Corporate investment, financing, and exit decisions with an earnings-based borrowing constraint

Abstract

This paper develops a real options model to study the effects of an earnings-based borrowing constraint (EBC) on a firm's investment, financing, and exit decisions. We highlight how EBC affects the decisions and values differently than a liquidation value-based borrowing constraint (LBC). Unlike LBC, the firm with EBC delays investment to increase the cap of debt. Investment reversibility (or equivalently, liquidation value) does not largely affect the firm with EBC, although it greatly affects the firm with LBC. Unlike LBC, EBC loosens with higher volatility because higher volatility delays investment, which increases the cap of debt. With low investment reversibility and high volatility, EBC is preferable to LBC from a firm value perspective, and in case of financial distress, the firm will go into reorganization bankruptcy rather than liquidation bankruptcy. This also implies a positive relation between EBC and reorganization bankruptcy. Our results are largely consistent with empirical observations.

JEL Classifications Code: G13; G32; G33.

Keywords: real options; borrowing constraints; capital structure; bankruptcy.

1 Introduction

Economics literature (e.g., Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999)) has traditionally investigated the effects of liquidation (or asset) value-based borrowing (or lending) constraint (LBC) on corporate investing and financing decisions, as well as on business cycles. Under LBC, a firm's debt issuance capacity is based on the liquidation value of its specific assets (e.g., real estate and equipment). On the other hand, recent empirical studies, such as Lian and Ma (2021), Kermani and Ma (2020b), and Drechsel (2020), have demonstrated the prevalence of earnings-based borrowing constraint (EBC) over LBC. According to Lian and Ma (2021), 80% of debt in the United States is issued based on EBC, while 20% is issued based on LBC. Under EBC, debt capacity is based on operating earnings—typically earnings before interest, taxes, depreciation, and amortization (EBITDA)—rather than asset values. Although some papers (e.g., Lian and Ma (2021) and Drechsel (2020)) investigate the effects of EBC on aggregate investment and debt dynamics of firms in models of macroeconomic theory, no papers have studied the effects of EBC on a firm's decisions for investment timing, leverage, debt type, exit timing, and exit type in a structural model of corporate finance theory.

The purpose of this paper is to fill the gaps by studying a structural model in corporate finance with EBC. We theoretically show how EBC affects the corporate investment, financing, and exit decisions differently than LBC; most of our results account for empirical observations, and the rest generate novel and testable predictions for future research. Following the standard real options models (e.g., Shibata and Nishihara (2012) and Sundaresan, Wang, and Yang (2015)), our model considers a firm that has an option to invest by incurring investment costs along with issuing consol debt. At the investment time, EBC (i.e., the cap of debt based on earnings) is imposed on the firm. As in Abel and Eberly (1996), Abel, Dixit, Eberly, and Pindyck (1996), and Shibata and Nishihara (2018), a part of the investment costs will remain as liquidation value (called investment reversibility). On bankruptcy, a fraction of firm value is lost, and debt holders, who take over the firm, choose between liquidating immediately (called liquidation bankruptcy) or operating the firm (called reorganization bankruptcy). For comparison, we also study the model with LBC (i.e., the cap of debt based on liquidation value).[1] The model results are summarized below.

Although very tight EBC can induce the firm to use riskless debt financing, plausible levels of tightness of EBC lead the firm to use constrained risky debt financing. The constrained firm's leverage is around 20%, which is consistent with the empirical observations in Graham (2000) and Frank and Goyal (2009). With tighter EBC, the firm's leverage and value decrease, and investment is delayed. This investment delay not only stems from the decreased investment value but also from the firm's motive to loosen EBC. Indeed, the firm can increase the cap of debt under EBC by postponing investment until the earnings level reaches a higher threshold. Compared to the

[1] The model with LBC is essentially the same as in Shibata and Nishihara (2018). Shibata and Nishihara (2018) examine not only investment timing, but also investment size. However, LBC does not affect the optimal size of investment.

ambiguous results in the LBC model,[2] the effects of EBC on investment timing are consistent with Adler (2020) and Kariya (2020)'s empirical observations, which indicate that tight EBC reduces corporate investment.

Notably, the effects of investment reversibility on the investment and financing decisions with EBC are quite different from those with LBC. The cap of debt is based on the liquidation value under LBC, and hence, lower investment reversibility directly tightens LBC, decreases leverage and firm value, and delays investment. In contrast, the cap of debt is not related to the liquidation value under EBC. Accordingly, lower investment reversibility does not significantly tighten EBC and does not largely affect leverage, investment timing, and firm value. Thus, for the firm with lower investment reversibility, EBC tends to be preferable to LBC. This result provides economic rationale for the empirical findings in Kermani and Ma (2020b) and Lian and Ma (2021) that show that EBC is more prevalent in firms with lower liquidation value. The model also shows that in case of bankruptcy, lower investment reversibility makes liquidation value lower than the going-concern value, which leads the firm to choose reorganization. Then, lower investment reversibility creates a positive relation between the prevalence of EBC and reorganization bankruptcy, which is consistent with the empirical observations in Lian and Ma (2021) and Kermani and Ma (2020b).

The model also shows the following notable effects of cash flow volatility on EBC. Consistent with the fundamental result of real options theory (e.g., Dixit and Pindyck (1994)), higher volatility increases the value of waiting for a better economic state and investment threshold (i.e., the level of earnings required for investing). The increased level of earnings expands the cap of debt under EBC at the investment time. Accordingly, EBC loosens with higher volatility from the investment timing effect, while the cap of LBC does not depend on investment timing. Then, contrary to the results in the unconstrained and LBC models, higher volatility induces the firm with EBC to take higher leverage, which leads to reorganization in case of bankruptcy. These results also imply that EBC tends to be preferable to LBC for the firm with higher volatility. The volatility effects through the investment timing channel are novel and have not been tested in empirical literature.

We explain our study's contributions to the related literature. This paper is closely related to the real options literature on investment and financing problems. Mauer and Sarkar (2005) develop an investment timing model of a levered firm to show how agency conflicts between shareholders and debt holders affect investment timing. Sundaresan and Wang (2007) and Sundaresan, Wang, and Yang (2015) analytically derive optimal investment timing with optimal capital structure and show the effects of optimal leverage on investment timing. Hackbarth and Mauer (2012) develop an investment timing model with multiple debt issues to explore optimal debt priority structure. Shibata and Nishihara (2012) and Shibata and Nishihara (2018) examine investment and financing models with exogenous debt capacity and LBC, respectively, and show that the debt borrowing constraints can counter-intuitively accelerate investment. However, to our knowledge, no papers

[2]Shibata and Nishihara (2018) show that LBC can potentially accelerate investment earlier than that of the unconstrained model. Unlike in the LBC model, the cap of debt is constant under LBC, and investment delay tightens LBC.

have studied a structural model in corporate finance related to EBC. This paper is the first to analyze a real options model with EBC to show how EBC affects a firm's optimal policies of investment, financing, and exit, and firm value.

This paper also contributes to the recent literature on EBC. Lian and Ma (2021), Kermani and Ma (2020b), and Kermani and Ma (2020a) fully investigate how EBC binds firms in practice and argue that firms that are expected to choose reorganization bankruptcy rather than liquidation bankruptcy tend to be bound by EBC. Adler (2020) and Kariya (2020) show empirical evidence that EBC reduces corporate investment. These papers focus mainly on empirics, while some papers (e.g., Lian and Ma (2021) and Drechsel (2020)) study the effects of EBC on aggregate investment and debt dynamics of firms in macroeconomic models. Unlike the structural models in corporate finance, the macroeconomic models are not useful for evaluations of firm value and default risk, and they have no implications for investment timing, capital structure, debt type, exit timing, and exit type. Thus, this paper complements the EBC literature by investigating EBC from these different aspects based on the structural model in corporate finance.

The remainder of this paper is organized as follows. Section 2 introduces the model setup. Section 3 formulates and solves the firm's investment and financing problem under EBC. Section 4 thoroughly explores the model solutions in numerical examples and illustrates empirical implications. Section 5 concludes the paper.

2 Model Setup

2.1 Entry to the market

The model builds on the standard setup of investment with optimal capital structure based on tradeoff theory (e.g., Shibata and Nishihara (2012) and Sundaresan, Wang, and Yang (2015)). Consider a firm that has an option to invest in a new project by incurring capital expenditure $I(>0)$ (cf. McDonald and Siegel (1986) and Dixit and Pindyck (1994)). At the investment time, the firm can use debt financing. Following the standard literature (e.g., Black and Cox (1976), Leland (1994), and Goldstein, Ju, and Leland (2001)), consider consol debt with coupon C. After investment, the firm receives continuous streams of earnings before interest and taxes (EBIT) $X(t)$, where $X(t)$ follows a geometric Brownian motion

$$\mathrm{d}X(t) = \mu X(t)\mathrm{d}t + \sigma X(t)\mathrm{d}B(t) \ (t > 0), \quad X(0) = x,$$

where $B(t)$ denotes the standard Brownian motion defined in a filtered probability space $(\Omega, \mathcal{F}, \mathbb{P}, \{\mathcal{F}_t\})$ and $\mu, \sigma(> 0)$ and $x(> 0)$ are constants. Assume that the initial value, $X(0) = x$, is sufficiently low to exclude the firm's entry at the initial time. For convergence, $r > \mu$ is assumed, where a positive constant r denotes the risk-free interest rate. Apply the corporate tax rate $\tau \in (0, 1)$ to $X(t) - C$.

