$. Equivalently, a biased manager places full confidence into the biased beliefs $\mathbf{b}'=(\mu',\sigma')$, representing managerial optimism and overconfidence. An optimistic manager exhibits an upward bias in the perception of EBIT's growth rate: $\mu'>\mu$. An overconfident manager displays a downward bias in the perception of EBIT's volatility: $\sigma'<\sigma$. Primes denote biased beliefs throughout the paper. This allows me to obtain a tractable modeling framework, in which a biased manager always maximizes the perceived (i.e., subjective) value of equity.

3.2. Value of the all-equity firm

The unlevered firm value consists of the value of assets in place and the value of growth:

$$V(X(t),t) = V_A(X(t)) + V_G(X(t)). \tag{2}$$

The value of the firm's assets in place over an infinite time horizon equals the discounted value of after-tax cash flows:

$$V_A(X(t)) = (1-\tau)\mathbf{E}_t\left[\int_t^\infty e^{-r(s-t)}X(s)\mathrm{d}s\right] = \frac{(1-\tau)X(t)}{r-\mu}, \tag{3}$$

[9] Apart from analytic tractability, the primary advantages of the contingent claims environment are a well-established neoclassical benchmark (Dixit and Pindyck, 1994), an intuitive way of modeling biased beliefs.

[10] Note that in an economy where all investors are risk neutral, μ is the actual expected growth rate of earnings. Alternatively, if the risk premium associated with X is constant, risk-averse investors who own well-diversified portfolios discount cash flows at a risk-adjusted rate $\rho>r$ (Garman, 1976).

[11] In the Zwiebel (1996) model, new investment projects require no initial capital outlay. Consequently, managers are always capable of undertaking new projects at their sole discretion. This is the condition assumed here.

where $X(t)$ denotes the current EBIT level and $\mathbf{E}_t[\cdot]\equiv\mathbf{E}[\cdot|X(t)]$ denotes the conditional expectations operator given the rational investor's information at time $t \in [0,\infty)$. The derivation of the firm's value and investment policy is standard. For brevity, I provide the solution and refer the interested reader to Dixit and Pindyck (1994) for further details.

Proposition 1. *Under the above assumptions, the value of the all-equity financed firm prior to investment equals for all* $t\geq 0$

$$V_G(X(t)) = (1-\tau)\left[\frac{(\Pi-1)X_s}{r-\mu} - \frac{I}{1-\tau}\right]\left(\frac{X(t)}{X_s}\right)^z \quad \forall X(t)\leq X_s \tag{4}$$

where

$$z\equiv z(\mu,\sigma) = -\frac{\mu-\sigma^2/2}{\sigma^2} + \sqrt{\left(\frac{\mu-\sigma^2/2}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} > 0\,. \tag{5}$$

The manager's strategy consists of investing when $X(t)$ *touches the threshold level*

$$X_s = \frac{z}{z-1}\frac{r-\mu}{1-\tau}\frac{I}{\Pi-1} \tag{6}$$

the first time from below.

3.3. Empirical predictions for the unlevered firm

The closed-form solutions in Proposition 1 permit a characterization of the investment rule and, in particular, of its comparative statics for optimistic and overconfident managers, which will be referred to as the timing effects of optimism and overconfidence.[12]

Proposition 2. *The real option exercise strategy X_s is decreasing in the growth rate of EBIT and increasing in EBIT's riskiness. Thus, an optimistic ($\mu'>\mu$) or overconfident ($\sigma'<\sigma$) manager perceives a lower exercise threshold for investment compared to a rational manager: $X_s'<X_s$.*

Proof. To start, observe that $X_s(\cdot)$ is at least C^1 in μ and σ. Differentiating the option exercise strategy (6) with respect to μ and σ^2 yields:

$$\frac{\partial X_s}{\partial\mu} = -\frac{1}{2}\frac{1}{\Pi-1}\frac{I}{1-\tau}\left[1-\left(\frac{\mu-\sigma^2/2}{\sigma^2}\right)\Big/\sqrt{\left(\frac{\mu-\sigma^2/2}{\sigma^2}\right)^2+\frac{2r}{\sigma^2}}\right], \tag{7}$$

and

$$\frac{\partial X_s}{\partial(\sigma^2)} = \frac{1}{4}\frac{1}{\Pi-1}\frac{I}{1-\tau}\left[1+\left(\frac{1}{2}+\frac{2r-\mu}{\sigma^2}\right)\Big/\sqrt{\left(\frac{\mu-\sigma^2/2}{\sigma^2}\right)^2+\frac{2r}{\sigma^2}}\right], \tag{8}$$

respectively. So, (7) is negative because the term in square brackets is always positive and $\tau<1$. Given the standing assumption $r>\mu$, (8) is always positive. However, it can be verified more generally that the sets $\mathcal{M}=\{\mu:\partial X_s/\partial\mu=0\}$ and $\mathcal{V}=\{\sigma^2:\partial X_s/\partial(\sigma^2)=0\}$ are empty for any $(\sigma,\tau,\Pi,I)\in\Re^4$ and $(\mu,\tau,\Pi,I)\in\Re^4$, respectively. Therefore, these continuous functions do not exhibit a sign change absent of any reasonable parameter restrictions, which complete the proof in that (7) is always negative and (8) is always positive. □

These comparative statics of the real option exercise strategy are depicted in Fig. 1, using the base case parameters given in Table 2. The parameter values roughly characterize a representative growth firm. For example, the unlevered value of assets in place given by (3) is equal to \$242.86, while the unlevered value of the investment opportunity priced by (4) equals \$256.86. The intuition underlying Fig. 1 relies on a classical result in real options theory. It predicts, *ceteris paribus*, that irreversible investments are undertaken earlier, in expectation, if waiting-to-invest is more costly (Dixit and Pindyck, 1994).

Panel A charts Proposition 2's first implication that a higher growth rate raises the opportunity cost of waiting to invest, which lowers the value of waiting to invest and hence trims the investment threshold $X_s=14.29$ down to 13.71 (13.17) if the growth rate increases by one (two) percent. In addition, a higher growth rate results in a value increase of the investment opportunity due to a lower appropriate discount rate. In this behavioral model, it is merely the perception of a higher EBIT growth rate that lowers the real option exercise strategy of an optimistic ($\mu'>\mu$) manager.

The second implication of Proposition 2 means that an environment surrounded by less uncertainty deems the opportunity to wait for new (potentially adverse) information about EBIT to be less valuable; i.e., the value of the waiting to invest is lower. Hence a lower real option exercise strategy X_s will arise if uncertainty tapers off. In fact, Panel B reveals that for a decrease in volatility

[12] The solution in (6) is similar to the asset-value-based investment rule in Dixit and Pindyck (1994). However, these authors rely exclusively on numerical examples to illustrate its comparative statics; see *idem* pp. 152–161.

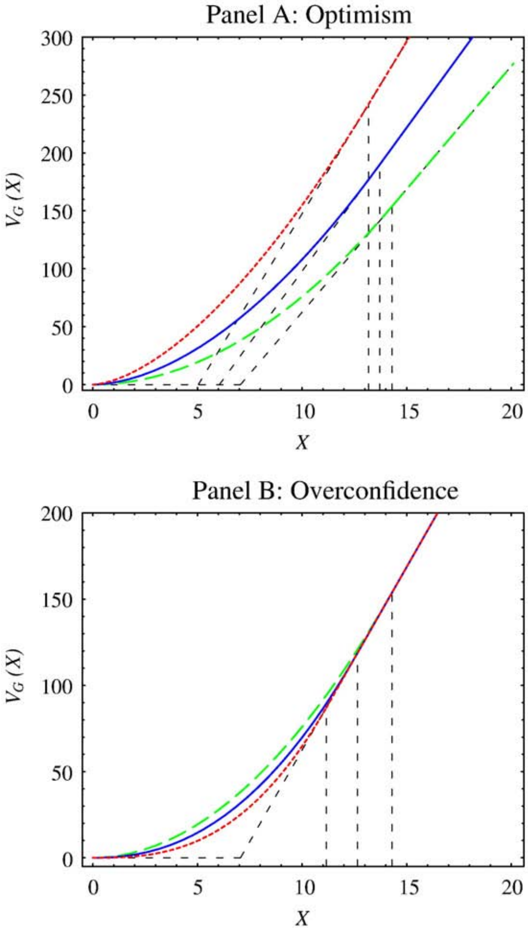

Fig. 1. Growth option exercise strategies for the all-equity firm. The effect of optimism and overconfidence on the perceived value of the firm's investment opportunity $V_G(X)$ as a function of EBIT X and the perceived option exercise strategies $X_s(\cdot)$ are depicted in Panels A and B, respectively. The true parameters are assumed to be $\mu=1\%$ and $\sigma=25\%$ (*green/long-dashed line*), $\mu'=2\%$ (*solid/blue line*) and $\mu''=3\%$ (*red/short-dashed line*) in Panel A, and $\sigma'=20\%$ (*blue/solid line*) and $\sigma''=25\%$ (*red/short-dashed line*) in Panel B. It is assumed that $\Pi=1.75$, $I=150$, $r=8\%$, and $\tau=15\%$. Observe optimism results in an upward bias in the manager's perceived value of the investment opportunity. However, it also raises the perceived opportunity cost of waiting to invest, which lowers the 'value of waiting to invest' and hence lowers the investment trigger X_s. Overconfidence decreases the perceived 'value of the waiting to invest' as well as the perceived value of the investment opportunity. Thus, investment is triggered at a lower X_s. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

from 25% to 20% (15%) the investment threshold drops from 14.29 to 12.64 (11.16). In this behavioral model, it is merely the perception of a lower EBIT volatility that lowers the investment timing threshold of an overconfident ($\sigma'<\sigma$) manager. Prediction 1 summarizes these implications.

Table 2
Base case parameter values of the model.

