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

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Abstract

This paper studies the effects of an earnings-based borrowing constraint (EBC) on a firm's investment, financing, and exit decisions by developing a real options model with EBC. We highlight how EBC affects the decisions and values differently from a liquidation value-based borrowing constraint (LBC). Unlike under LBC, the firm delays investment to increase the cap of debt under EBC. 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 goes 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.

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1 Introduction

Economics literature, including 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 (hereafter, denoted by LBC) on corporate investment and financing decisions, as well as on business cycles. Under LBC, a firm faces a debt issuance capacity 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 shown the prevalence of earnings-based borrowing constraint (hereafter, denoted by 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—earnings before interest, taxes, depreciation, and amortization (EBITDA) are typically used—rather than asset values.

This paper aims to theoretically show the effects of EBC on corporate investment, financing, and exit decisions. In particular, we focus on how EBC affects the corporate policies and values differently from LBC. The paper builds a standard real options model (e.g., Shibata and Nishihara (2012) and Sundaresan, Wang, and Yang (2015)), which combines McDonald and Siegel (1986)'s optimal investment timing model and Leland (1994)'s optimal leverage model. The model considers a firm that has an option to invest by incurring investment costs along with issuing consol debt. Based on Abel and Eberly (1996), Abel, Dixit, Eberly, and Pindyck (1996), and Shibata and Nishihara (2018), the model assumes partial investment reversibility, where a part of investment costs will remain as liquidation value. On bankruptcy, a fraction of firm value is lost, and debt holders, who take over the firm, choose between liquidating or operating the firm by comparing the liquidation and going-concern values. The former is called liquidation bankruptcy, while the latter is called reorganization bankruptcy. In addition to this standard setup, the model imposes EBC at the investment time. For comparison, we also investigate a model with LBC rather than EBC.[1] The model results are summarized below.

With very tight EBC, the firm relinquishes risky debt issuance but resorts to riskless debt. The possibility of riskless debt financing is consistent with empirical observations by Corbae and D'Erasmo (2021). Reasonable levels of tightness of EBC (implied by Lian and Ma (2021) and Drechsel (2020)) lead to realistic levels of leverage, which are lower than that of the unconstrained model. With less tightness of EBC, the firm increases risky debt to increase firm value. This high leverage makes the firm choose reorganization bankruptcy rather than liquidation bankruptcy in case of financial distress. Reorganization bankruptcy by the firm with high leverage is consistent with empirical evidence of Bris, Welch, and Zhu (2006) and Corbae and D'Erasmo (2021). EBC can increase the investment threshold beyond that of the riskless debt financing case, and 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 investment size.

investment threshold decreases with less tightness of EBC. The investment delay EBC causes is consistent with Adler (2020) and Kariya (2020)'s empirical evidence, which shows that EBC reduces corporate investment. This effect of EBC on investment timing is contrasted with that of LBC. In fact, Shibata and Nishihara (2018) show that LBC can accelerate investment earlier than that of the unconstrained model.

The effects of investment reversibility on the investment and financing decisions under EBC are quite different from those under LBC. The cap of debt is not related to liquidation value under EBC, although the cap of debt is based on liquidation value under LBC. Then, higher investment reversibility does not largely affect EBC, leverage, investment timing, and firm value under EBC, although it greatly relaxes LBC, increases leverage and firm value, and accelerates investment under LBC. These different effects under EBC and LBC are consistent with empirical observations of Kermani and Ma (2020b). The comparison results also imply that for the firm with lower investment reversibility, EBC tends to be preferable to LBC. This result is also consistent with Kermani and Ma (2020b) and Lian and Ma (2021)'s empirical findings that EBC is more prevalent for firms with lower liquidation value. Under EBC, the firm with lower investment reversibility tends to choose reorganization bankruptcy in case of financial distress. Then, the model predicts a positive relation between the prevalence of EBC and reorganization bankruptcy through low liquidation value. This prediction is consistent with empirical evidence of Lian and Ma (2021) and Kermani and Ma (2020b).