The firm optimizes both investment time T^i and coupon C (which determines leverage) to maximize the investment option value. At investment time T^i, EBC

$$D^d(X(T^i), C) \leq \phi_E X(T^i) \tag{1}$$

is enforced, where $D^d(X(T^i), C)$ and ϕ_E denote the risky debt value at time T^i and the tightness parameter of EBC, respectively. Throughout the paper, superscript d stands for the risky debt financing case.[3] In EBC (1), we use EBIT right after investment because in this model the firm receives no EBIT until investment. If we consider a growth option model, we can use EBIT before investment in EBC. Technically, it does not matter whether to use EBIT before or after investment by adjusting the level of ϕ_E. If the firm can choose debt issuance timing apart from investment timing, the firm can increase the cap of debt by issuing debt after investment rather than before investment.[4] Hence, the main results of this paper will remain unchanged in a growth option model.

EBC (1) means that the borrowing amount is restricted by EBIT. We use this particular type of EBC in this study because it is the most prevalent type among various types of EBC (see Lian and Ma (2021) and Drechsel (2020)). Another prevalent type of EBC is an interest coverage constraint, which sets the cap on the ratio of interest payments to earnings (see Greenwald (2019)), and this type can be modeled as[5]

$$C \leq \phi_E X(T^i). \tag{2}$$

However, whether EBC (1) or (2) is assumed, this paper's main results will remain unchanged. According to Lian and Ma (2021), EBC can be periodically monitored after the debt issuance time (especially for bank debt). For model tractability, the model assumes debt with infinite maturity and EBC only at the debt issuance time, but debt rebalancing with short-term debt under periodic EBC will be an interesting issue for future research. Shibata and Nishihara (2018) also assume debt with infinite maturity and LBC only at the debt issuance time to show the effects of LBC. By adopting the same assumption, we will be able to compare the results in the EBC and LBC models in Sections 3.3 and 4.

2.2 Exit from the market

Following the standard literature (e.g., Abel and Eberly (1996), Abel, Dixit, Eberly, and Pindyck (1996), and Shibata and Nishihara (2018)), the model assumes partial investment reversibility, where a fraction $k \in (0, 1)$ of capital expenditure I will remain as liquidation value. Higher k stands for higher investment reversibility.[6] In the presence of liquidation value $kI > 0$, one of the following three exit forms occurs when EBIT $X(t)$ deteriorates.

The first type is exit without bankruptcy (called sellout). In sellout, the distressed firm's shareholders liquidate all assets by kI. According to the absolute priority rule (APR) of debt, debt

[3] We will derive $D^d(X(T^i), C)$ in (9) in Section 3.2.

[4] The behavior of debt financing after investment is consistent with the empirical evidence of Drechsel (2020).

[5] Plausible levels of ϕ_E in (2) are different from those in (1). EBC (2) can also be regarded as the face value of debt C/r constrained by EBIT.

[6] Several papers, such as Lambrecht and Myers (2008) and Nishihara and Shibata (2021), assume that the liquidation value includes both the fixed and variable component (say $kI + lX(t)$). In the presence of $l \in (0, 1)$, this paper's main results and implications will vary only quantitatively but not qualitatively. The larger l, the smaller the difference between EBC and LBC, and hence, the smaller the difference between those effects on the firm's investment, financing, and exit decisions.

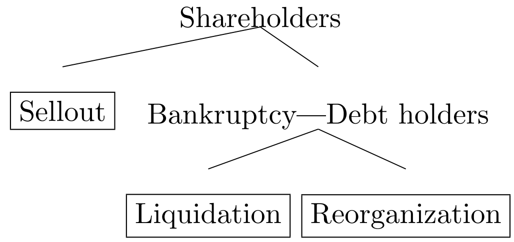

Figure 1: Three exit types.

holders are repaid the face value of debt, which equals C/r for the consol debt. This corresponds to a standard debt covenant (e.g., Morellec (2001) and Lambrecht and Myers (2008)) that restricts the disposition of assets unless debt holders are fully compensated. Shareholders receive positive residual value, i.e., $(1-\tau)kI - C/r \geq 0$. In this case, there are no deadweight costs of bankruptcy, although the level of k reflects inefficiency in asset liquidation.

The second type is liquidation bankruptcy. In liquidation bankruptcy, the firm's shareholders do not liquidate the firm due to negative residual value, i.e., $(1-\tau)kI - C/r < 0$. Instead, shareholders stop coupon payments to debt holders and receive nothing. Based on the APR, debt holders take over the firm and liquidate all assets immediately to gain liquidation value $(1-\alpha)kI$, where a fraction $\alpha \in (0,1)$ of the firm value is lost to the deadweight costs of bankruptcy (e.g., filing and attorney fees). Debt holders choose liquidation bankruptcy if this liquidation value is higher than the going-concern value in the third type.

The third type is bankruptcy without immediate liquidation (called reorganization bankruptcy). In reorganization bankruptcy, the firm's shareholders do not liquidate the firm due to negative residual value, i.e., $(1-\tau)kI - C/r < 0$. As in liquidation bankruptcy, shareholders stop coupon payments to debt holders and receive nothing. Based on the APR, debt holders take over the firm and operate the firm as a going concern. As in liquidation bankruptcy, a fraction $\alpha \in (0,1)$ of the firm value is lost to the deadweight costs of bankruptcy, i.e., EBIT shrinks to $(1-\alpha)X(t)$ after reorganization. Debt holders choose reorganization bankruptcy if this going-concern value is higher than the liquidation value.

As summarized in Figure 1, shareholders choose between sellout and bankruptcy, and debt holders choose between liquidation and reorganization. Note that for $k = 0$, the exit model is essentially the same as in Leland (1994) and Goldstein, Ju, and Leland (2001), where only the third type of exit arises.[7] In the presence of positive liquidation value kI, as in Mella-Barral and Perraudin (1997), Lambrecht and Myers (2008), and Shibata and Nishihara (2018), the two other possibilities arise. The three potential exit forms are consistent with Corbae and D'Erasmo (2021)'s empirical observations. In practice, the reorganization bankruptcy procedure is not as simple as the above

[7] Leland (1994) and Goldstein, Ju, and Leland (2001) do not explicitly distinguish between liquidation and reorganization bankruptcy, but the firm value on bankruptcy agrees with that of the third type, i.e., the unlevered firm value multiplied by $(1-\alpha)$.

model. Indeed, especially in Chapter 11 in the United States, reorganization bankruptcy frequently accompanies debt renegotiation (e.g., coupon reductions) between shareholders and debt holders. For detailed modeling of Chapter 11, refer to Broadie, Chernov, and Sundaresan (2007) and Antill and Grenadier (2019). Although our model simplifies the reorganization bankruptcy procedure, our model captures the interactions between EBC and exit forms. Empirical papers motivate our analysis on the interactions, including Lian and Ma (2021) and Kermani and Ma (2020b), who argue that there is a positive correlation between EBC and reorganization bankruptcy.

3 Model Solution

3.1 Debt holders' choice between liquidation and reorganization bankruptcy

As in the standard literature (e.g., Sundaresan and Wang (2007), Shibata and Nishihara (2012), and Sundaresan, Wang, and Yang (2015), and Shibata and Nishihara (2018)), the model is solved backward. First, we derive the firm's going-concern for debt holders. Suppose that the firm goes into reorganization bankruptcy at time T^d satisfying $X(T^d) = x^d(C)$, where $x^d(C)$ denotes the bankruptcy threshold, which will be later specified as a function of coupon C in (8) in Section 3.2. At bankruptcy time T^d, the going-concern value, denoted by $G(x^d(C))$, becomes

$$\begin{aligned} G(x^d(C)) &= \sup_{T^l \geq T^d} \mathbb{E}\Big[\int_{T^d}^{T^l} \mathrm{e}^{-r(t-T^d)}(1-\tau)(1-\alpha)X(t)\mathrm{d}t + \mathrm{e}^{-rT^l}(1-\tau)(1-\alpha)kI\Big] \\ &= (1-\tau)(1-\alpha)\left(\frac{x^d(C)}{r-\mu} + \left(\frac{x^d(C)}{x^l}\right)^{\gamma}\left(kI - \frac{x^l}{r-\mu}\right)\right) \end{aligned} \tag{3}$$

for $x^d(C) \geq x^l$, where $T^l = \inf\{t \geq T^d \mid X(t) \leq x^l\}$ and x^l denote the liquidation time and threshold (optimized by former debt holders), respectively, and we can easily derive

$$x^l = \frac{\gamma(r-\mu)kI}{\gamma-1}, \tag{4}$$

following the standard real options literature (cf. the value matching and smooth pasting conditions in Dixit and Pindyck (1994)). Notation $\gamma = 0.5 - \mu/\sigma^2 - \sqrt{(\mu/\sigma^2 - 0.5)^2 + 2r/\sigma^2}$ denotes the negative characteristic root. Note that after reorganization bankruptcy, the firm operates as an all-equity firm and pays the corporate tax until liquidation. In (3), $(1-\tau)(1-\alpha)x^d(C)/(r-\mu)$ denotes the value of perpetually operating the firm, and the extra term is the value of the liquidation option.[8] For $x^d(C) \leq x^l$, we have $G(x^d(C)) = (1-\tau)(1-\alpha)kI$, which means liquidation immediately after reorganization bankruptcy. However, due to corporate tax τ, this value is lower than that of liquidation bankruptcy, i.e., $(1-\alpha)kI$. Note that debt holders can obtain $(1-\alpha)kI$ by choosing liquidation bankruptcy directly. Thus, debt holders choose reorganization bankruptcy for $G(x^d(C)) > (1-\alpha)kI$, where $x^d(C) > x^l$ is satisfied. They choose liquidation bankruptcy for $G(x^d(C)) \leq (1-\alpha)kI$. As will be studied in debt valuation (9) in Section 3.2, debt holders

[8] For $k = 0$, we have $G(x^d(C)) = (1-\tau)(1-\alpha)x^d(C)/(r-\mu)$, which agrees with the firm value on bankruptcy in Leland (1994) and Goldstein, Ju, and Leland (2001).

receive the maximum of liquidation and reorganization values, i.e., $\max\{(1-\alpha)kI, G(x^d(C))\}$ on bankruptcy.