Parameter	Symbol	Value
Initial EBIT	X_0	20
Risk-free rate	r	8%
EBIT growth rate	μ	1.0%
Perceived growth rate	μ'	2.0%
EBIT riskiness	σ	25%
Perceived riskiness	σ'	20%
Default costs	α	25%
Tax rate	τ	15%
Growth factor	Π	1.75
Investment cost	I	150

The table summarizes the firm's base case parameter values chosen for initial EBIT level X_0, return on the risk-free asset r, growth rate of EBIT μ, volatility of EBIT σ, costs of financial distress α, corporate taxes τ, EBIT scaling factor of investment opportunity Π, cost of exercising investment opportunity I. Primes indicate the biased beliefs of optimistic and/or overconfident managers.

Prediction 1. *For the all-equity financed firm, managerial optimism and overconfidence produce earlier investment which corresponds to, in expectation, more investment in a present value sense.*

As a consequence of Prediction 1, both managerial optimism and overconfidence represent a cost for the shareholders of an unlevered firm. This is because biased managers erode the value of waiting to invest and hence make sub-optimal investment decisions relative to rational managers. But biased managers do not necessarily invest into negative net present value projects, which go beyond just eroding the investment option value. Interestingly, the model has different implications for optimism and overconfidence.

Given that $\lim_{s \downarrow 0} z/(z-1)=1$, the real options model implies for managerial overconfidence that any biased investment strategy encompasses only positive net present value projects given rational beliefs; that is, for any degree of overconfidence $0 \le \sigma' < \sigma$ we have $X_n \le X_s'$ where the (zero) net present value investment threshold is given by

$$X_n = \frac{r-\mu}{1-\tau}\frac{I}{\Pi - 1}. \tag{9}$$

Intuitively, the information structure of the model is sufficiently rich in the sense that knowing the current EBIT level places a lower bound on overconfident managers' value-destroying investments.

In contrast, the real options model has different implications for managerial optimism in that biased investment strategies can encompass positive and negative net present value projects depending on the degree of optimism. That is, there exists a critical level of optimism, $\overline{\mu} \in (\mu, r)$, such that again $X_n \le X_s'$ so long as $\mu' \in (\mu, \overline{\mu}]$, but $X_n > X_s'$ when $\mu' \in (\overline{\mu}, r)$. Prediction 2 summarizes the different limiting behaviors of the comparative statics for optimism and overconfidence relative to the (zero) net present value rule of investment.

Prediction 2. *From rational shareholders' point of view, biased managers destroy equity value. Managerial optimism can lead to investment into positive or negative net present value projects. Managerial overconfidence only leads to investment into (weakly) positive net present value projects.*

In reality, however, firms do frequently issue (risky) debt, which renders the abstraction of an all-equity firm a moot point. To address the endogenous interaction between financing and investment decisions, the next section integrates this real options model of an all-equity financed firm into a contingent claims capital structure environment.

4. Financing and investment decisions

Assuming investor rationality, this section analyzes the consequences of optimism and overconfidence within a neoclassical tax shield–bankruptcy cost framework extended to treat real option exercise decisions. That is, I explore the endogenous interaction between *ex ante* leverage choice (leverage effect) and *ex post* determined exercise strategies for default and investment (timing effect).

4.1. Setting

Modigliani and Miller (1958) assume a given investment policy for their value-invariance theorem. In reality, financing decisions affect investment decisions and vice versa. My approach to studying the relevance of financial policy is conceptually distinct from informational asymmetries (Leland and Pyle, 1977; Ross, 1977) or moral hazard (Grossman and Hart, 1982; Hart and Moore, 1995) that leads to a positive role for capital structure decisions in traditional models, and I rule those out here. While the main interest of this paper lies in real options in the sense of Myers (1977), it should be pointed out that my approach is more general. Other corporate real options like the opportunity to prolong the expected life-time of the firm under current owners by increasing investment risk, asset stripping, contraction options, or other types of operating and strategic flexibility all can be embraced by the paper's analysis. Some of these extensions are discussed in Section 5.2.

In addition to investment, the manager has discretion over financing decisions (i.e., debt and default). In particular, the manager can issue a single class of debt at time 0. Debt pays a promised coupon flow C to bondholders up to default, which is tax-deductible with full loss offsets. Debt remains outstanding forever unless default is triggered when the firm's EBIT falls beneath some level, say $X_d \in (0,X)$, which is determined endogenously (e.g., Black and Cox, 1976).[13] Economically, debt contracts can be justified by the presence of a tax advantage of debt.

Expanding on Section 3, the manager can make a one-time investment decision *ex post* (i.e., after debt is in place) by solving for the investment threshold $X_s \in (X,\infty)$. Due to the positive externality that investment creates for existing bondholders, X_s is increasing in the *ex ante* debt coupon choice C. The manager's real option exercise strategy cannot be precontracted in the bond covenants or otherwise credibly precommitted. This contractual incompleteness may stem from frictions such as contracting costs and complexity, or limited verifiability of investments.

Following Mello and Parsons (1992), a fraction $\alpha \in (0,1]$ of unlevered value of assets in place $V_A(X)$ is lost in the event of default due to direct and indirect costs of financial distress.[14] The firm's investment opportunities evaporate at the onset of financial distress, e.g.,

[13] Assuming bond covenants trigger default exogenously removes one managerial decision variable from the analysis. Though this changes the quantitative predictions of the model, the economic results of this paper are unaffected.

[14] Empirical studies have found that direct costs of financial distress are in the ballpark of 10–20%, while the indirect bankruptcy costs appear to pose a much more delicate estimation exercise; see, e.g., Weiss (1990). The base case parameter value of $\alpha=25\%$ lies in the upper range of estimates of Andrade and Kaplan (1998). Given these authors' sample contains firms, which were initially highly levered, and high leverage is likely to be optimal for firms with low default costs, Leland (1998) concludes their estimates may exhibit a downward bias due to this endogeneity.

due to an imperfect protection of intellectual capital by the jurisdiction or simply inalienable managerial capital. Therefore, the value of the reorganized firm is simply $L(X)=(1-\alpha)V_A(X)$. Following Leland (1994), debt and equity are sold at time 0. At the debt–equity issuance date, the manager maximizes the perceived (i.e., subjective) firm value by choosing a debt coupon C.[15] In doing so, the manager trades off tax benefits versus bankruptcy costs and foresees the *ex post* choices of default and investment thresholds, which are implied by the initial debt coupon choice. The ratio of debt to firm value captures the degree of leverage. The *ex ante* value of equity prior to the leverage decision differs from the *ex post* value of equity, i.e., at the time when the debt is already in place. In particular, the *ex post* value of equity is the value of the perpetual entitlement to the firm's cash flows net of its promised debt service. The *ex ante* value of equity equals total firm value at $t=0$; i.e., the sum of the *ex post* value of equity and the issuance value of debt.

4.2. Value of the levered firm after investment

For irreversible investments under uncertainty there exists a critical investment threshold X_s that divides up the state space into two distinct regions: before and after investment or, formally, $X(t)<X_s$ and $X(t)\geq X_s$, respectively. Let the subscripts L and H denote contingent claim values prior to the event of X hitting X_s the first time from below and thereafter, respectively.

After the investment has been undertaken (i.e., after X touched X_s the first time from below), a new (i.e., multiplicatively scaled) process initiated at ΠX_s with constant drift μ and volatility σ emerges. The unlevered firm value equals the discounted value of after-tax cash flows:

$$V_{\mathrm{H}}(X(t)) = (1-\tau)\mathbf{E}_t\left[\int_t^{\infty} e^{-r(s-t)}\Pi X(s)\mathrm{d}s\right] = \frac{(1-\tau)\Pi X(t)}{r-\mu}, \tag{10}$$

and hence the value of the reorganized firm denoted by $L_{\mathrm{H}}(X)$ is:

$$L_{\mathrm{H}}(X(t)) = (1-\alpha)V_{\mathrm{H}}(X(t)). \tag{11}$$

For notational convenience only, I subsequently suppress the deterministic dependence on time t.

Proposition 3. *Risky corporate debt $D_{\mathrm{H}}(X,C)$ bearing a promised coupon flow of $C>0$ is worth*:

$$D_{\mathrm{H}}(X,C;\mu,\sigma) = \frac{C}{r}\left[1-\left(\frac{X}{X_{d\mathrm{H}}}\right)^a\right] + L_{\mathrm{H}}(X_{d\mathrm{H}})\left(\frac{X}{X_{d\mathrm{H}}}\right)^a \tag{12}$$

for all $X\geq X_{d\mathrm{H}}$. $X_{d\mathrm{H}}\in(0,X_s)$ is the default point, $a\equiv a(\mu,\sigma)<0$ is (A.6) of Appendix A.

The function $D_{\mathrm{H}}(X,C)$ is increasing and concave in X, while first increasing and then decreasing in C. Similarly, the value of equity can be derived analytically.

Proposition 4. *The levered firm's equity $E_{\mathrm{H}}(X,C)$ yielding a dividend flow of $(1-\tau)(X-C)$ is worth*:

$$E_{\mathrm{H}}(X,C;\mu,\sigma) = (1-\tau)\left[\left(\frac{\Pi X}{r-\mu}-\frac{C}{r}\right)-\left(\frac{\Pi X_{d\mathrm{H}}}{r-\mu}-\frac{C}{r}\right)\left(\frac{X}{X_{d\mathrm{H}}}\right)^a\right] \tag{13}$$

for all $X\geq X_{d\mathrm{H}}$. $X_{d\mathrm{H}}\in(0,X_s)$ is the default point, $a\equiv a(\mu,\sigma)<0$ is (A.6) of Appendix A.

The function $E_{\mathrm{H}}(X,C)$ is increasing and convex in X, while it is decreasing and concave in C.