The effects of cash flow volatility on the firm with EBC is also different from those with LBC. Higher volatility does not change the cap of debt under LBC, but it increases the cap of debt under EBC because higher volatility increases the investment threshold. Through this investment timing channel, EBC is less binding with higher volatility, but LBC is more binding with higher volatility. Then, contrary to the results in unconstrained and LBC models, higher volatility induces the firm with EBC to take higher leverage, which tends to lead to reorganization bankruptcy in case of financial distress. The comparison results also imply that for the firm with higher volatility, EBC tends to be preferable to LBC. These volatility effects are novel and have not been tested in empirical literature.

At the end of this section, we briefly explain 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 and 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 and 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 investigate an investment and financing problem with EBC. This paper is the first to analyze a real options model with EBC and show how EBC affects the corporate investment, financing, and exit decisions.

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. These papers argue that firms that are expected to choose reorganization bankruptcy rather than liquidation bankruptcy in case of financial distress tend to be bound by EBC rather than LBC. Adler (2020) and Kariya (2020) show empirical evidence that EBC reduces corporate investment. However, they focus mainly on empirics, and to our knowledge, no papers develop dynamic corporate finance theory that accounts for the empirical observations. Thus, this paper complements the EBC literature by theoretically showing the effects of EBC on the investment timing, capital structure, exit timing, and exit type in the dynamic model.

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 explores the model solutions in full details in numerical examples and illustrates empirical implications. This section also shows how EBC affects the corporate investment, financing, and exit decisions differently from LBC. Section 5 concludes the paper.

2 Model Setup

2.1 Entry to the market

The model builds on the standard setup (e.g., Shibata and Nishihara (2012) and Sundaresan, Wang, and Yang (2015)) of investment with optimal capital structure based on tradeoff theory. 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. The corporate tax rate $\tau \in (0,1)$ is applied for $X(t) - C$.

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, an earnings-based borrowing constraint (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.[2] In EBC (1), we use EBIT just after investment because in this model, the firm receives no EBIT until investment. If we consider a growth option model, we can use EBIT just 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 optimally choose debt issuance timing apart from investment timing, the firm would issue debt just after investment rather than before investment to increase the cap of debt.[3] 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 assume this particular type of EBC 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 a cap on the ratio of interest payments to earnings (see Greenwald (2019)), and this type can be modeled as[4]

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

However, this paper's main results will remain unchanged, whether EBC (1) or (2) is assumed. According to Lian and Ma (2021), EBC (especially for bank debt) can be periodically monitored after the debt issuance time. For model tractability, the model assumes debt with infinite maturity and EBC only at the debt issuance time, although 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. In the presence of liquidation value $kI > 0$, the firm chooses one of the following three exit forms when EBIT $X(t)$ deteriorates.

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

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

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

[4] 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 is constrained by EBIT.

receive positive residual value, i.e., $(1-\tau)kI - C/r \geq 0$. In this case, there is 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. Debt holders take over the firm based on the APR 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 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 (hereafter, 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. Debt holders take over the firm based on the APR 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 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.

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.[5] 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. 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, the model can capture 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 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

[5] 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 $(1-\alpha)$.

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

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

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 operating the firm perpetually, and the extra term is the value of the liquidation option.[6] 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 $G(x^d(C)) \leq (1-\alpha)kI$. The debt holders' choice $\max\{(1-\alpha)kI, G(x^d(C))\}$ will be relevant in debt valuation (9) in Section 3.2.

Higher investment reversibility k increases $(1-\alpha)kI$ more than $G(x^d(C))$. Higher coupon C increases $x^d(C)$ (cf. (8) in Section 3.2), and higher $x^d(C)$ increases $G(x^d(C))$ in (3). Then, with lower k and with higher C and $x^d(C)$, the firm is more likely to go into reorganization bankruptcy.[7] 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

[6] 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).

[7] 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.

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

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

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

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

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 operating the firm perpetually, 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 the 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)). Sellout by the firm with low debt level (i.e., $C \leq C^s$) is consistent with empirical findings in Corbae and D'Erasmo (2021).