Higher investment reversibility k increases liquidation value $(1-\alpha)kI$ more than reorganization value $G(x^d(C))$. Higher coupon C increases $x^d(C)$ (cf. (8) in Section 3.2), and higher $x^d(C)$ increases reorganization value $G(x^d(C))$ in (3). Then, with lower k, and higher C and $x^d(C)$, the firm is more likely to go into reorganization bankruptcy.[9] These results are consistent with empirical evidence. For instance, Kermani and Ma (2020a) show that firms in the industries with high liquidation value (e.g., transportation industries) tend to go into liquidation bankruptcy. Bris, Welch, and Zhu (2006) and Corbae and D'Erasmo (2021) show that reorganization bankruptcy is more prevalent for firms with higher levels of EBITDA and debt.

3.2 Shareholders' choice between sellout and default

This subsection examines shareholders' exit choice between sellout and default. Suppose that the firm issues consol debt with coupon C at investment time T^i satisfying $X(T^i) = x^i$, where x^i denotes the investment threshold. Shareholders of the firm choose sellout for positive residual value, i.e., $(1-\tau)kI - C/r \geq 0$. Let C^s be $C^s = r(1-\tau)kI$, which means the maximum coupon within the sellout region. For $C \in [0, C^s]$, the equity value, denoted by $E^s(x^i, C)$, becomes

$$\begin{aligned} E^s(x^i, C) &= \sup_{T^s \geq T^i} \mathbb{E}[\int_{T^i}^{T^s} \mathrm{e}^{-r(t-T^i)}(1-\tau)(X(t)-C)\mathrm{d}t + \mathrm{e}^{-rT^s}\left((1-\tau)kI - \frac{C}{r}\right)] \\ &= (1-\tau)\left(\frac{x^i}{r-\mu} - \frac{C}{r} + \left(\frac{x^i}{x^s(C)}\right)^\gamma \left(kI - \frac{\tau C}{(1-\tau)r} - \frac{x^s(C)}{r-\mu}\right)\right) \end{aligned} \tag{5}$$

for $x^i \geq x^s(C)$, where $T^s = \inf\{t \geq T^i \mid X(t) \leq x^s\}$ and $x^s(C)$ denote the sellout time and threshold (optimized by shareholders), respectively, and we can easily derive

$$x^s(C) = \frac{\gamma(r-\mu)}{(\gamma-1)}\left(kI - \frac{\tau C}{(1-\tau)r}\right). \tag{6}$$

in the standard manner. Throughout the paper, the superscript s denotes the sellout case. Note that $x^s(C) > 0$ follows from $C \leq C^s$. In (5), $(1-\tau)(x^i/(r-\mu) - C/r)$ denotes the value of perpetually operating the firm, and the remaining term denotes the value of the sellout option, where shareholders lose the tax benefits of debt and future cash flows instead of obtaining the constant liquidation value. In (6), $x^s(C)$ decreases in C because the tax benefits of debt increase in C. There is no possibility of bankruptcy, and hence, the debt value is the riskless value $D^s(x^i, C) = C/r$. Although there is no possibility of sellout in models without constant liquidation value (e.g., Leland (1994) and Goldstein, Ju, and Leland (2001)), sellout can potentially arise in models with fixed liquidation value (e.g., Mella-Barral and Perraudin (1997), Lambrecht and Myers (2008), and Shibata and Nishihara (2018)). The possibility of sellout is consistent with Corbae and D'Erasmo (2021), who show that firms with low debt levels tend to choose sellout, whereas firms with high debt levels tend to choose bankruptcy.

[9]Antill and Grenadier (2019) also show the same results. Although our model simplifies reorganization bankruptcy process, the model can capture the stylized results on the choice between liquidation and reorganization bankruptcy.

On the other hand, shareholders choose default for negative residual value, i.e, $C > C^s$. In this case, the equity value, denoted by $E^d(x, C)$, becomes

$$
\begin{aligned}
E^d(x^i, C) &= \sup_{T^d \geq T^i} \mathbb{E}[\int_{T^i}^{T^d} \mathrm{e}^{-r(t-T^i)}(1-\tau)(X(t)-C)\mathrm{d}t] \\
&= (1-\tau)\left(\frac{x^i}{r-\mu} - \frac{C}{r} + \left(\frac{x^i}{x^d(C)}\right)^{\gamma}\left(\frac{C}{r} - \frac{x^d(C)}{r-\mu}\right)\right)
\end{aligned} \tag{7}
$$

for $x^i \geq x^d(C)$, where $T^d = \inf\{t \geq T^i \mid X(t) \leq x^d\}$ and $x^d(C)$ denote the default time and threshold (optimized by shareholders), respectively, and we can easily derive

$$
x^d(C) = \frac{\gamma(r-\mu)C}{(\gamma-1)r}. \tag{8}
$$

in the standard manner. In (7), $(1-\tau)(x^i/(r-\mu) - C/r)$ denotes the value of perpetually operating the firm, and the remaining term reflects the value of the default option. Equations (7) and (8) are essentially the same as in Black and Cox (1976), Leland (1994) and Goldstein, Ju, and Leland (2001) because investment reversibility k does not matter to the equity value in the risky debt financing case. Following the standard literature (e.g., Leland (1994) and Goldstein, Ju, and Leland (2001)), shareholders do not take into account debt in place and choose $x^d(C)$ for their own interests. This leads to agency conflicts between shareholders and debt holders, and debt is priced under the rational expectation of shareholders' default timing. The debt value becomes

$$
D^d(x^i, C) = \frac{C}{r} + \left(\frac{x^i}{x^d(C)}\right)^{\gamma}\left(\max\{(1-\alpha)kI, G(x^d(C))\} - \frac{C}{r}\right), \tag{9}
$$

where $\max\{(1-\alpha)kI, G(x^d(C))\}$ reflects debt holders' choice between liquidation and reorganization bankruptcy, as shown in Section 3.1. In (9), the first term stands for the riskless debt value, whereas the remaining term reflects loss from bankruptcy.

3.3 Investment and financing decisions

This subsection examines the firm's investment and financing decisions. Following the standard literature (e.g., Leland (1994), Sundaresan and Wang (2007), and Shibata and Nishihara (2018)), investment time T^i and coupon C are chosen to maximize the firm value. This is because the initial firm value agrees with the ex-ante shareholders' value when debt is fairly priced.

First, consider the problem subject to riskless debt financing, i.e., $C \in [0, C^s]$. Although this paper does not endogenously explore the rationale of EBC, debt holders usually impose EBC to mitigate default risk. Therefore, no financial constraints are imposed for riskless debt. The riskless firm value at time 0, denoted by $V^s(x)$, becomes

$$
\begin{aligned}
V^s(x) &= \sup_{T^i \geq 0, C \in [0, C^s]} \mathbb{E}[\mathrm{e}^{-rT^i}(E^s(X(T^i), C) + C/r - I)] \\
&= \sup_{x^i \geq x} \underbrace{\left(\frac{x}{x^i}\right)^{\beta}\left(\frac{(1-\tau)x}{r-\mu} + \frac{\tau C^s}{r} - I + \left(\frac{x^i}{x^s(C^s)}\right)^{\gamma}\left((1-\tau)kI - \frac{(1-\tau)x^s(C^s)}{r-\mu} - \frac{\tau C^s}{r}\right)\right)}_{=v^s(x, x^i)},
\end{aligned} \tag{10}
$$

where $T^i = \inf\{t \geq 0 \mid X(t) \geq x^i\}$ and x^i denote the investment time and threshold (optimized by shareholders), respectively. Notation $\beta = 0.5 - \mu/\sigma^2 + \sqrt{(\mu/\sigma^2 - 0.5)^2 + 2r/\sigma^2}$ denotes the positive characteristic root. We have (10) because $E^s(X(T^i), C) + C/r$ monotonically increases in C. Indeed, $E^s(x^i, C) + C/r$ (see (5)) can be decomposed as the unlevered firm value and tax benefits of debt, and C^s maximizes the tax benefits of debt. Although the solution x^i to problem (10) cannot be derived analytically, the first-order condition becomes $\partial v^s(x, x^i)/\partial x^i = 0$, where $v^s(x, x^i)$ is defined as the objective function of problem (10).