Proposition 5. *Let $\upsilon(X,C)$ denote the value of the levered firm under current management. The value of the debt–equity financed firm for all $X>X_{d\mathrm{H}}$ is given by*:

$$\upsilon_{\mathrm{H}}(X,C) = V_{\mathrm{H}}(X) + \frac{\tau C}{r}\left[1-\left(\frac{X}{X_{d\mathrm{H}}}\right)^a\right] - \alpha V_{\mathrm{H}}(X_{d\mathrm{H}})\left(\frac{X}{X_{d\mathrm{H}}}\right)^a \tag{14}$$

for all $X\geq X_{d\mathrm{H}}$. $X_{d\mathrm{H}}\in(0,X_s)$ is the default point, $a\equiv a(\mu,\sigma)<0$ is (A.6) of Appendix A. *For $X<X_{d\mathrm{H}}$, the firm's value is equal to its reorganization value*: $L_{\mathrm{H}}(X_{d\mathrm{H}})$.

Unsurprisingly, the total value of the levered firm after investment can be expressed in closed form, showing clear traces of the underlying tax shield–bankruptcy cost tradeoff model.

Proposition 6. *The ex post chosen, incentive compatible default point is*:

$$X_{d\mathrm{H}}(C;\mu,\sigma) = \frac{a}{a-1}\frac{r-\mu}{r}\frac{C}{\Pi}, \tag{15}$$

where $a\equiv a(\mu,\sigma)<0$ is (A.6) of Appendix A.

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[15] A richer choice set of decision variables (e.g., debt principal, debt maturity, or debt call provisions) can be incorporated into this framework (Leland and Toft, 1996; Leland, 1998; Goldstein et al., 2001).

The solution for firm's default-triggering EBIT level after investment has taken place in (15) is lower than the one of a firm without an investment opportunity:

$$X_d(C;\mu,\sigma) = \frac{a}{a-1}\frac{r-\mu}{r}C, \tag{16}$$

which is a first but imperfect proxy for the benefits bondholders obtain from shareholders' investment: Debt becomes safer, which could mean that the value of debt discontinuously changes to a higher value at the switch point X_s. But in the absence of arbitrage, bondholders' and shareholders' rational expectations about the investment opportunity have to be impounded into bond and share prices prior to the manager's investment decision. Hence this is only a scent of the full problem. Default and investment thresholds as well as asset prices prior to the manager's exercising decision have to be re-derived consistent with investors' rational expectations. This is the object of the next subsection.

4.3. Value of the levered firm prior to investment

Analogous to Section 4.2, the value of debt, equity, and the levered firm are derived for a given default-triggering EBIT level X_{dL} and for a given investment strategy X_s. Subsequently, the default policy X_{dL} and the investment policy X_s are obtained from the manager's maximization problem using these contingent claim values as ingredients.

Proposition 7. *Until the firm's EBIT process X takes the first excursion from the open interval* (X_{dL}, X_s), *risky corporate debt* $D_L(X,C)$ *bearing a promised coupon flow of* $C>0$ *is worth*

$$D_L(X,C;\mu,\sigma) = \frac{C}{r}\left[1-\Delta(X)-\Sigma(X)\left(\frac{X_s}{X_{dH}}\right)^a\right] + (1-\alpha)(1-\tau)\left[\Delta(X)\frac{X_{dL}}{r-\mu} + \Sigma(X)\frac{\Pi X_{dH}}{r-\mu}\left(\frac{X_s}{X_{dH}}\right)^a\right], \tag{17}$$

where the two-sided hitting claims

$$\Delta(X;X_{dL},X_s) = \frac{X^z X_s^a - X^a X_s^z}{X_{dL}^z X_s^a - X_{dL}^a X_s^z} \quad \text{and} \quad \Sigma(X;X_{dL},X_s) = \frac{X^a X_{dL}^z - X^z X_{dL}^a}{X_{dL}^z X_s^a - X_{dL}^a X_s^z}, \tag{18}$$

$a\equiv a(\mu,s)<0$, *and* $z\equiv z(\mu,\sigma)>1$ *are derived in* Appendix A.

The result makes intuitive sense. Economically, these functions are related to two-sided hitting claims or primary (Arrow) securities. A two-sided hitting claim is a non-dividend paying security that promises \$1 contingent upon the firm's EBIT process X reaching the level X_{dL} (X_s) the first time from above (below) prior to having ever touched X_s (X_{dL}) from below (above). Both the default and the option exercise trigger act as absorbing barriers for the process $X(t)$; i.e., it is either killed in the event of default or replaced by a new (scaled) process initiated at ΠX_s with drift μ and volatility s. Appendix A demonstrates that $\Delta(X; X_{dL}, X_s)$ and $\Sigma(X; X_{dL}, X_s)$ are in fact the values of two-sided hitting claims for reaching first the default-triggering EBIT level X_{dL} and for reaching first the investment-triggering EBIT level X_s, respectively.

Mathematically, the real-valued functions $\Delta:\Re_+\to[0,1]$ and $\Sigma:\Re_+\to[0,1]$ are operating as switches at the bounds of the waiting-to-invest region; that is, when the geometric Brownian motion process X takes its first excursion from the range $(X_{dL}, X_s)\subset\Re_+$ between the barriers. For example, $\Delta(X_s)=0$ and $\Delta(X_{dL})=1$ upon exit. As a consequence of these functions, the lower and the higher debt value functions are matching values at $X=X_s$; i.e.,

$$D_L(X_s,C;\mu,\sigma) = D_H(X_s,C;\mu,\sigma). \tag{19}$$

Similarly, the lower debt value function is equal to the stipulated recovery value at $X=X_{dL}$; i.e.,

$$D_L(X_{dL},C;\mu,\sigma) = L(X_{dL}), \tag{20}$$

which equals $(1-\alpha)(1-\tau)X_{dL}/(r-\mu)$. These are two necessary (but not sufficient) conditions for optimality. When the firm defaults on its obligation to bondholders prior to investment, the investment opportunity vanishes to exist.[16]

Similar arguments lead to an expression for the value of equity prior to investment.

[16] The assumption that default costs on future investment opportunities are 100% can be relaxed.

Proposition 8. *Until the firm's EBIT process X takes the first excursion from the open interval* (X_{dL}, X_s)*, the levered firm's equity* $E_L(X,C)$ *yielding a dividend flow of* $(1-\tau)(X-C)$ *is worth*

$$E_L(X,C;\mu,\sigma) = (1-\tau)\left(\frac{X}{r-\mu} - \frac{C}{r}\right) - (1-\tau)\left(\frac{X_{dL}}{r-\mu} - \frac{C}{r}\right)\Delta(X) + (1-\tau)\left[\frac{(\Pi-1)X_s}{r-\mu} - \frac{I}{1-\tau} - \left(\frac{\Pi X_{dH}}{r-\mu} - \frac{C}{r}\right)\left(\frac{X_s}{X_{dH}}\right)^a\right]\Sigma(X), \tag{21}$$

where the two-sided hitting claims $\Delta(X)$ *and* $\Delta(X)$ *are given in* (18).

First, observe that at $X = X_s$ the lower and the higher equity value functions are matching values, i.e., $E_L(X_s, C; \mu,\sigma) = E_H(X_s, C; \mu, \sigma)$ and at $X = X_{dL}$ the lower equity value function is equal to the stipulated recovery value in accord with the Absolute Priority Rule (APR), i.e., $E_L(X_{dL}, C; \mu,\sigma) = 0$. These are two necessary (but not sufficient) conditions for optimality. Second, the first line of equity's value in (21) is composed of the unlevered firm's assets in place, $V_A(X)$, less the after-tax coupon payments, less the after-tax value of the firm at the onset of reorganization multiplied by the two-sided hitting claim for default, $\Delta(X)$. The second line in (21) represents the levered value of the investment opportunity in the waiting-to-invest region,

$$V_G(X,C) = (1-\tau)\left[\frac{(\Pi-1)X_s}{r-\mu} - \frac{I}{1-\tau}\right]\Sigma(X) \quad \forall X \in (X_{dL}, X_s), \tag{22}$$

less the post-investment recovery value that has been derived in (13).

By the firm value identity, which always holds in the absence of arbitrage, $\upsilon_L(X_s, C; \mu,\sigma) = \upsilon_H(X_s, C; \mu,\sigma)$. Therefore it is perhaps less surprising that in addition an expression for the levered firm value prior to investment can be derived.

Proposition 9. *Until the firm's EBIT process X takes the first excursion from the open interval* (X_{dL}, X_s)*, the total levered firm* $v_L(X,C)$ *yielding a dividend flow of* $(1-\tau)X + \tau C$ *is worth*

$$\begin{aligned}\upsilon_L(X,C;\mu,\sigma) = {} & \frac{(1-\tau)X}{r-\mu} + \frac{\tau C}{r}\left[1 - \Sigma(X)\left(\frac{X_s}{X_{dH}}\right)^a - \Delta(X)\right] - \alpha(1-\tau)\left[\Sigma(X)\frac{\Pi X_{dH}}{r-\mu}\left(\frac{X_s}{X_{dH}}\right)^a + \Delta(X)\frac{X_{dL}}{r-\mu}\right] \\ & + (1-\tau)\left[\frac{(\Pi-1)X_s}{r-\mu} - \frac{I}{1-\tau}\right]\Sigma(X),\end{aligned} \tag{23}$$

where the two-sided hitting claims $\Delta(X)$ *and* $\Delta(X)$ *are given in (18).*

Taking investment cost into account, there are no discontinuities in asset prices at the upper free boundary yet there is still one more condition required to ensure optimality. This is the object of the following two subsections. Recall that a fundamental problem for bondholders is that the manager's real option exercise strategy cannot be precontracted in the bond covenants or otherwise precommitted credibly. Bondholders' rational expectations enable them to anticipate shareholders' *ex post* investment policy in determining the fair value of debt at its issuance date. Thus, bondholders place a commensurate discount on the firm's bonds.