On the other hand, shareholders choose default for negative residual value, i.e, $C > C^s$. Bankruptcy by the firm with high debt level is consistent with empirical findings in Corbae and D'Erasmo (2021). In this case, the equity value, denoted by $E^d(x, C)$, becomes

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

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

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

in the standard manner. In (7), $(1-\tau)(x^i/(r-\mu) - C/r)$ denotes the value of operating the firm perpetually, 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 but choose $x^d(C)$ in 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

Finally, 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

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	$(1-\alpha)kI$

bankruptcy costs determines C under EBC (12). Unfortunately, we cannot analytically solve x^i and C in problem (11) subject to EBC (12). Let $v^d(x, x^i, C)$ as 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 the solution satisfies EBC (12) and $C > C^s$, EBC is not binding. Otherwise, EBC is binding, where the first-order condition becomes

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

where λ is a positive Lagrange multiplier.[8] 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 examine 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:

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

where ϕ_L denotes the tightness parameter of LBC. LBC (13) means that the cap of debt is based on liquidation value $(1-\alpha)kI$, which is consistent with Kiyotaki and Moore (1997)'s model. The model with LBC (13) is essentially the same as in Shibata and Nishihara (2018). Table 1 summarizes the caps of debt under EBC and LBC as well as 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 (see Table 1). Indeed, $G(x)$ is approximately equal to $(1-\tau)(1-\alpha)x/(r-\mu)$ (i.e., a linear function of x) for low k because the option value (i.e., the second term in (3)) is nearly zero. As we will show in the next section, this relation leads to a positive relation between the prevalence of EBC and reorganization bankruptcy.

4 Numerical analysis and implications

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

[8]We remove the possibility $C \to C^s$ because $v^d(x, x^i, C^s)$ is lower than $v^s(x, x^i)$.

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

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 observations (e.g., Lian and Ma (2021) and Drechsel (2020)) that the cap of debt under EBC is usually set between 3 and 5 times EBITDA.

For the baseline parameter values, EBC is binding. The 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 $CS = C/D^d(x^i, C)) - r$ 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 firm invests at $x^i = 0.9728$ and issue debt with coupon $C = 0.6062$. At 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, LV, and CS. These deleverage effects of EBC are consistent with empirical observations that debt holders mitigate default risk by imposing EBC. Although Leland-type models (e.g., Leland (1994) and Goldstein, Ju, and Leland (2001)) tend to generate much higher leverage than those observed in the real world (e.g., Graham (2000) and Frank and Goyal (2009)), reasonable tightness of EBC generates observed leverage levels. EBC also delays investment and decreases the firm value through the deleverage effect.

4.1 How EBC and LBC bind the firm

This subsection examines how EBC binds the firm. The top left panel of Figure 1 shows the binding and nonbinding regions 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 is binding.

Notably, k does not largely affect whether EBC is binding in the top left panel of Figure 1, although k greatly affects whether LBC is binding in the right panel.[9] 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 kI under LBC. Then, unlike under LBC, k does not largely affect whether EBC binds the firm. This observation also leads to the following implications about firm value. For the firm with lower k, EBC tends to be preferable to LBC because EBC tends to be looser than LBC.[10] This result is consistent with 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 1 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.[11] This difference is explained as follows. 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, which leads to the new empirical predictions.

4.2 Tightness of EBC

Figure 2 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 does not rely on risky debt but resorts to riskless debt. This result is consistent with that of LBC in Shibata and Nishihara (2018). The result is also consistent with that of Corbae and D'Erasmo (2021), who

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

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

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

show that firms with low levels of debt can exit without declaring bankruptcy (i.e., sellout in this paper).

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 increases in ϕ_E. This means the straightforward result that with less tightness of EBC, the firm issues more and riskier 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, the firm is more likely to go into reorganization bankruptcy rather than liquidation bankruptcy in case of financial distress. This can be seen in the center-left panel of Figure 2, 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 are consistent with 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.