Second, consider the problem subject to risky debt financing, i.e., $C > C^s$. In this case, EBC (1) is imposed. The risky firm value at time 0, denoted by $V^d(x)$, becomes

$$V^d(x) = \sup_{x^i \geq x, C > C^s} \underbrace{\left(\frac{x}{x^i}\right)^\beta (E^d(x^i, C) + D^d(x^i, C) - I)}_{= v^d(x, x^i, C)} \tag{11}$$

subject to

$$D^d(x^i, C) \leq \phi_E x^i. \tag{12}$$

As in Leland (1994), $E^d(x^i, C) + D^d(x^i, C)$ can be decomposed as the unlevered firm value, tax benefits of debt, and bankruptcy costs; hence, the tradeoff between the tax benefits of debt and bankruptcy costs determines C under EBC (12). Unfortunately, we cannot analytically solve x^i and C in problem (11) subject to EBC (12). Let $v^d(x, x^i, C)$ be the objective function of problem (11). We will numerically solve problem (11) with no constraints, where the first-order condition becomes $\partial v^d(x, x^i, C)/\partial x^i = 0$ and $\partial v^d(x, x^i, C)/\partial C = 0$. If this first-best solution satisfies EBC (12) and $C > C^s$, EBC is not binding. Otherwise, EBC is binding, where the first-order condition becomes

$$\begin{aligned} \frac{\partial v^d(x, x^i, C)}{\partial x^i} - \lambda \left(\frac{\partial D^d(x^i, C)}{\partial x^i} - \phi_E \right) &= 0, \\ \frac{\partial v^d(x, x^i, C)}{\partial C} - \lambda \frac{\partial D^d(x^i, C)}{\partial C} &= 0, \\ D^d(x^i, C) - \phi_E x^i &= 0, \end{aligned}$$

where λ is a positive Lagrange multiplier for EBC (12).[10] The firm chooses between riskless and risky debt financing by comparing $V^s(x)$ and $V^d(x)$, and hence, the initial firm (option) value is equal to $V(x) = \max\{V^s(x), V^d(x)\}$.

The next section also examines a model with LBC to highlight the differences between the effects of EBC and LBC on the corporate investment, financing, and exit decisions. The LBC model assumes the following constraint for risky debt:

$$D^d(x^i, C) \leq \phi_L (1 - \alpha) k I, \tag{13}$$

where ϕ_L denotes the tightness parameter of LBC. LBC (13) means that the cap of debt is based on liquidation value $(1 - \alpha)kI$. The model with LBC (13) is essentially the same as in Shibata

[10] We remove the possibility $C \to C^s$ because $v^d(x, x^i, C^s)$ is lower than $v^s(x, x^i)$. The inequality $x^i \geq x$ is not binding because we set a sufficiently low $X(0) = x$ to exclude the firm's entry at the initial time. Hence, we have only one Lagrange multiplier for EBC (12).

Table 1: Borrowing constraints and bankruptcy types.

(a) Cap of debt.

EBC	$\phi_E x$
LBC	$\phi_L(1-\alpha)kI$

(b) Value on bankruptcy.

Reorganization	$G(x) = \frac{(1-\tau)(1-\alpha)x}{r-\mu} +$ (Option value)
Liquidation	$(1-\alpha)kI$

and Nishihara (2018). LBC (13) is also similar to the LBC constraints in Almeida and Campello (2007) and IA.5 of Lian and Ma (2021).[11] Table 1 summarizes the caps of debt under EBC and LBC and the reorganization and liquidation values. Although the cap of debt under LBC is based on the liquidation value, the cap of debt under EBC is closely related to the reorganization value. Indeed, for lower k, the going concern value $G(x)$ is approximately equal to $(1-\tau)(1-\alpha)x/(r-\mu)$ (i.e., a linear function of x) because the option value (i.e., the second term in (3)) is nearly zero. Consistent with the main argument in Lian and Ma (2021), higher k leads to LBC being looser than EBC and the liquidation value being higher than the reorganization value, whereas lower k leads to EBC being looser than LBC and the reorganization value being higher than the liquidation value. In the next section, we show that this relation leads to a positive relation between the prevalence of EBC and reorganization bankruptcy.

4 Numerical Analysis and Implications

4.1 The baseline results

This section conducts numerical analyses, including comparative statics with respect to tightness of EBC ϕ_E, investment reversibility k, and volatility σ. The baseline parameter values are set as in Table 2, where the values of r, μ, σ, τ, and α are standard in dynamic corporate finance literature and reflect a typical S&P firm (e.g., Morellec (2001) and Arnold (2014)). The investment reversibility is set at $k = 0.23$ based on empirical evidence that average liquidation value of plant, property, and equipment (PPE) and working capital is 23% of the book value in Kermani and Ma (2020a). The tightness parameter is set at $\phi_E = 4$ based on empirical evidence that the cap of debt under EBC is usually set between 3 and 5 times EBITDA (e.g., Lian and Ma (2021) and Drechsel (2020)).

For the baseline parameter values, EBC is binding. The constrained firm invests at $x^i = 0.996$ and issues debt with coupon $C = 0.2047 (> C^s = 0.0978)$. At the investment time, the leverage $LV = D^d(x^i, C)/(E^d(x^i, C) + D^d(x^i, C))$ is 0.1833, and the credit spread $CS = C/D^d(x^i, C)) - r$

[11] On the other hand, some macroeconomic models, including Kiyotaki and Moore (1997), consider LBC based on a liquidation value that is not fixed but dynamically changes with future expectation. Lian and Ma (2021) state that collateral value is infrequently reevaluated, but it may be more practical to assume that the liquidation value is not constant but includes a dynamic component of $X(t)$. As explained in footnote 6, even in such a setup, this paper's main results and implications will vary only quantitatively but not qualitatively.

Table 2: Baseline parameter values.

r	μ	σ	τ	α	k	ϕ_E	I	x
0.05	0.01	0.2	0.15	0.4	0.23	4	10	0.5

is 0.0014. The firm goes into reorganization bankruptcy when $X(t)$ falls to $x^d = 0.0941$. After reorganization bankruptcy, former debt holders operate the firm until $X(t)$ falls to $x^l = 0.0529$. At time 0, the firm value $V(x)$ becomes 3.276.

As a benchmark case, we also compute the first-best solution in the absence of EBC. In this case, the unconstrained firm invests at $x^i = 0.9728$ and issue debt with coupon $C = 0.6062$. At the investment time, LV is 0.4856, and CS is 0.0075. The firm goes into reorganization bankruptcy when $X(t)$ falls to $x^d = 0.2787$. After reorganization bankruptcy, former debt holders operate the firm until $X(t)$ falls to $x^l = 0.0529$. At time 0, the firm value $V(x)$ becomes 3.421.

By comparing the results in the two cases, we find the following effects of EBC on the corporate investment, financing, and exit decisions. EBC greatly decreases C and LV, and CS, by imposing the cap of debt on the firm. EBC also delays investment and decreases the firm value through the deleverage effect. The deleverage effects of EBC are consistent with empirical observations that debt holders mitigate default risk by imposing EBC. It is well known that Leland-type unconstrained models (e.g., Leland (1994) and Goldstein, Ju, and Leland (2001)) imply much higher leverage than those observed in the real world (e.g., Graham (2000) and Frank and Goyal (2009)). The EBC model can resolve this puzzle and generate observed leverage levels. On the other hand, the EBC model is not helpful in resolution of the credit spread puzzle. As in structural models based on a geometric Brownian motion (e.g., Merton (1974), Black and Cox (1976), and Leland (1994)), credit spreads implied by the EBC model are too low. To obtain observed levels of credit spreads, we may have to incorporate downward jumps in the state process (e.g., Bai, Goldstein, and Yang (2020)), but it is beyond the scope of this paper.

4.2 How EBC and LBC bind the firm

This subsection examines how EBC binds the firm. The top left panel of Figure 2 shows the binding and nonbinding regions of EBC for varying levels of tightness ϕ_E and investment reversibility k. For comparison, the top right panel shows those of LBC. In the left panel, with higher ϕ_E, EBC is less likely to bind the firm. For realistic values $\phi_E \in [3, 5]$ (implied by Lian and Ma (2021) and Drechsel (2020)), EBC binds the firm.

Notably, k does not largely affect whether EBC is binding in the top left panel of Figure 2, although k greatly affects whether LBC is binding in the right panel.[12] This difference arises from the difference of the right-hand sides of EBC (12) and LBC (13) (cf. Table 1). Indeed, the cap of debt is not related to k under EBC, although the cap of debt stems from liquidation value

[12]The effect of k on LBC is the same as in Shibata and Nishihara (2018).

kI under LBC. Thus, unlike under LBC, k does not largely affect whether EBC binds the firm. This observation also leads to the following implications for firm value. For the firm with lower k, EBC tends to be preferable to LBC because EBC tends to be looser than LBC.[13] This result is consistent with the empirical evidence of Kermani and Ma (2020b) and Lian and Ma (2021). In fact, Kermani and Ma (2020b) show that EBC is more prevalent for firms with lower liquidation value, and Lian and Ma (2021) show that EBC is more frequent for countries with bankruptcy laws that facilitate reorganization rather than liquidation (which means countries with relatively high costs of liquidation).