The case without precommitment can be contrasted with the hypothetical environment in which the manager's financing and investment decisions can be contracted upon *ex ante* (or otherwise credibly precommitted). In this case, total firm value is maximized by choosing simultaneously financing and investment strategies at time 0. Following Mello and Parsons (1992), the difference in maximal firm values between the *ex ante* and the *ex post* investment environments provide a measure for the magnitude of the debt overhang agency costs:

$$A(X) = \upsilon_L^{fb}(X, C^{fb*}) - \upsilon_L^{sb}(X, C^{sb*}). \tag{24}$$

Intuitively, this difference reflects the loss in total firm value that stems from maximizing equity value rather than total firm value. Interchangeably, the latter is referred to as the *first-best* (fb) and to the former as the *second-best* (sb) outcome. Under rational expectations, *ex post* option exercise behavior matters for *ex ante* financial decision-making. Therefore, it is crucial to distinguish the debt coupon choices associated with first- and second-best real option exercise strategies, i.e., C^{fb*} and C^{sb*}. In fact, we will see in a moment that $C^{fb*} \geq C^{sb*}$.

In addition to the financing decisions concerning debt coupon C and default-triggering EBIT level after investment X_{dH}, there are two more managerial decision variables: (1) The investment threshold X_s and (2) the default threshold prior to investment X_{dL}. All choice variables are derived in the following two subsections under firm value-maximization and equity value-maximization.

4.3.1. The case with precommitment

The first-best financing and real option exercise strategies arise when the manager can make a commitment to an investment-triggering EBIT level at the debt issuance date. Therefore, the manager will *ex post* continue to maximize (perceived) firm value in determining the default and investment switches. In other words, the manager commits not to change his investment behavior *ex post* looking after shareholder's wealth. This way bondholders enjoy maximal benefits from the investment opportunity. They therefore reward shareholders by paying *ex ante* a commensurate price for these benefits. Though higher bond prices prevail, the investment costs are still fully borne by shareholders, which is the ultimate source of the free-rider problem. Especially because *ex post* deviations from this commitment can generate higher payoffs to equity, an additional time-consistency would be required to make it believable. As a consequence, the search for a credible commitment device to actually going down this alley is of interest not only to academics but more importantly to firms' shareholders.

At time 0, the manager simultaneously chooses the debt coupon $C \equiv C^{\text{fb}*}$, and two free boundaries: (1) the default threshold $X_{\text{dL}} \equiv X_{\text{dL}}^{\text{fb}}$ and (2) the first-best investment threshold $X_s \equiv X_s^{\text{fb}}$. This involves solving the following optimization program.

$$P1: \quad \max_{C, X_{\text{dL}}, X_{\text{dH}}, X_s} \upsilon_{\text{L}}(X, C; X_s, X_{\text{dL}})|_{X=X_0}, \tag{25}$$

subject to

$$\frac{\partial E_L(X,C)}{\partial X}|_{X=X_{\text{dL}}} = 0, \tag{26}$$

$$\frac{\partial E_H(X,C)}{\partial X}|_{X=X_{\text{dH}}} = 0, \tag{27}$$

$$\frac{\partial \upsilon_{\text{L}}(X,C)}{\partial X}|_{X=X_s} = \frac{\partial \upsilon_{\text{H}}(X,C)}{\partial X}|_{X=X_s}, \tag{28}$$

where $E_{\text{L}}(\cdot)$, $E_{\text{H}}(\cdot)$, $\upsilon_{\text{L}}(\cdot)$, and $\upsilon_{\text{H}}(\cdot)$ are given by (21), (13), (23), and (14), respectively. (26) and (27) are the required smooth-pasting conditions for default before and after investment. The former condition ensures that the manager's investment incentives are zeroed out smoothly at the onset of financial distress. Similarly, (28) is the smooth-pasting condition for investment when firm value is maximized. Intuitively, the expected capital gains from owning the firm an instant prior to or just after investment must be equal, which is equivalent to a flow condition. They are together with the value-matching conditions necessary and sufficient for optimality.

A central feature of this model is that the manager's optimization program P1 endogenously anchors firm value into three smooth-pasting conditions. Hence they need to be solved simultaneously in making the leverage decision C. However, pre-investment firm value $\upsilon_{\text{L}}(\cdot)$ is only affected by C, X_{dL}, and X_s. Therefore, the pre-investment choice of C implies a post-investment level for X_{dH}. The solution to (27) has already been derived in (15) of Proposition 6.

Using Propositions 5, 8, and 9, (26) and (28) are analytically characterized by next proposition.

Proposition 10. *The manager's strategy consists of defaulting when $X(t)$ touches the threshold level X_{dL} the first time from above and investing when $X(t)$ touches the threshold level X_s the first time from below. The default and investment thresholds simultaneously solve the following equations*:

$$\begin{aligned} 0 = {} & \frac{1-\tau}{X_{\text{dL}}}\Gamma(X_{\text{dL}}, X_s)\left[\frac{(\Pi-1)X_s}{r-\mu} - \frac{I}{1-\tau} - \left(\frac{\Pi X_{\text{dH}}}{r-\mu} - \frac{C}{r}\right)\left(\frac{X_s}{X_{\text{dH}}}\right)^a\right] \\ & + \frac{1-\tau}{X_{\text{dL}}}\left(\frac{X_{\text{dL}}}{r-\mu} - \frac{C}{r}\right)\Omega(X_{\text{dL}}, X_s) + \frac{1-\tau}{r-\mu}, \end{aligned} \tag{26'}$$

where

$$\Omega(X_{\text{dL}}, X_s) = \frac{aX_s^z X_{\text{dL}}^a - zX_s^a X_{\text{dL}}^z}{X_{\text{dL}}^z X_s^a - X_{\text{dL}}^a X_s^z} \quad \text{and} \quad \Gamma(X_{\text{dL}}, X_s) = \frac{(a-z)X_{\text{dL}}^{a+z}}{X_{\text{dL}}^z X_s^a - X_{\text{dL}}^a X_s^z},$$

and

$$\begin{aligned} 0 = {} & \left[\frac{(1-\tau)(\Pi-1)}{r-\mu} - \frac{I}{X_s}\right]\Theta(X_{\text{dL}}, X_s) - \frac{(1-\tau)\Pi}{r-\mu}\left[1 - a\alpha\left(\frac{X_s}{X_{\text{dH}}}\right)^{a-1}\right] \\ & - \frac{\tau C}{rX_s}\left[[\Theta(X_{\text{dL}}, X_s) - a]\left(\frac{X_s}{X_{\text{dH}}}\right)^a - \Lambda(X_{\text{dL}}, X_s)\right] + \frac{1-\tau}{r-\mu} \\ & - \frac{\alpha(1-\tau)}{X_s}\left[\frac{\Pi X_{\text{dH}}}{r-\mu}\left(\frac{X_s}{X_{\text{dH}}}\right)^a \Theta(X_{\text{dL}}, X_s) - \frac{X_{\text{dL}}}{r-\mu}\Lambda(X_{\text{dL}}, X_s)\right], \end{aligned} \tag{28'}$$

where

$$\Theta(X_{\text{dL}}, X_s) = \frac{aX_s^a X_{\text{dL}}^z - zX_s^z X_{\text{dL}}^a}{X_{\text{dL}}^z X_s^a - X_{\text{dL}}^a X_s^z} \quad \text{and} \quad \Lambda(X_{\text{dL}}, X_s) = \frac{(a-z)X_s^{a+z}}{X_{\text{dL}}^z X_s^a - X_{\text{dL}}^a X_s^z}.$$

Going forward, the hypothetical case of precommitment can be contrasted with the more realistic environment in which the manager's financing and investment decisions cannot be contracted upon *ex ante* (or otherwise credibly precommitted). The next subsection investigates this case.

4.3.2. The case without precommitment

When the investment policy cannot be contracted upon, it is chosen *ex post* to maximize (perceived) equity value given the initial capital structure decision. However, at time 0 the manager, who is perfectly rational in all regards other than having potentially biased beliefs about the future evolution of EBIT, anticipates that investment behavior may be affected or even adversely constrained by initial financing decisions. As a consequence, the manager simultaneously chooses the debt coupon $C \equiv C^{sb*}$, the second-best default threshold $X_{dL} \equiv X_{dL}^{sb}$, and the second-best investment threshold $X_s \equiv X_s^{sb}$. A slightly modified optimization problem obtains:

$$\text{P2}: \quad \max_{C, X_{dL}, X_{dH}, X_s} \upsilon_L(X, C; X_s, X_{dL})|_{X=X_0}, \tag{29}$$

subject to

$$\frac{\partial E_L(X,C)}{\partial X}|_{X=X_{dL}} = 0, \tag{30}$$

$$\frac{\partial E_H(X,C)}{\partial X}|_{X=X_{dH}} = 0, \tag{31}$$

$$\frac{\partial E_L(X,C)}{\partial X}|_{X=X_s} = \frac{\partial E_H(X,C)}{\partial X}|_{X=X_s}, \tag{32}$$

where $E_L(\cdot)$ and $E_H(\cdot)$ are given in (21) and (13). (30) and (31) are the required optimality conditions for default before and after investment. Similarly, (32) is the optimality condition for investment when equity value is maximized. The solution to (31) is given in (15).

Using Propositions 4 and 8, (30) and (32) are analytically characterized by next proposition.