More notably, in the top-left panel of Figure 2, 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. Then, 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, tighter EBC delays corporate investment. This result is consistent with Adler (2020) and Kariya (2020)'s empirical evidence, which shows that tighter EBC reduces corporate investment. More generally, the result is consistent with the stylized facts that limited access to debt financing tend to prevent firms from investing (e.g., Hoshi, Kashyap, and Scharfstein (1991) and Whited (1992)). 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 than that of the unconstrained case. Contrasted with LBC's ambiguous effects on investment timing, EBC clearly delays investment.

4.3 Impacts of investment reversibility

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 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 go into liquidation bankruptcy rather than reorganization bankruptcy in case of financial distress. This can be seen in the center-left panel of

Figure 3, 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 4.1, our model predicts a positive relation between the prevalence of EBC and reorganization bankruptcy through low liquidation value. This prediction is consistent with empirical evidence of Lian and Ma (2021) and Kermani and Ma (2020b).

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 3, 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 of 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, because of the leverage effect. Our results are consistent with empirical observations by Kermani and Ma (2020b). They show that total borrowing does not depend on liquidation value for large firms and firms with positive earnings (these firms are likely to be unconstrained or constrained by EBC), while total borrowing increases with 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. As explained in Section 3.3, the optimal coupon is equal to $C^s = r(1-\tau)kI$ in the riskless debt case. Then, higher k increases C^s and LV, and this leverage effect decreases x^i and increases x^s and LV. These effects are stronger than that of $k < 0.43$ because higher k directly increases the cap of riskless debt. Hence, for $k \geq 0.43$, $V^s(x)$ increases beyond $V^d(x)$, and the firm prefers investment with riskless debt financing. In the bottom-right panel of Figure 3, CS remains 0 for $k \geq 0.43$ because of riskless debt.

4.4 Impacts of cash flow volatility

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 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. This result is explained by the investment timing and EBC as follows. In the top-left panel, x^i increases in σ. This is consistent with the standard volatility effect that higher σ increases the option value of waiting and the hurdle rate for investment (e.g., Dixit and Pindyck (1994)). An increase in x^i relaxes the cap of debt in EBC (12), and then, the firm issues more debt to benefit from the leverage effect. In fact, in the top-right and bottom-left panels, C and $LV(x^i)$ increases in σ. As explained in Section 3.1, higher C induces the firm to go into reorganization bankruptcy rather than liquidation bankruptcy. Combining this result with the result that the firm with high σ prefers EBC to LBC as shown in Section 4.1, our model predicts a positive relation between the prevalence of EBC and reorganization bankruptcy through high σ. The positive relation is consistent with that of Section 4.3, as well as empirical evidence of Lian and Ma (2021) and Kermani and Ma (2020b).

These effects of σ on C, LV, and the choice between liquidation and reorganization are contrary to those of Antill and Grenadier (2019). They study the optimal capital structure and bankruptcy choice by developing a more detailed model of the reorganization bankruptcy procedure, but their model includes neither optimal investment timing nor debt issuance constraint. Then, as in Leland (1994), in their model, 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 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 the bank and market debt are related to the reorganization and liquidation bankruptcy, Shibata and Nishihara (2015)'s results are consistent with those of the current paper.

5 Conclusion

This paper develops a dynamic investment and financing 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 the model analyses, this paper shows 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 delaying investment, although investment timing is not related to the cap of debt under LBC. Then, unlike with LBC, the firm with EBC delays investment to utilize more debt financing. This investment delay that EBC causes is consistent with empirical findings. Investment reversibility does not largely affect the firm with EBC, although it greatly affects the firm with LBC. The difference implies that the firm with low investment reversibility, which leads to reorganization bankruptcy rather than liquidation bankruptcy in case of financial distress, prefers EBC to LBC. This also leads to a positive relation between the prevalence of EBC and reorganization bankruptcy through low liquidation value. These results also are consistent with empirical evidence. 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. Then, contrary to the results in unconstrained and LBC models, under EBC, the firm with higher volatility increases leverage and chooses reorganization bankruptcy in case of financial distress. These volatility effects through the investment timing channel entail the new empirical predictions.