The bottom left panel of Figure 2 shows the binding and nonbinding regions for tightness ϕ_E and volatility σ. For comparison, the bottom right panel shows those of LBC. EBC is less likely to be binding with higher σ, although LBC is more likely to be binding with higher σ.[14] This difference is explained by the following investment delay effects. As it is well known in the real options literature (e.g., Dixit and Pindyck (1994)), higher σ increases the option value of waiting and investment threshold x^i. An increase in x^i increases both sides of EBC (12), and the right-hand side effect dominates. In other words, higher σ relaxes EBC through the investment delay channel. On the other hand, an increase in x^i increases the left-hand side of LBC (13), but does not change the right-hand side of LBC (13). That is, the cap of debt in LBC (13) does not depend on x^i; hence, higher σ tightens LBC through the investment delay channel. From the firm value perspective, with higher σ, the firm tends to prefer EBC to LBC. This also means that when the economic environment is more volatile, firms with EBC can be more advantageous than those with LBC. These results show the notable difference between the impacts of σ on EBC and LBC through the investment timing channel. To our knowledge, no papers investigate a relation between EBC and volatility, but our prediction presents an interesting issue for future empirical research. Note that these effects of σ on EBC and LBC hold true if tightness parameters ϕ_E and ϕ_L do not depend on σ. In Section 4.5, we will discuss this point more closely.

4.3 Tightness of EBC

Figure 3 plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS with varying levels of tightness of EBC ϕ_E. In all figures, x^l denotes the liquidation threshold both in reorganization and liquidation bankruptcy. That is, $x^l < x^d$ indicates reorganization bankruptcy, while $x^l = x^d$ indicates liquidation bankruptcy. For $\phi_E < 2.1$, the firm invests at $x^i = 0.9918$ and issues riskless debt with coupon $C^s = 0.0978$. In this region, CS is 0 because of riskless debt. That is, with very tight EBC, the firm relinquishes risky debt financing but resorts to riskless debt financing. In other words, the firm is better off issuing riskless debt to avoid very tight EBC. In this case, the firm chooses sellout (i.e., exit without bankruptcy) when exiting. The result regarding the exit choice is consistent with the empirical

[13] This preference comes only from the perspective of firm value (ex-ante shareholder value). However, in reality, negotiations between shareholders and debt holders determine such debt constraints and terms.

[14] The effect of σ on LBC is the same as in Shibata and Nishihara (2018).

observations of Corbae and D'Erasmo (2021). In fact, they show that firms with low levels of debt exit without declaring bankruptcy. Riskless debt financing can also happen under very tight LBC (see Shibata and Nishihara (2018)).

For $\phi_E \in [2.1, 10.8]$, the firm issues risky debt although EBC binds it. In this region, $C, x^d, V(x), LV$, and CS increase in ϕ_E. This means the straightforward result that with less tightness of EBC, the firm issues more debt to increase firm value. This result is also consistent with that of LBC in Shibata and Nishihara (2018). Note that realistic levels of ϕ_E (i.e., 3 to 5 by Lian and Ma (2021) and Drechsel (2020)) lead to realistic levels of LV (i.e., about 0.2 by Graham (2000) and Frank and Goyal (2009)) in the bottom panels. As explained in Section 3.1, with higher C, reorganization value $G(x^d(C))$ increases, and hence, the firm is more likely to go into reorganization rather than liquidation in case of bankruptcy. This can be seen in the center-left panel of Figure 3, where $x^d = x^l$ (liquidation bankruptcy) holds for $\phi_E \in [2.1, 3.7]$, and $x^d > x^l$ (reorganization bankruptcy) holds for $\phi_E > 3.7$. That is, with less tightness of EBC, the firm issues more debt; hence, it will go into reorganization bankruptcy at the higher threshold. These results on the exit choice are consistent with the empirical evidence of Bris, Welch, and Zhu (2006) and Corbae and D'Erasmo (2021). In fact, they show that firms with higher EBITDA and leverage tend to go into reorganization bankruptcy rather than liquidation bankruptcy.

Notably, in the top-left panel of Figure 3, x^i is not monotonic with respect to ϕ_E. Indeed, x^i is higher for $\phi_E \in [2.1, 4.7]$ than $x^i = 0.9918$ for $\phi_E < 2.1$ (riskless debt). Note that the firm suffers from no constraints in riskless debt financing. When the firm replaces riskless debt financing with risky debt financing, EBC binds the firm. It is clear from EBC (12) that higher x^i increases the cap of debt. Hence, under tight EBC (i.e., $\phi_E \in [2.1, 4.7]$), the firm increases x^i beyond that of the riskless debt case to relax the cap of debt. For $\phi_E \in [4.7, 10.8]$, x^i lies between $x^i = 0.9728$ (the unconstrained case) and $x^i = 0.9918$ (the riskless debt case). Although x^i has a kink at $\phi_E = 3.7$ (on which the bankruptcy types change), x^i decreases in ϕ_E. That is, with tighter EBC, the firm delays investment. There are two reasons for this result. One is that tighter EBC reduces the investment value through the deleverage effect. The other is that the firm tries to offset tighter EBC by delaying investment and increasing the cap of debt.

The investment delay with EBC is consistent with Adler (2020) and Kariya (2020)'s empirical evidence, which shows that tighter EBC reduces corporate investment. Although our model examines one-shot and strict EBC at the investment time, Adler (2020) examines EBC-type covenants of debt and shows that a firm reduces debt issuance and investment before it reaches the covenant limit to avoid potentially costly covenant breach. More generally, the investment delay result is consistent with the stylized fact that limited access to debt financing tend to prevent firms from investing (e.g., Hoshi, Kashyap, and Scharfstein (1991) and Whited (1992)). On the other hand, EBC's effect on investment is contrasted with that of LBC in Shibata and Nishihara (2018). Shibata and Nishihara (2018) show that the investment threshold is U-shaped with respect to the tightness of LBC. In particular, the investment threshold can be lower in the LBC model than that of the unconstrained case. This difference arises because the cap of debt under LBC, unlike under EBC, does not depend on investment timing, and investment delay does not relax but tightens LBC (see the last paragraph of Section 4.2).

4.4 Impacts of investment reversibility

Figure 4 plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS with varying levels of investment reversibility k. In the depicted region, EBC is binding. For $k < 0.43$, the firm invests and issues risky debt. As explained in Section 3.1, with higher k, the firm is more likely to choose liquidation rather than reorganization in case of bankruptcy. This can be seen in the center-left panel of Figure 4, where $x^d > x^l$ (reorganization bankruptcy) holds for $k \leq 0.24$, and $x^d = x^l$ (liquidation bankruptcy) holds for $k \in (0.24, 0.43)$. Combining this result with the result that the firm with low k prefers EBC to LBC as shown in Section 4.2, our model predicts a positive relation between the prevalence of EBC and reorganization bankruptcy through low investment reversibility. This prediction is consistent with the empirical evidence of Lian and Ma (2021) and Kermani and Ma (2020b). That is, low liquidation value causes the dominance of reorganization over liquidation, as well as the dominance of EBC over LBC.

Notably, x^i, C, and LV are almost constant with varying levels of $k(< 0.43)$. Unlike in LBC (13), the cap of debt in EBC (12) does not depend on k. Although higher k increases debt value after default (through this channel, $V(x)$ slightly increases in k), the effects of k on x^i, C, and LV through this channel are weak. In the bottom-right panel of Figure 4, CS sharply decreases in $k(< 0.43)$. This is because higher k does not affect debt issuance but increases debt value after default. That is, higher k mitigates the risk of debt by increasing debt recovery after bankruptcy. These effects of k on x^i, C, LV, and CS are contrasted with those under LBC in Shibata and Nishihara (2018). Under LBC, higher k greatly increases C and LV because it directly increases the cap of debt in (13). Then, under LBC, x^i decreases in k, while CS increases in k due to the higher leverage. In this way, the difference between the caps of debt in EBC and LBC causes the different investment and financing reactions for higher k. The results regarding C and LV are consistent with the empirical observations in Kermani and Ma (2020b). In fact, they show that total borrowing does not depend on the liquidation values for large firms and firms with positive earnings (these firms are likely to be unconstrained or constrained by EBC), while total borrowing increases with the liquidation values for small firms and firms with negative earnings (these firms are likely to be constrained by LBC).

On the other hand, for $k \geq 0.43$, the firm uses riskless debt financing. In the bottom-right panel of Figure 4, CS remains 0 for $k \geq 0.43$ because of riskless debt. As explained in Section 3.3, in the riskless debt financing region, the coupon is equal to $C^s = r(1-\tau)kI$, (i.e., the maximum debt for which the firm does not default but sells out). Higher k expands the riskless debt capacity C^s by increasing the sellout value. Hence, higher k increases LV, and the leverage effect decreases x^i and increases x^s and $V^s(x)$. These effects are stronger than that of $k < 0.43$ because higher k directly expands the riskless debt capacity. Then, for $k \geq 0.43$, $V^s(x)$ increases beyond $V^d(x)$, and the firm prefers investment with riskless debt financing. In other words, for $k \geq 0.43$, the firm can issue enough riskless debt to obtain a higher value than the firm value with constrained risky debt.