Proposition 11. *The manager's strategy consists of defaulting when $X(t)$ touches the threshold level X_{dL} the first time from above and investing when $X(t)$ touches the threshold level X_s the first time from below. The default and investment thresholds simultaneously solve the following equations*:

$$\begin{aligned} 0 = {} & \frac{1-\tau}{X_{dL}} \Gamma(X_{dL}, X_s) \left[\frac{(\Pi - 1)X_s}{r-\mu} - \frac{I}{1-\tau} - \left(\frac{\Pi X_{dH}}{r-\mu} - \frac{C}{r} \right) \left(\frac{X_s}{X_{dH}} \right)^a \right] \\ & + \frac{1-\tau}{X_{dL}} \left(\frac{X_{dL}}{r-\mu} - \frac{C}{r} \right) \Omega(X_{dL}, X_s) + \frac{1-\tau}{r-\mu} \end{aligned} \tag{30'}$$

where

$$\Omega(X_{dL}, X_s) = \frac{a X_s^z X_{dL}^a - z X_s^a X_{dL}^z}{X_{dL}^z X_s^a - X_{dL}^a X_s^z} \quad \textit{and} \quad \Gamma(X_{dL}, X_s) = \frac{(a-z) X_{dL}^{a+z}}{X_{dL}^z X_s^a - X_{dL}^a X_s^z}.$$

and

$$\begin{aligned} 0 = {} & \frac{1-\tau}{X_s} \Bigg\{ \left(\frac{X_{dL}}{r-\mu} - \frac{C}{r} \right) \Lambda(X_{dL}, X_s) - \frac{\Pi X_s}{r-\mu} + a \left(\frac{\Pi X_{dH}}{r-\mu} - \frac{C}{r} \right) \left(\frac{X_s}{X_{dH}} \right)^a \\ & + \left[\frac{(\Pi - 1)X_s}{r-\mu} - \frac{I}{1-\tau} - \left(\frac{\Pi X_{dH}}{r-\mu} - \frac{C}{r} \right) \left(\frac{X_s}{X_{dH}} \right)^a \right] \Theta(X_{dL}, X_s) \Bigg\} + \frac{1-\tau}{r-\mu} \end{aligned} \tag{32'}$$

where

$$\Theta(X_{dL}, X_s) = \frac{a X_s^a X_{dL}^z - z X_s^z X_{dL}^a}{X_{dL}^z X_s^a - X_{dL}^a X_s^z} \quad \textit{and} \quad \Lambda(X_{dL}, X_s) = \frac{(a-z) X_s^{a+z}}{X_{dL}^z X_s^a - X_{dL}^a X_s^z}.$$

5. Empirical predictions for the levered firm

This section applies the model to examine some of its key properties. The main focus is on the endogenous interaction between corporate borrowing and future investment opportunities and, in particular, on the role of optimism and overconfidence. Recall that the model enables me to distinguish between the effects of optimism ($\mu' > \mu$) and overconfidence ($\sigma' < \sigma$) on the dynamics of financing and investment decisions. Yet, empirical and experimental evidences in social psychology indicate that these personality traits tend to go hand in hand with each other.[17] Therefore, Sections 5.1 and 5.2 develop empirical predictions more broadly and realistically for biased beliefs (i.e., $\mu' > \mu$ and $\sigma' < \sigma$). For the same reason, I also consider the effect of optimism about investment benefits (i.e., $\Pi' > \Pi$) as an extension in Section 5.3.

The model's predictions are either directly testable via survey responses of managers or indirectly testable via empirical proxies of managers' biases. Some recent papers using the survey approach are Ben-David, Graham, and Harvey (2006) and Puri and Robinson (2007). Malmendier and Tate (2005) and Malmendier, Tate, and Yan (2007) propose an empirical identification of managerial biases using managers' stock option exercise behavior. These studies are consistent with the view that managerial optimism and overconfidence affect firms' financing and investment decisions.

5.1. Financing and investment decisions

In the model for the levered firm from Section 4, the manager selects the debt coupon C, the default threshold before investment X_{dL}, the default threshold after investment X_{dH}, and the investment threshold X_s, which are linked by the smooth-pasting conditions in Propositions 10 and 11.[18] In particular, inspecting (26′) and (28′) or (30′) and (32′) reveals that the manager's choice variables enter into two non-linear equations, which lead to an interaction between the timing effect and the leverage effect. This endogenous interaction between financing and investment decisions also provides interesting and novel insights into the relation between default and investment thresholds.

5.1.1. Interactions between default and investment

The manager's real option exercise strategies may not be part of the space of admissible and reinforcable contracts. So, the *ex ante* optimality condition (32) may not be *ex post* incentive compatible. That is, it may not maximize equity value, E_L, at any EBIT level, X, prior to investment at $X_s > X$ or default at $X_{dL} < X$. However, Merton (1973) shows that the condition

$$dE_L(X,C)\,/\,dX_s = 0 \quad \forall X \in (X_{dL}, X_s), \tag{33}$$

which captures *ex post* incentive compatibility, is equivalent to *ex ante* optimality in the sense of (32). Therefore, after the debt coupon, C, is chosen, the manager acting on behalf of shareholders has no incentive to deviate from the equity value-maximizing investment policy envisioned based on solving (32) at $t=0$, and *a fortiori* for $X \in (X_{dL}, X_s)$ at $t>0$; that is, in the waiting-to-invest region. The total derivative in (33) can be evaluated at $X = X_s$ to gain further economic insights:

$$\frac{dE_L(X,C)}{dX_s}\Big|_{X=X_s} = \frac{\partial E_L(X,C)}{\partial X_s}\Big|_{X=X_s} + \frac{\partial E_L(X,C)}{\partial X_{dL}}\Big|_{X=X_s}\frac{\partial X_{dL}}{\partial X_s}, \tag{34}$$

where

$$\frac{\partial X_{dL}}{\partial X_s} = -\frac{\partial\left(\partial E_L(X,C)/\partial X|_{X=X_{dL}}\right)/\partial X_s}{\partial\left(\partial E_L(X,C)/\partial X|_{X=X_{dL}}\right)/\partial X_{dL}} \tag{35}$$

In words, (34) gauges the change in equity value that would result from a small change of the investment threshold at $X = X_s$, recognizing that X_{dL} will change with X_s but debt coupon C will not after it is selected at $t=0$. That is, for a given capital structure, an incremental change in X_s has a direct effect on equity value captured by the first term on the r.h.s. of (34), but also an indirect one due to a change of X_{dL} captured by the second term on the r.h.s. of (34). Comparing the unlevered and the levered value of the investment opportunity explains this interaction between default and investment thresholds, given that (4) emerges as a special case of (22) for $X_{dL} = 0$; that is, a higher (lower) default threshold, X_{dL} increases (decreases) the likelihood of losing the unexercised investment opportunity in financial distress and hence lowers (raises) its value in (22). This change of the investment option's value yields a lower (higher) investment threshold X_s. So, the boundaries of the waiting-to-invest regime move in opposite directions once debt policy is set.

What may influence the default boundary when the debt coupon, C, is fixed? The wealth transfer from equity to debt at the time of investment, which causes the underinvestment problem, is equal to the reduction in equity's default option value upon investment. Recalling (26) ensures that the default option value is maximized because default is endogenously chosen (i.e., maximizes equity value), the default option value is, for example, lower when default is not endogenous, perhaps because net worth covenants govern a default threshold outside of equity's control. Thus, compared to exogenously selecting a higher default threshold than the endogenous one, the interaction between default and investment leads to a higher investment threshold when default is endogenous. Put differently, investment is less frequent when default is endogenous rather than exogenous because the

[17] See, e.g., Taylor and Brown (1988) and the references therein.
[18] Recall that Table 1 provides an index of the model's notation.

wealth transfer from equity to debt upon investment is larger. Like endogenizing default, introducing debt renegotiation or risk-shifting may also lower the default boundary, which is summarized by the next prediction.

Prediction 3. *A decline in the default boundary e.g. due to endogenizing default, permitting strategic debt renegotiations or risk-shifting reduces the investment option's sensitivity to EBIT and therefore increases the underinvestment problem* (*i.e., investment will be less frequent or likely*).

I next turn to the effect of managerial optimism and overconfidence on the interaction between financing and investment decisions. Recall the base case parameters are summarized in Table 2.

5.1.2. Investment

To begin, Fig. 2 charts the manager's investment strategies as a function of beliefs. As reference points, the first-best $X_s^{\text{fb}}=31.95$ and the second-best $X_s^{\text{sb}}=34.91$ investment thresholds under the correct beliefs ($\mu=1\%$ and $s=25\%$) are depicted on the left (right) endpoints of Panel A,B. In accordance with the analytical results on the comparative statics of the investment behavior in Section 3, an increase in the growth rate decreases the second-best investment threshold. Similarly, a decrease in volatility results in a lower second-best investment threshold. The figure thus reveals that the timing effect of optimism and overconfidence also obtains for the levered firm.