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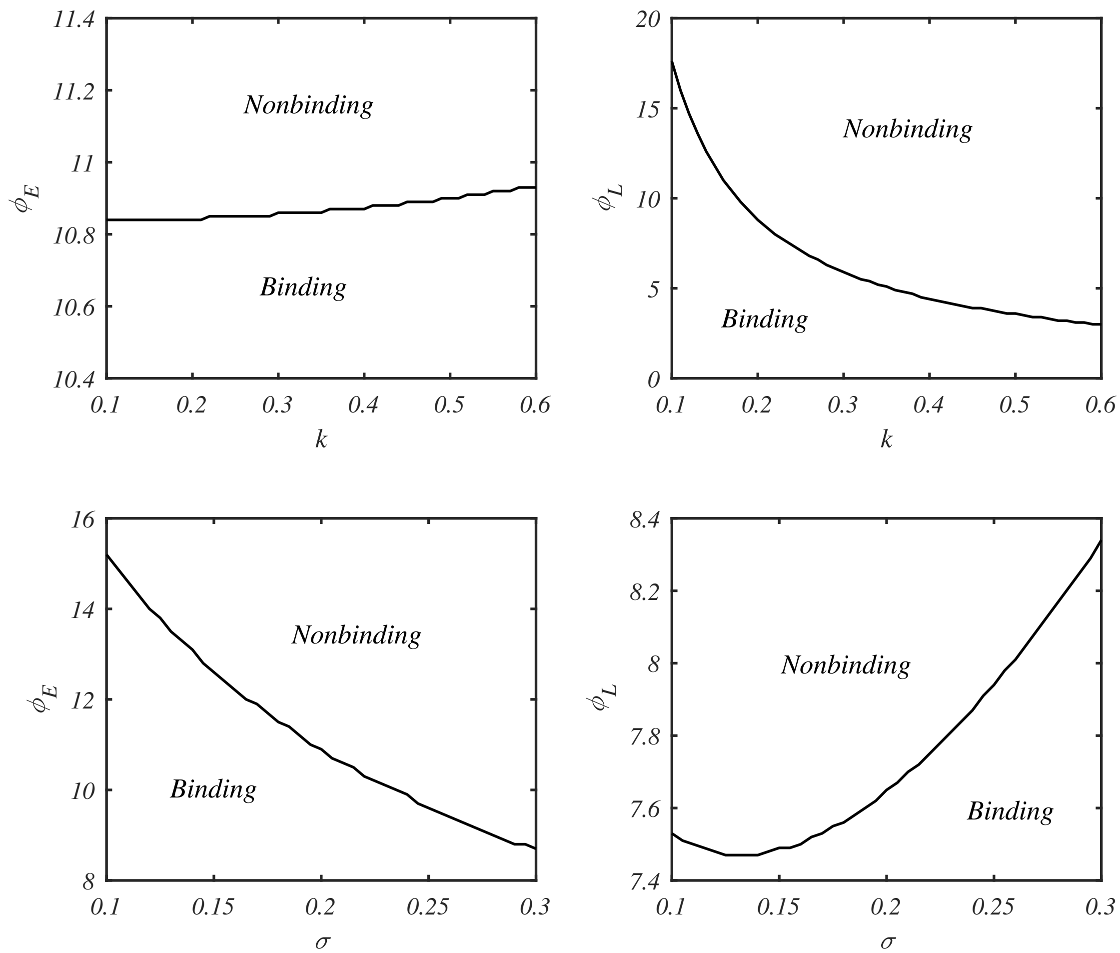

Figure 1: Binding and nonbinding regions under EBC and LBC. The left panels show the binding and nonbinding regions under EBC for varying levels of tightness ϕ_E, investment reversibility k, and volatility σ, whereas the right panels show the binding and nonbinding regions under LBC for varying levels of tightness ϕ_L, investment reversibility k, and volatility σ.