4.5 Impacts of cash flow volatility

Figure 5 plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS with varying levels of cash flow volatility σ. In the depicted region, EBC is binding, and the firm uses risky debt financing. In the center-left panel, $x^d = x^l$ (liquidation bankruptcy) holds for $\sigma \leq 0.172$, while $x^d > x^l$ (reorganization bankruptcy) holds for $\sigma > 0.172$. This means that higher σ is more likely to induce the firm to go into reorganization bankruptcy rather than liquidation bankruptcy. The reason is that higher σ increases debt C and LV (see the top-right and bottom-left panels). Indeed, as explained in Section 3.1, higher C increases the reorganization value $G(x^d(C))$ beyond liquidation value $(1-\alpha)kI$. However, a remaining question is why higher σ increases C and LV. This is explained by the interactions between σ, investment threshold x^i, and EBC (12). Investment threshold x^i increases in σ because higher σ increases the option value of waiting and the hurdle rate for investment (i.e., the fundamental result of real options theory, e.g., Dixit and Pindyck (1994)). An increase in x^i increases the cap of debt in EBC (12), so that the firm is less constrained and issues more debt to increase the firm value. That is, higher σ relaxes EBC through the investment delay channel.

These effects of σ on C, LV, and the choice between liquidation and reorganization are novel and contrary to those of Antill and Grenadier (2019). They study the optimal capital structure and bankruptcy choice by developing a more detailed model for the procedure of the reorganization bankruptcy, but their model includes neither optimal investment timing nor debt issuance constraint. Thus, in their model, as in Leland (1994), higher volatility decreases optimal coupon and leverage; hence, it induces the firm to go into liquidation bankruptcy rather than reorganization bankruptcy. Even if we consider optimal investment timing in the unconstrained and LBC models, higher σ decreases leverage, leading the firm to go into liquidation bankruptcy rather than reorganization bankruptcy. Unlike in this paper, Shibata and Nishihara (2015) investigate the optimal choice between bank debt (which is renegotiable) and market debt (which is nonrenegotiable). They show that with higher σ, the firm tends to prefer bank debt to market debt. If bank and market debt are related to reorganization and liquidation bankruptcy, Shibata and Nishihara (2015)'s results are consistent with those of this study.

Last, we explain two limitations of our results regarding σ. The key driver of all these results is that higher σ delays investment and then relaxes the cap of debt under EBC. These results could change if higher σ affects tightness parameter ϕ_E. We have no direct evidence for the relation between ϕ_E and σ. Instead, Graham (2022), who does not study EBC directly but focuses on firms' leverage targets, shows that most firms have upper limits of the ratio of debt to EBITDA and infrequently change the limits (for details, see Section 4.A and Internet Appendix: Section 7 in Graham (2022)). This may imply that, once ϕ_E is set for a firm, it does not frequently change with changes in the market environment (e.g., parameters σ, μ, and r). However, lenders may try to force lower ϕ_E against a firm with higher σ to reduce its risk of bankruptcy. In such cases, the effects of volatility σ can be offset or reversed by the tightened parameter ϕ_E.

Another limitation relates to types of uncertainty. As in the standard literature (e.g., Goldstein, Ju, and Leland (2001) and Sundaresan, Wang, and Yang (2015)), we assume market (cash flow) uncertainty driven by the one-dimensional geometric Brownian motion $X(t)$ to derive equity and debt value functions (3)–(9) explicitly. Even if market uncertainty is driven by a more general stochastic process (such as a jump-diffusion process), the sensitivity results with respect to market uncertainty would not qualitatively change. As the negative sensitivity of market uncertainty to investment timing is widely established in theory and empirics (e.g., Dixit and Pindyck (1994) and Schwartz and Trigeorgis (2004)), higher market uncertainty increases the value of waiting for a better economic state, and hence, it relaxes the cap of debt under EBC. However, if we consider a different type of uncertainty that can be resolved by investing (e.g., technical uncertainty that can be resolved by experiments), higher uncertainty can accelerate investment (e.g., Dixit and Pindyck (1994) and Nishihara (2018)). For this sort of uncertainty, higher uncertainty tightens the cap of debt in EBC through the investment acceleration channel, and hence the effects of uncertainty would differ from those in this study.

5 Conclusion

This paper develops a structural model with EBC. The model captures a firm's decisions on investment timing, debt issuance, leverage, exit timing, and exit choice among sellout, liquidation bankruptcy, and reorganization bankruptcy. Through model analyses, this paper shows that the effects of EBC on the firm's decisions and values are quite different from those of LBC. The results are summarized below.

Although very tight EBC induces the firm to resort to riskless debt, plausible levels of EBC lead the firm to use risky debt financing with realistic levels of leverage. The firm can increase the cap of debt under EBC by postponing investment until the earnings level reaches a higher threshold, although investment timing is not related to the cap of debt under LBC. Thus, unlike with LBC, the firm with EBC delays investment to utilize more debt financing. The investment delay with EBC is consistent with empirical findings. Investment reversibility does not largely affect the firm with EBC, although it greatly affects the firm with LBC. This is mainly because the cap of EBC, unlike that of LBC, does not directly depend on liquidation value. This difference implies that the firm with low investment reversibility, which leads to reorganization rather than liquidation in case of bankruptcy, prefers EBC to LBC. That is, low investment reversibility causes the dominance of EBC and reorganization bankruptcy over LBC and liquidation bankruptcy. These results can account for empirical observations regarding EBC and LBC. Notably, higher volatility increases the cap of debt under EBC by delaying investment, although the cap of debt under LBC does not depend on investment timing. Thus, contrary to the results in the unconstrained and LBC models, under EBC, the firm with higher volatility increases leverage and chooses reorganization in case of bankruptcy. These volatility effects through the investment timing channel are novel and provoke an interesting issue for future empirical research.

References

Abel, A., A. Dixit, J. Eberly, and R. Pindyck, 1996, Options, the value of capital, and investment, *Quarterly Journal of Economics* 111, 753–777.

Abel, A., and J. Eberly, 1996, Optimal investment with costly reversibility, *Review of Economic Studies* 63, 581–593.

Adler, K., 2020, Financial covenants, firm financing, and investment, Working Paper, University of Bonn.

Almeida, H., and M. Campello, 2007, Financial constraints, asset tangibility, and corporate investment, *Review of Financial Studies* 20, 1429–1460.

Antill, S., and S. Grenadier, 2019, Optimal capital structure and bankruptcy choice: Dynamic bargaining versus liquidation, *Journal of Financial Economics* 133, 198–224.

Arnold, M., 2014, Managerial cash use, default, and corporate financial policies, *Journal of Corporate Finance* 27, 305–325.

Bai, J., R. Goldstein, and F. Yang, 2020, Is the credit spread puzzle a myth?, *Journal of Financial Economics* 137, 297–319.

Bernanke, B., M. Gertler, and S. Gilchrist, 1999, The financial accelerator in a quantitative business cycle framework, *Handbook of Macroeconomics* 1, 1341–1393.

Black, F., and J. Cox, 1976, Valuing corporate securities: Some effects of bond indenture provisions, *Journal of Finance* 31, 351–367.

Bris, A., I. Welch, and N. Zhu, 2006, The costs of bankruptcy: Chapter 7 liquidation versus chapter 11 reorganization, *Journal of Finance* 61, 1253–1303.

Broadie, M., M. Chernov, and S. Sundaresan, 2007, Optimal debt and equity values in the presence of chapter 7 and chapter 11, *Journal of Finance* 62, 1341–1377.

Corbae, D., and P. D'Erasmo, 2021, Reorganization or liquidation: Bankruptcy choice and firm dynamics, *Review of Economic Studies* 88, 2239–2274.

Dixit, A., and R. Pindyck, 1994, *Investment Under Uncertainty* (Princeton University Press: Princeton).

Drechsel, T., 2020, Earnings-based borrowing constraints and macroeconomic fluctuations, Working Paper, University of Maryland.

Frank, M., and V. Goyal, 2009, Capital structure decisions: Which factors are reliably important?, *Financial Management* 38, 1–37.

Goldstein, R., N. Ju, and H. Leland, 2001, An EBIT-based model of dynamic capital structure, *Journal of Business* 74, 483–512.

Graham, J., 2000, How big are the tax benefits of debt?, *Journal of Finance* 55, 1901–1941.

Graham, J, 2022, Presidential address: Corporate finance and reality, *Journal of Finance* 77, 1975–2049.

Greenwald, D., 2019, Firm debt covenants and the macroeconomy: The interest coverage channel, Working Paper, MIT.

Hackbarth, D., and D. Mauer, 2012, Optimal priority structure, capital structure, and investment, *Review of Financial Studies* 25, 747–796.

Hoshi, T., A. Kashyap, and D. Scharfstein, 1991, Corporate structure, liquidity, and investment: Evidence from japanese industrial groups, *Quarterly Journal of Economics* 106, 33–60.

Kariya, A., 2020, Earnings-based borrowing constraints and corporate investments in 2007-09 financial crisis, Working Paper, Indian Institute of Management.

Kermani, A., and Y. Ma, 2020a, Asset specificity of non-financial firms, Working Paper, NATIONAL BUREAU OF ECONOMIC RESEARCH.

Kermani, A., and Y. Ma, 2020b, Two tales of debt, Working Paper, NATIONAL BUREAU OF ECONOMIC RESEARCH.

Kiyotaki, N., and J. Moore, 1997, Credit cycles, *Journal of Political Economy* 105, 211–248.

Lambrecht, B., and S. Myers, 2008, Debt and managerial rents in a real-options model of the firm, *Journal of Financial Economics* 89, 209–231.