This makes economic sense, recalling the intuition for the value of waiting to invest discussed, e.g., by Dixit and Pindyck (1994). First, a higher growth rate of EBIT implies a higher opportunity cost of waiting to invest, which immediately lowers the option value of waiting to invest. Thus, second-best investment decisions are made, in expectation, earlier; that is, at a lower critical threshold, X_s^{sb}. In this behavioral model, it is merely the perception of a higher growth rate that lowers the investment timing threshold of an optimistic ($\mu'>\mu$) manager. Second, in an environment surrounded by less uncertainty the opportunity to wait on new information about EBIT to arrive is less valuable, which leads to a lower option value of waiting to invest. Hence second-best

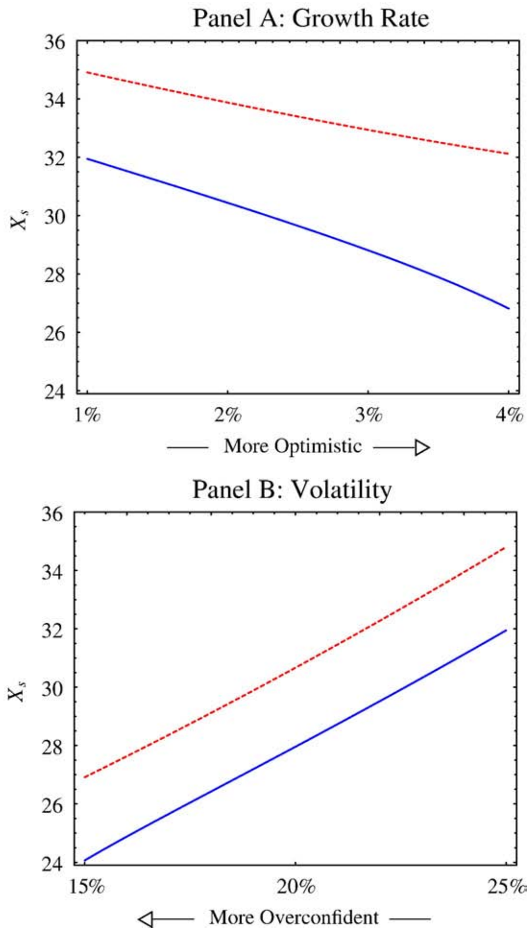

Fig. 2. Growth option exercise strategies of the optimally levered firm. The isolated effect of optimism and overconfidence on the first-best X_s^{fb} (*solid/blue line*) and second-best X_s^{sb} (*dashed/red line*) optimal investment thresholds is depicted in Panels A and B, respectively. It is assumed that $X_0=20$, $\Pi=1.75$, $I=150$, $r=8\%$, $\mu=1\%$, $\sigma=25\%$, $\alpha=25\%$, and $\tau=15\%$. Default, leverage, and investment are chosen endogenously, which yields the real option exercise strategies $X_s^{\text{fb}}=31.95<X_s^{\text{sb}}=34.91$ in the base case. Note that modest optimism and overconfidence *ceteris paribus* both ameliorate shareholder–bondholder conflicts because investments will optimally be undertaken earlier. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

investment decisions are made, in expectation, earlier; that is, at a lower critical threshold, X_s^{sb}. In this behavioral model, it is merely the perception of a lower volatility that lowers the investment timing threshold of an overconfident ($s'<s$) manager. Consistent with Prediction 1 for the unlevered firm, comparative statics for shifts in optimism and overconfidence cause greater investment for the levered firm, which leads to the next prediction.

Prediction 4. *For the debt–equity financed firm, managerial optimism and overconfidence produce earlier investment which corresponds to, in expectation, more investment in a present value sense.*

5.1.3. Leverage

As argued above, a different, say biased, investment policy, X_s', calls for a different financial policy; i.e., default thresholds, X_{dL}' and X_{dH}', and debt coupon, C'. Concerning leverage, Fig. 3 confirms findings in Hackbarth (2008) in the presence of investment opportunities. Managerial optimism and overconfidence about assets in place create a predisposition to debt finance. In particular, when default, leverage, and investment are chosen endogenously, the leverage ratio is $\ell^*=53.67\%$ in the first-best and $\ell^*=52.00\%$ in the second-best case. As shown by the figure, both leverage ratios are increasing in the degree of managerial optimism and overconfidence. The next empirical prediction states the leverage effect of optimism and overconfidence.

Prediction 5. *For the debt–equity financed firm, managerial optimism and overconfidence create, in equilibrium, a higher debt coupon level and hence a higher leverage ratio given rational beliefs.*

5.1.4. Default

Fig. 4 illustrates the effect of optimism and overconfidence on the default-triggering EBIT level prior to investment X_{dL} in Panels A and B. Panels C and D show the relation between the manager's beliefs and the post-investment default threshold X_{dH}. The default

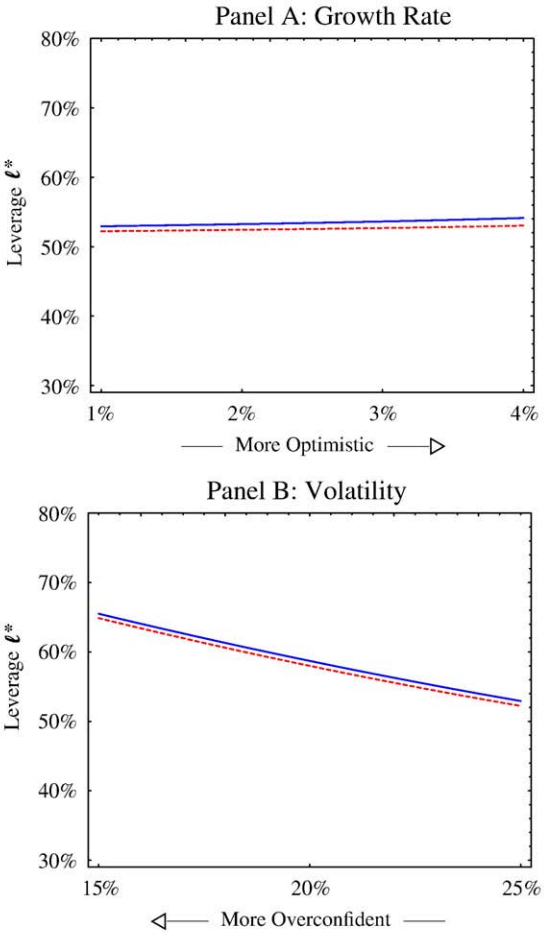

Fig. 3. Optimism and overconfidence about assets in place. The *isolated effect* of optimism and overconfidence on the manager's perceived optimal leverage choice in the presence of growth is depicted in Panels A and B, respectively. The (*solid*/*blue line*) is the first-best optimal leverage policy and the (*dashed*/*red line*) is the second-best optimal leverage policy. It is assumed that $X_0=20$, $\Pi=1.75$, $I=150$, $r=8\%$, $\mu=1\%$, $\sigma=25\%$, $\alpha=25\%$, and $\tau=15\%$. Default, leverage, and investment are chosen endogenously. In the base case, optimal leverage is $\ell^*=53.67\%$ under the first-best and $\ell^*=52.00\%$ under the second-best strategies. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

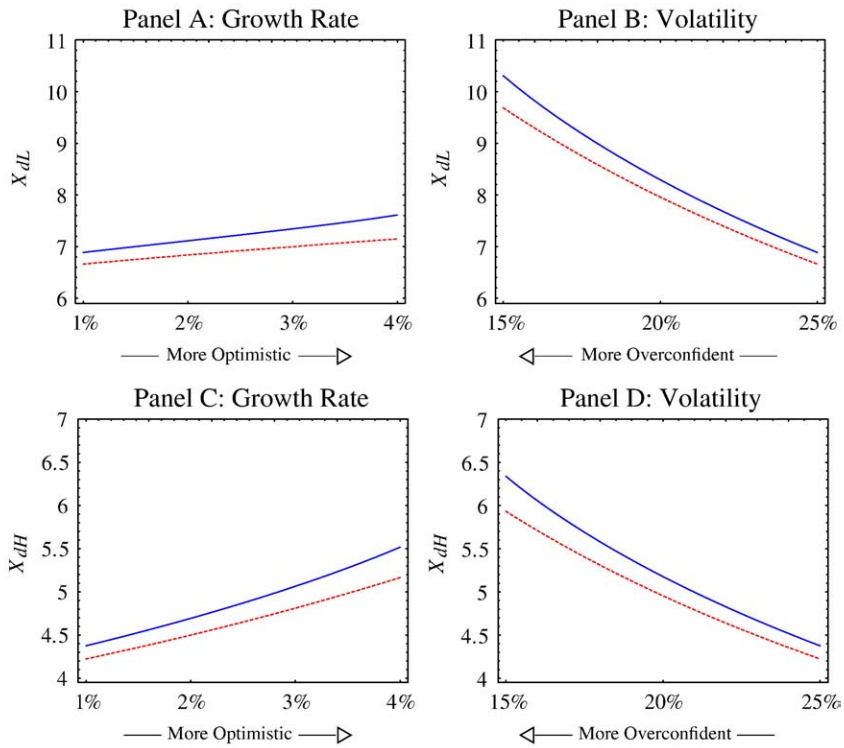

Fig. 4. Endogenous default thresholds before and after investment. The *isolated effect* of optimism and overconfidence on the manager's perceived optimal default decisions before investment X_{dL}^{fb} (*solid/blue line*) and X_{dL}^{sb} (*dashed/red line*) given optimal leverage and investment decisions are depicted in Panels A and B, respectively. The *isolated effect* of optimism and overconfidence on the manager's perceived optimal default decisions after investment X_{dH}^{fb} (*solid/blue line*) and X_{dH}^{sb} (*dashed/red line*) given optimal leverage and investment decisions are depicted in Panels C and D, respectively. It is assumed that $X_0=20$, $\Pi=1.75$, $I=150$, $r=8\%$, $\mu=1\%$, $\sigma=25\%$, $\alpha=25\%$, and $\tau=15\%$. Default, leverage, and investment are chosen endogenously, which yields the pre-investment default policies $X_{dL}^{fb}=6.89>X_{dL}^{sb}=6.66$ in the base case. The post-investment default policies are $X_{dH}^{fb}=4.38<X_{dH}^{sb}=4.22$ in the base case. Note modest optimism and overconfidence *ceteris paribus* both ameliorate shareholder–bondholder conflicts because default will optimally be chosen earlier. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

policies in the base case are $X_{dL}^{fb}=6.89>X_{dL}^{sb}=6.66$ and $X_{dH}^{fb}=4.38>X_{dH}^{sb}=4.22$. In this behavioral model, it is merely the perception of a higher growth rate (lower volatility) that increases the default-triggering EBIT level of an optimistic (overconfident) manager. Though the next prediction is largely a result of the leverage effect of optimism and overconfidence, it could still be tested separately.

Prediction 6. *For the debt–equity financed firm, managerial optimism and overconfidence create, in equilibrium, a higher default threshold (i.e., default will be more frequent or likely).*

5.1.5. Firm value

At the debt issuance date, a rational manager cannot make a credible commitment to implement a policy that maximizes *ex post* firm value rather than only equity value. Bondholders with rational expectations anticipate that the manager's incentives to deviate from a firm value-maximizing investment policy *ex post*. In computing the fair price implied by the anticipated default risk-return tradeoff of the firm's bonds, bondholders therefore discount the firm's debt appropriately. In turn, shareholders can raise less external resources from creditors. This is the classic agency result: shareholders as residual claimants have to bear agency costs.

In contrast, consider an optimistic ($\mu'>\mu$) and/or overconfident ($\sigma'<\sigma$) manager whose tenure goes beyond the investment horizon at hand. The bias in beliefs implies a more favorable policy from the bondholders' perspective; i.e., tighter default and investment boundaries. Again, bondholders' rational expectations permit them to compute the fair price implied by the default risk–return tradeoff implicit in the firm's bonds. As a consequence, they discount the firm's debt less severely and hence shareholders can attract relatively more external capital when a biased manager is in office. *Ceteris paribus*, the firm's initial share price is higher.[19] This is the key prediction of the behavioral model: Investor welfare increases and hence shareholders as residual claimants will be seeking out the labor market of mangers for those who — naïvely or unwittingly — ameliorate the traditional commitment problem by means of their personality traits: optimism and overconfidence.

[19] Though *ex post* equity value is slightly reduced by optimistic and overconfident management, *ex ante* firm value increases for mild biases given the higher proceeds from floating debt. Hence initial shareholders' welfare improves.

Prediction 7. *In contrast to an unlevered firm, a levered firm's shareholders should rationally seek out the labor market of managers for candidates who are mildly optimistic and/or overconfident because hiring managers biased in this way leads to better firm performance and hence firm value.*

Interestingly, it is precisely this type of — either naïve or unwitting — managerial behavior that increases firm value. In particular, the wedge between first-best and second-best values of the levered firm is shrinking over some region of mild biases. The first-best and the second-best corporate strategies of a rational manager (i.e., under the correct beliefs of $\mu=1\%$ and $\sigma=25\%$) imply levered firm values of $\upsilon^{\text{fb}*}=315.12$ and $\upsilon^{\text{sb}*}=308.84$, respectively. Debt overhang costs are moderate in that the percentage loss relative to the firm value under full commitment is about 2%.[20] Combining the effects on financing and investment decisions from Sections 5.1.1–5.1.3, the timing effect outweighs the leverage effect for mild biases, which means that the benefits of managerial biases exceed their costs. Said differently, debt overhang agency costs are reduced by mildly biased managers' decisions, while extreme biases of course exacerbate debt overhang agency costs. Hence these managerial traits may be regarded as commitment devices for approaching first-best investment, leverage, and default policies, and for attaining higher firm performance and value.

5.2. Exercise decisions of other real options

One may be tempted to ask whether the above results are unique to the debt overhang problem. It turns out that the underinvestment results extend to environments in which managers have prior to the onset of financial distress other real options at their discretion. First, managers of a levered firm can potentially transfer value from bondholders to shareholders by increasing investment risk after debt is in place, giving rise to the asset substitution problem. Leland (1998) points out that even if the manager's risk-shifting policy can be committed to at time 0 to maximize joint benefits of bondholders and shareholders, it is nevertheless optimal to increase investment risk at some sufficiently low cash flow level prior to default. Therefore, the precommitment problem of asset substitution manifests itself in the wedge between the equity value-maximizing switch point and the firm value-maximizing switch point. Second, another possibility for the manager is to strip some of the firm's assets to pay a respectable dividend to shareholders when approaching financial distress (asset stripping). Third, Morellec (2001) studies contraction options of the firm that arise because only a fraction of the firm's assets are pledged to its lenders in the bond covenants. The next prediction extends the results on debt overhang to these bondholder–shareholder conflicts.

Prediction 8. *For the debt–equity financed firm, a mild degree of managerial optimism and overconfidence ameliorates other bondholder–shareholder conflicts, such as asset stripping or risk-shifting.*

These real options have in common a favorable timing effect of optimism and overconfidence. Asset stripping, contraction, and risk-shifting only become desirable from equity's perspective after a mediocre performance; that is, at a low EBIT level. Intuitively, a higher growth rate implies a lower probability of default. Due to this lower opportunity cost of waiting, a higher option value of waiting to risk-shift or asset-strip prevails. Hence a later change in investment risk or a later initiation of asset sales will occur; i.e., at a lower critical threshold. In this behavioral model, it is merely the perception of a higher growth rate that lowers the risk selection or asset stripping thresholds of an optimistic ($\mu'>\mu$) manager. The traditional approach also predicts that an environment surrounded by less uncertainty deems the risk of default to be lower, which renders the opportunity to wait for more (adverse) information about EBIT to arrive is more valuable. In the parlance of real options, this is equivalent to a higher option value of waiting to divest or risk-shift, and hence a lower critical threshold obtains. In this behavioral model, it is merely the perception of a lower volatility that lowers the risk selection or asset stripping threshold of an overconfident ($\sigma'<\sigma$) manager.

5.3. Optimism about investment benefits

As another extension, I examine the effect of managerial optimism about investment benefits on leverage. Recall that managerial optimism and overconfidence about asset in place produce the leverage effect, which is detrimental to the underinvestment problem and hence to firm value. Given the evidence in social psychology that perception biases tend to go hand in hand with each other, one may be tempted to ask whether the above results for debt overhang are robust to introducing optimism about the magnitude of future investment benefits.

A firm with higher investment benefits, Π, trades off the same tax benefits and default costs on assets in place, but, by issuing debt, takes the risk of losing a more valuable investment option. As depicted in Panel A of Fig. 5, an inverse relation between leverage and investment obtains. Optimism about the magnitude of investment benefits corresponds to an EBIT scaling parameter $\Pi'>\Pi$.[21] Therefore, the above inverse relation between leverage and investment is steepened, which can be seen in Panel B of Fig. 5 for $\Pi'=1.1*\Pi$. Put differently, optimism about the magnitude of future investment opportunities tends to moderate the leverage effect of optimism and overconfidence about assets in place (see Section 5.1.3). Managerial biases about assets in place and about benefits from investment increase the region in which the timing effect dominates the leverage effect. Hence this extension provides more scope for positive net

[20] The well-known study by Mauer and Ott (2000) reports agency costs in the range of 0.5%–6%. In contrast, Parrino and Weisbach (1999) conclude from their numerical simulations that "distortions from stockholder–bondholder conflicts [...] are too small to explain the observed cross-sectional variation in capital structure."

[21] It follows directly from Proposition 1 that $\partial X_s/\partial\Pi<0$ and hence a manager with an upward bias about investment benefits will invest, in expectation, earlier; that is, a lower investment threshold, X'_s, obtains.

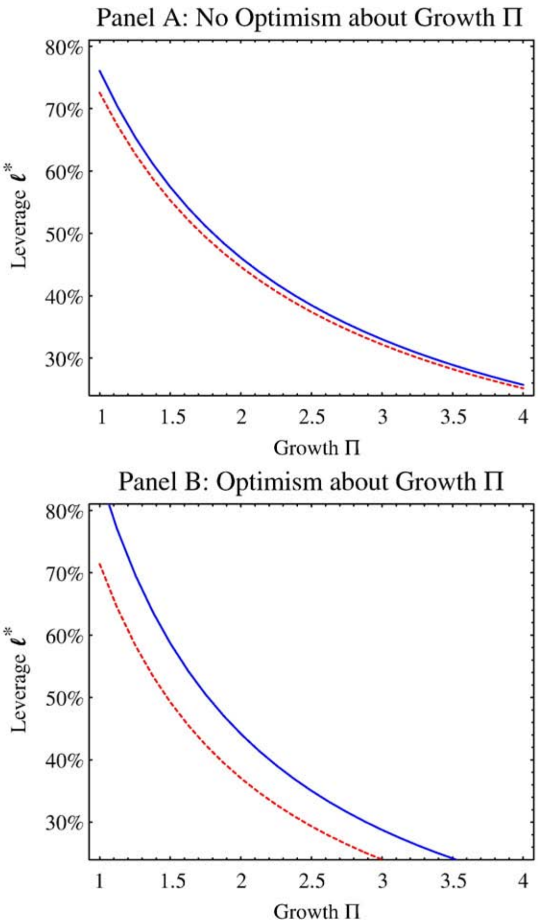

Fig. 5. Optimism about investment benefits and leverage. The figure charts the effect of optimism about the firm's EBIT scaling factor (Π) on the manager's perceived first-best (*solid*/*blue line*) and second-best (*dashed*/*red line*) optimal leverage decisions. The manager in Panel A has unbiased beliefs about Π, while the manager in Panel B believes $\Pi' = 1.1 * \Pi$ instead of Π. It is assumed that $X_0 = 20$, $I = 150$, $r = 8\%$, $\mu = 1\%$, $\sigma = 25\%$, $\alpha = 25\%$, and $\tau = 15\%$. Default, leverage, and investment are chosen endogenously. The biased manager selects an optimal leverage of $\ell^* = 54.79\%$ in the first-best and $\ell^* = 45.75\%$ in the second-best case for the baseline growth parameter $\Pi = 1.75$. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

benefits to a debt–equity-financed firm from hiring biased managers. In addition, this extension helps in explaining the debt conservatism puzzle of seemingly too low leverage ratios observed in practice (Graham, 2000).

Prediction 9. *For the debt–equity financed firm, managerial optimism about future investment benefits creates a lower debt coupon choice and hence a lower leverage ratio given rational beliefs. This moderates the leverage effect and hence promotes the positive role of optimism and overconfidence.*

6. Conclusions

A nascent literature in financial economics considers corporate managers' personality traits. The primary objective of this article is to study the interaction between financing and investment decisions from a behavioral perspective, i.e., in the presence of managerial optimism and overconfidence. I develop a contingent claims approach that integrates a simple real options model into an earnings-based capital structure environment. Analytic expressions for arbitrary beliefs, with rational beliefs as a special case, are derived from the model in which managers' financing and real option exercise decisions are endogenously linked to each other by optimality conditions.