Leland, H., 1994, Corporate debt value, bond covenants, and optimal capital structure, *Journal of Finance* 49, 1213–1252.

Lian, C., and Y. Ma, 2021, Anatomy of corporate borrowing constraints, *Quarterly Journal of Economics* 136, 229–291.

Mauer, D., and S. Sarkar, 2005, Real options, agency conflicts, and optimal capital structure, *Journal of Banking and Finance* 29, 1405–1428.

McDonald, R., and D. Siegel, 1986, The value of waiting to invest, *Quarterly Journal of Economics* 101, 707–727.

Mella-Barral, P., and W. Perraudin, 1997, Strategic debt service, *Journal of Finance* 52, 531–556.

Merton, R., 1974, On the pricing of corporate debt: The risk structure of interest rates, *Journal of Finance* 29, 449–470.

Morellec, E., 2001, Asset liquidity, capital structure, and secured debt, *Journal of Financial Economics* 61, 173–206.

Nishihara, M., 2018, Valuation of R&D investment under technological, market, and rival preemption uncertainty, *Managerial and Decision Economics* 39, 200–212.

Nishihara, M., and T. Shibata, 2021, Optimal capital structure and simultaneous bankruptcy of firms in corporate networks, *Journal of Economic Dynamics and Control* 133, 104264.

Schwartz, E., and L. Trigeorgis (eds.), 2004, *Real Options and Investment Under Uncertainty: Classical Readings and Recent Contributions* (MIT Press: London).

Shibata, T., and M. Nishihara, 2012, Investment timing under debt issuance constraint, *Journal of Banking and Finance* 36, 981–991.

Shibata, T., and M. Nishihara, 2015, Investment timing, debt structure, and financing constraints, *European Journal of Operational Research* 241, 513–526.

Shibata, T., and M. Nishihara, 2018, Investment timing, reversibility, and financing constraints, *Journal of Corporate Finance* 48, 771–796.

Sundaresan, S., and N. Wang, 2007, Investment under uncertainty with strategic debt service, *American Economic Review, Papers & Proceedings* 97, 256–261.

Sundaresan, S., N. Wang, and J. Yang, 2015, Dynamic investment, capital structure, and debt overhang, *Review of Corporate Finance Studies* 4, 1–42.

Whited, T., 1992, Debt, liquidity constraints, and corporate investment: Evidence from panel data, *Journal of Finance* 47, 1425–1460.

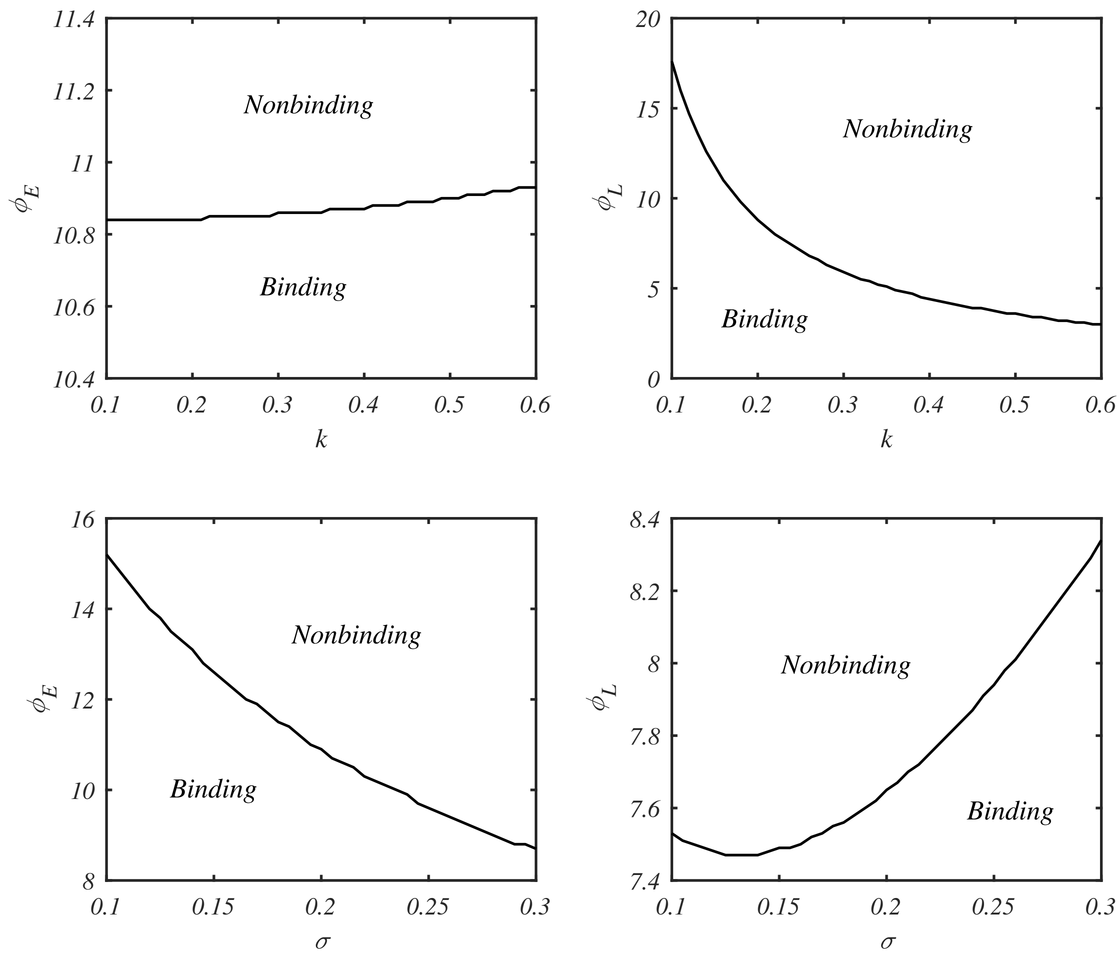

Figure 2: Binding and nonbinding regions under EBC and LBC. The left panels show the binding and nonbinding regions under EBC for varying levels of tightness ϕ_E, investment reversibility k, and volatility σ, whereas the right panels show the binding and nonbinding regions under LBC for varying levels of tightness ϕ_L, investment reversibility k, and volatility σ.

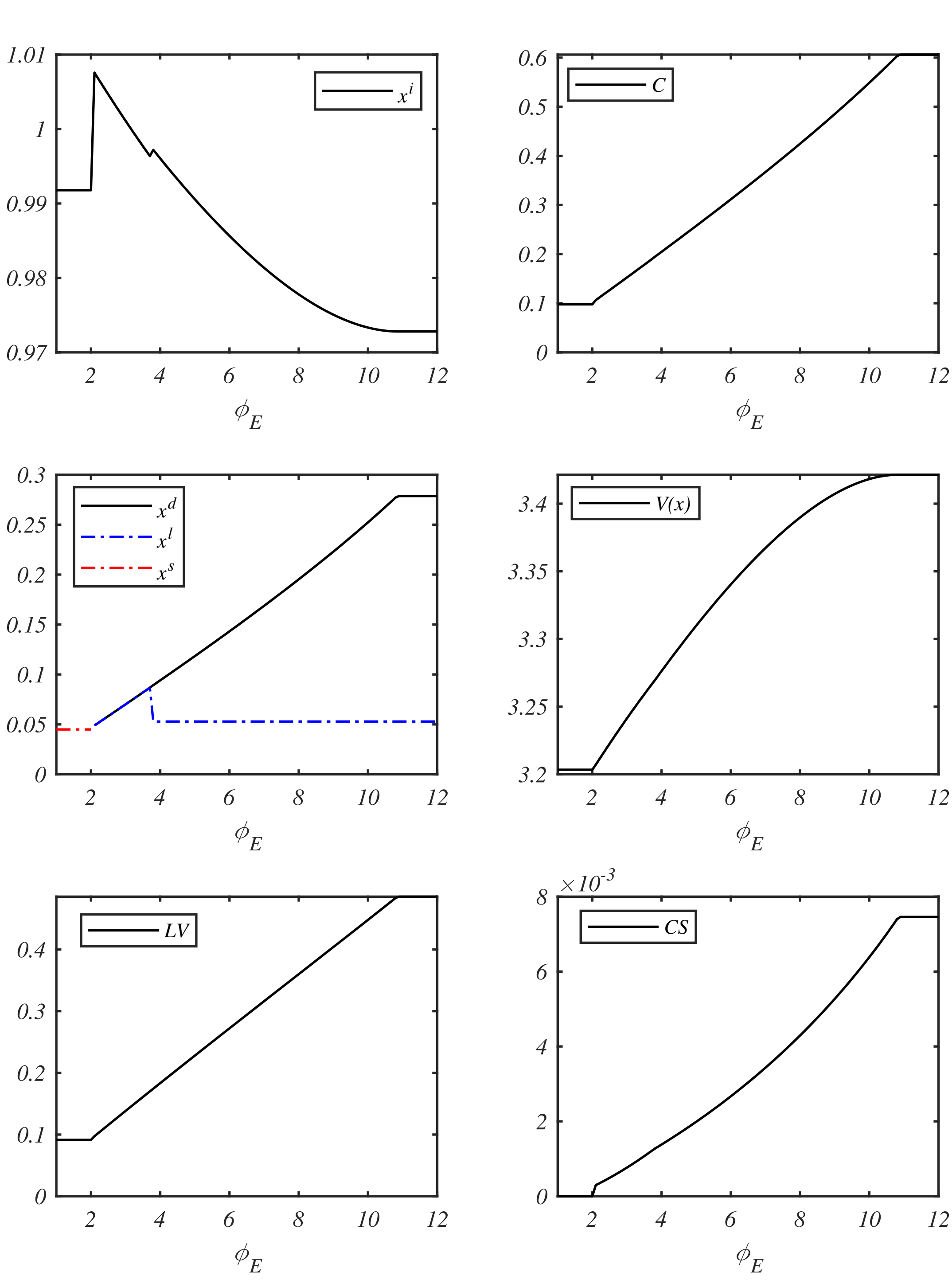

Figure 3: Comparative statics with respect to tightness ϕ_E. The figure plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS. The firm chooses riskless debt for $\phi_E < 2.1$, risky debt with liquidation bankruptcy for $\phi_E \in [2.1, 3.7]$, and risky debt with reorganization bankruptcy for $\phi_E > 3.7$. EBC is not binding for $\phi_E > 10.8$.

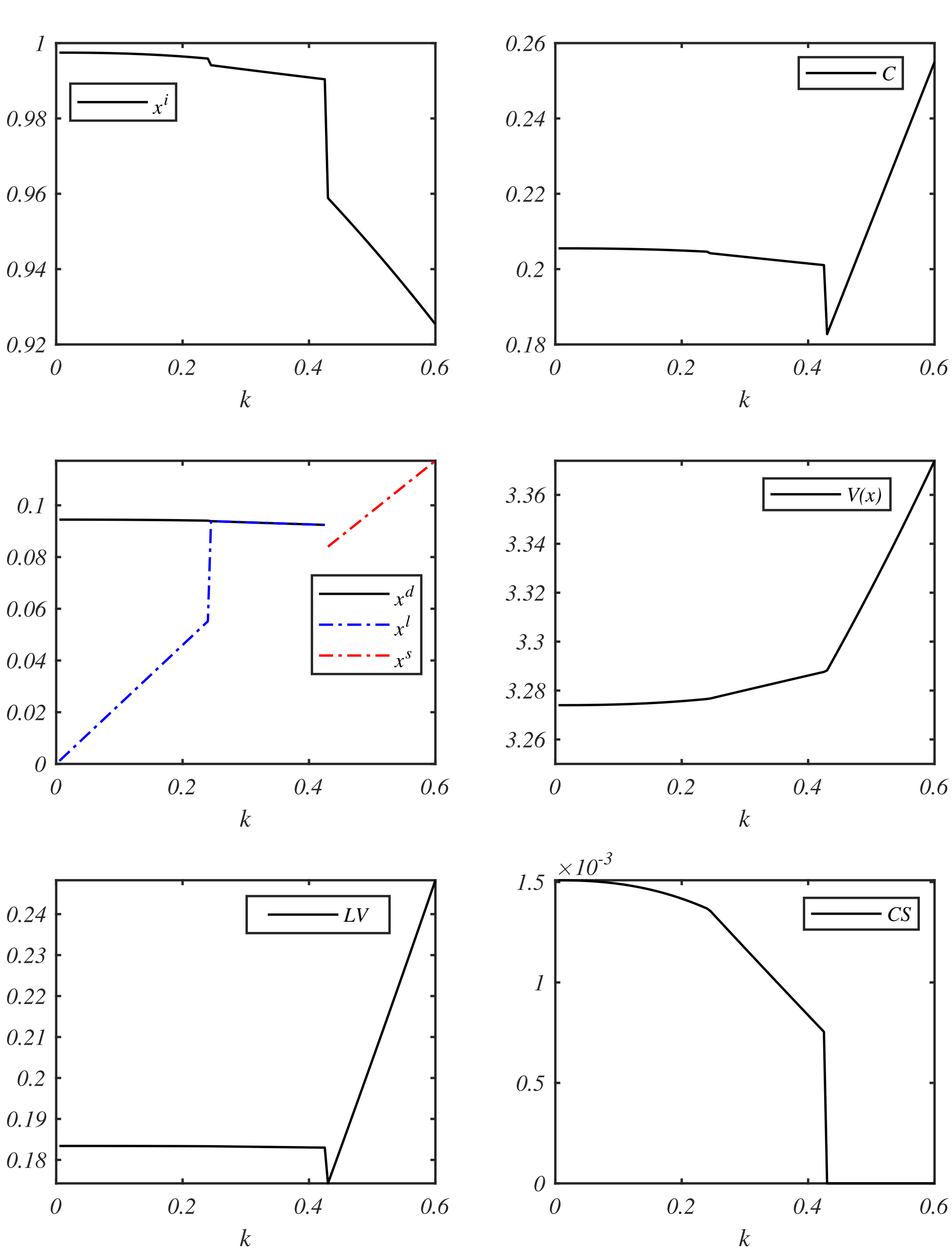

Figure 4: Comparative statics with respect to investment reversibility k. The figure plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS. The firm chooses risky debt with reorganization bankruptcy for $k \leq 0.24$, risky debt with liquidation bankruptcy for $k \in (0.24, 0.43)$, and riskless debt for $k \geq 0.43$. In all the regions, EBC is binding.

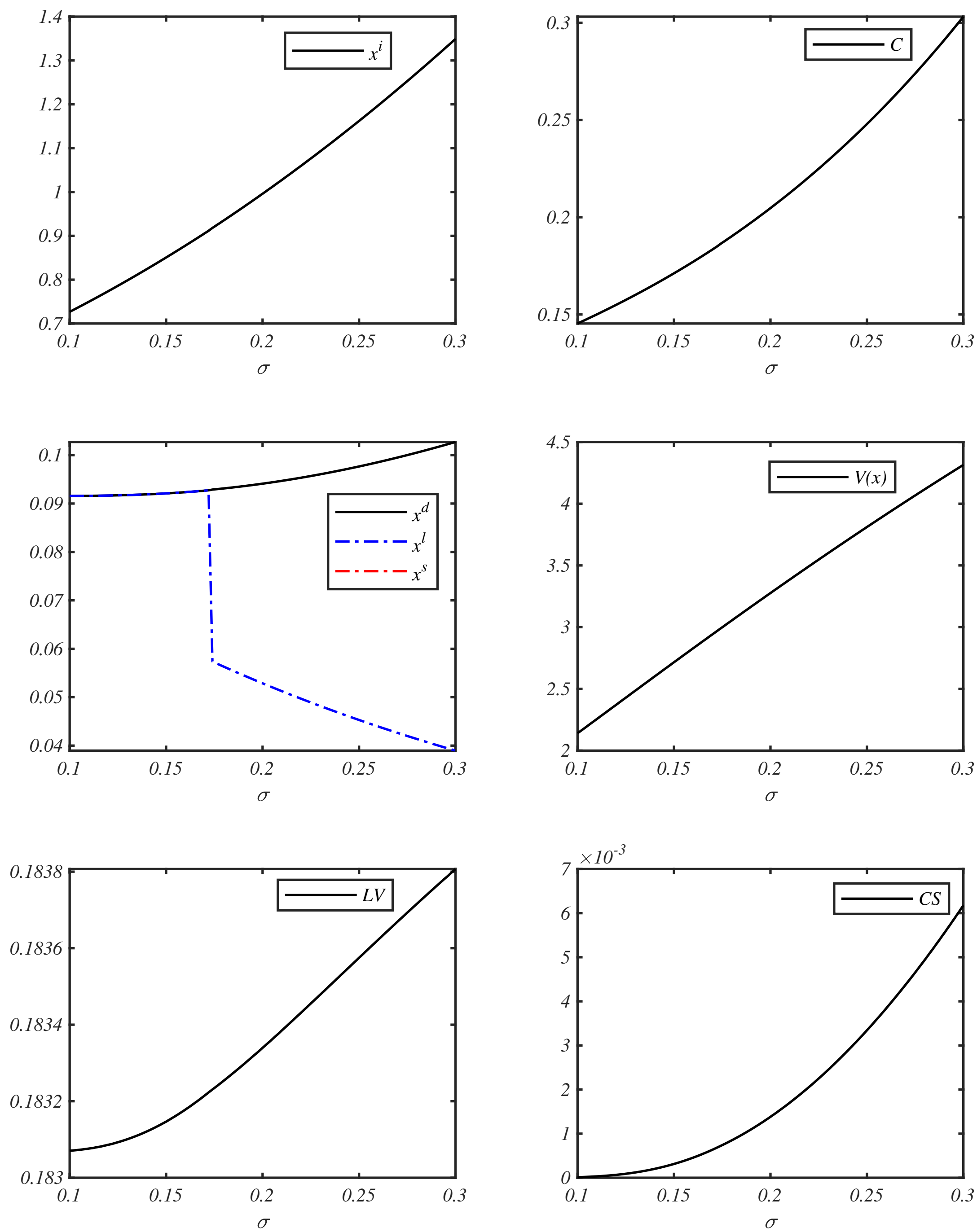

Figure 5: Comparative statics with respect to volatility σ. The figure plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS. The firm chooses risky debt with liquidation bankruptcy for $\sigma \leq 0.172$ and risky debt with reorganization bankruptcy for $\sigma > 0.172$. In all the regions, EBC is binding.