Focusing on this behavioral perspective, I find managerial biases can play a positive role because of two balancing economic effects. First, biased managers choose higher debt levels than rational managers, exacerbating underinvestment. Second, biased managers invest earlier than rational managers, attenuating underinvestment. The latter dominates the former effect for mild biases and hence the benefits of mild biases exceed their costs. Debt overhang agency costs decline and investor welfare improves. The bottom-line of this paper is, however, the more general, agency-theoretic observation that mildly biased managers can ameliorate bondholder–shareholder conflicts (e.g., debt overhang, asset substitution, or asset stripping). Intuitively, managerial biases can act as commitment devices for implementing second-best strategies of a levered firm that are closer to first-best real option exercise strategies.

More generally, my behavioral model reveals that shareholders of debt–equity financed firms, or the board of directors in representing shareholders' interest, should rationally seek out the labor market of managers for candidates with the aforementioned personality traits in addition to demonstrable leadership and charismatic qualities. It has been argued that overconfident managers are better at shaping and communicating a vision for the firm, which promotes a more productive evolution of corporate culture. Furthermore, it may be desirable from shareholders' perspective to design several organizational layers below top executive positions. This way promotion decisions can implicitly reward optimism and overconfidence and perhaps even condition rational individuals to turn into optimists. Alternatively, firms can institute an incentive scheme that lets their rational managers appear to be biased from the investor perspective. However, this route may conceivably be rather costly and suffers from concerns about the traditional commitment problem. Either way, these open issues indicate a fruitful path for future research in behavioral corporate finance.

Appendix A

A.1. Mathematical preliminaries

For the geometric Brownian motion process of (1), consider an arbitrary contingent claim paying its owner the EBIT contingent flow benefits $\pi(X_t,t)$. The value function $F(\cdot)$ for that claim must satisfy the following equilibrium or no-arbitrage condition:

$$rF(X_t,t) = \pi(X_t,t) + \frac{1}{\mathrm{d}t}E_t\left[F\left(X_{t+\mathrm{d}t}, t+\mathrm{d}t\right)\right], \tag{A.1}$$

which has a very intuitive interpretation. The expression on the left side of this equation is the equilibrium return per unit of time an investor requires for holding this asset. Considering an asset (contingent claim) as a perpetual entitlement to an income flow, on the right side of (A.1), the first term is the current period dividend from the asset, while the second term is the expected capital gain from holding the asset from period t to period $t+\mathrm{d}t$. Applying Itô's Lemma inside the expectation operator in (A.1) yields a Partial Differential Equation (PDE) the value $F(\cdot)$ of any contingent claim on the process in (1) must satisfy:

$$rF(X_t,t) = \frac{1}{2}\sigma^2 X_t^2\frac{\partial^2 F(X_t,t)}{\partial X_t^2} + \mu X_t\frac{\partial F(X_t,t)}{\partial X_t} + \frac{\partial F(X_t,t)}{\partial t} + \pi(X_t,t). \tag{A.2}$$

In general there exists no closed-form solutions to (A.2). If I in addition abstract from any explicit time dependence of the arbitrary contingent claim and assume its dividend flows are affine in the state variable, i.e., $\pi(X_t,t)=mX_t+k$, then $\partial F(X_t,t)/\partial t=0$ — the function $\pi(\cdot)$ need not be affine and therefore this assumption can be weakened. Then (A.2) turns into the Ordinary Differential Equation (ODE):

$$rF = \frac{1}{2}\sigma^2X^2\frac{\partial^2 F}{\partial X^2} + \mu X\frac{\partial F}{\partial X} + mX + k. \tag{A.3}$$

The sum of the first two terms in (A.3) is the current expected capital appreciation on the contingent claim F, measured per unit of time. Under risk-neutrality this expected capital gain plus current flows, $mX+k$, equals the riskless return rF, all measured per unit of time. The general solution to this ODE is:

$$F(X) = A_1X^a + A_2X^z + \frac{mX}{r-\mu} + \frac{k}{r}, \tag{A.4}$$

where $a<0$ and $z>1$ denote the roots of the fundamental quadratic equation:

$$\frac{1}{2}\sigma^2(x-1)x + \mu x - r = 0, \tag{A.5}$$

that is,

$$a\equiv a(\mu,\sigma) = -\frac{\mu-\sigma^2/2}{\sigma^2} - \sqrt{\left(\frac{\mu-\sigma^2/2}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} < 0, \tag{A.6}$$

and

$$z\equiv z(\mu,\sigma) = -\frac{\mu-\sigma^2/2}{\sigma^2} + \sqrt{\left(\frac{\mu-\sigma^2/2}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} > 1. \tag{A.7}$$

All of the contingent claims priced below have solutions of this form, with suitable boundary conditions pinning down unknown constants.

A.2. One-sided hitting claims

Before moving on to the proofs, it is convenient to study the one-sided hitting claim that pays $1 contingent on the firm's EBIT process touching the level $X_{dH} \in (0,X)$ the first time from above, where the EBIT level X denotes the initial or current level of the geometric Brownian motion process. Denote the value of this primary (Arrow) security by $p_{dH}(X)$. We know that the value of this contingent claim is of the form (A.4) and obeys a differential equation like (A.3) except that the nonhomogenous term $(mX+k)$ needs to be replaced by 0 given that it does not receive any intermediate cash flows. The unknown parameters A_1 and A_2 in (A.4) will be derived using the following boundary conditions.

$$\lim_{X\uparrow\infty} p_{dH}(X) = 0 \tag{A.8}$$

$$\lim_{X\downarrow X_{dH}} p_{dH}(X) = 1 \tag{A.9}$$

The solution for the default claim is as follows:

$$p_{dH}(X) = \left(\frac{X}{X_{dH}}\right)^{a}. \tag{A.10}$$

The primary (Arrow) security that pays $1 contingent on the firm's EBIT process not (or never) touching the level X_{dH} from above describes the no-default claim. By construction, its value is:

$$p_{dH}^{no}(X) = 1 - p_{dH}(X) = \left[1-\left(\frac{X}{X_{dH}}\right)^{a}\right]. \tag{A.11}$$

Now the derivations of asset prices after exercising the real option are immediate. Propositions 3, 4, and 5 are obtained using the formulae (A.10) and (A.11) as default risk weighting factors in combination with the appropriately capitalized flow payoffs to debt, equity, and the firm in the default and no-default regions, respectively. Proposition 6 follows from differentiating (13) with respect to X, substituting X by X_d, setting the expression equal to zero, and solving for X_d.

A.3. Two-sided hitting claims

For some other proofs, it is convenient to study two-sided hitting claims whose value depends upon a geometric Brownian motion's first excursion from a strip, e.g., for some initially interior EBIT level X exiting the open interval $(X_{dL}, X_s) \subseteq \Re_+$ to either side the first time. A two-sided hitting claim that pays that pays $1 contingent on the firm's EBIT process touching the level X_{dL} (X_s) the first time from above (below) prior to having ever reached X_s (X_{dL}) from below (above). Intuitively, both the default and the option exercise trigger act as absorbing barriers for the process $X(t)$ — it is either killed in the event of default or replaced by a new (scaled) process staring out at ΠX_s in the case of investment, for example.

The value of the primary (Arrow) security for hitting the default boundary prior to the option exercise boundary is denoted by $\Delta(X)$ and the one for reaching the real option exercise threshold prior to default by $\Sigma(X)$. We know that the value of these contingent claims is of the form (A.4) and obeys a differential equation like (A.3) except that the nonhomogenous term $(mX+k)$ needs to be replaced by 0 given that they do not receive any intermediate dividends. The unknown parameters A_1 and A_2 in (A.4) will be derived using the following sets of boundary conditions. The two-sided hitting claim for default obeys:

$$\lim_{X\uparrow X_s} \Delta(X; X_{dL}, X_s) = 0, \tag{A.12}$$

$$\lim_{X\downarrow X_{dL}} \Delta(X; X_{dL}, X_s) = 1, \tag{A.13}$$

and the two-sided hitting claim for the real option exercise barrier satisfies:

$$\lim_{X\uparrow X_s} \Sigma(X; X_{dL}, X_s) = 1, \tag{A.14}$$

$$\lim_{X\downarrow X_{dL}} \Sigma(X; X_{dL}, X_s) = 0. \tag{A.15}$$

The solutions are:

$$\Delta(X; X_{dL}, X_s) = \frac{X^z X_s^a - X^a X_s^z}{X_{dL}^z X_s^a - X_{dL}^a X_s^z}, \tag{A.16}$$

and

$$\Sigma(X; X_{dL}, X_s) = \frac{X^a X_{dL}^z - X^z X_{dL}^a}{X_{dL}^z X_s^a - X_{dL}^a X_s^z}, \tag{A.17}$$

respectively. Now the derivations of asset prices prior to exercising the real option are immediate. Propositions 7, 8, and 9 are obtained using the formulae (A.16) and (A.17) as default risk and investment chance weighting factors in combination with the appropriately capitalized flow payoffs to debt, equity, and the firm in the default and no-default regions, respectively. Notice that, in the parts of the formulae of the no-default regions that are accounting for the chance of investment being undertaken at $X=X_s$, i.e. the terms multiplied by $\Sigma(X)$, the one-sided hitting claim for default after investment, i.e.,

$$p_{dH}(X_s) = \left(\frac{X_s}{X_{dH}}\right)^a, \tag{A.18}$$

has to enter the asset value equations to ensure the absence of arbitrage at $X=X_s$. Upon the first excursion of X from the no-default or waiting-to-invest region (X_{dL}, X_s) towards the upper boundary, the analysis from the previous part of the appendix applies, since, at $X=X_s$, the firm with an investment option turns into a larger firm without an investment option.

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