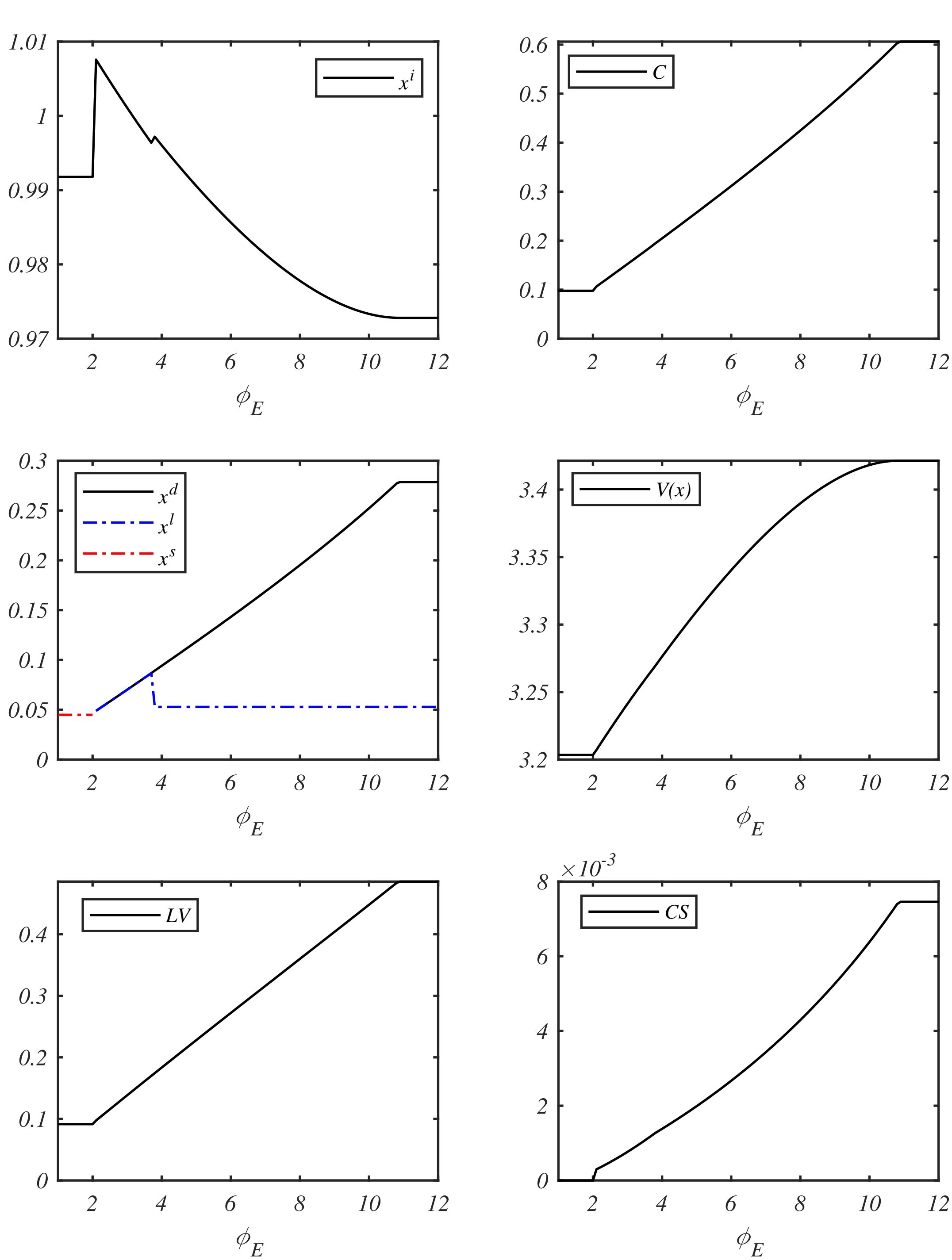

Figure 2: Comparative statics with respect to tightness ϕ_E. The figure plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS. The firm chooses riskless debt for $\phi_E < 2.1$, risky debt with liquidation bankruptcy for $\phi_E \in [2.1, 3.7]$, and risky debt with reorganization bankruptcy for $\phi_E > 3.7$. EBC is not binding for $\phi_E > 10.8$.

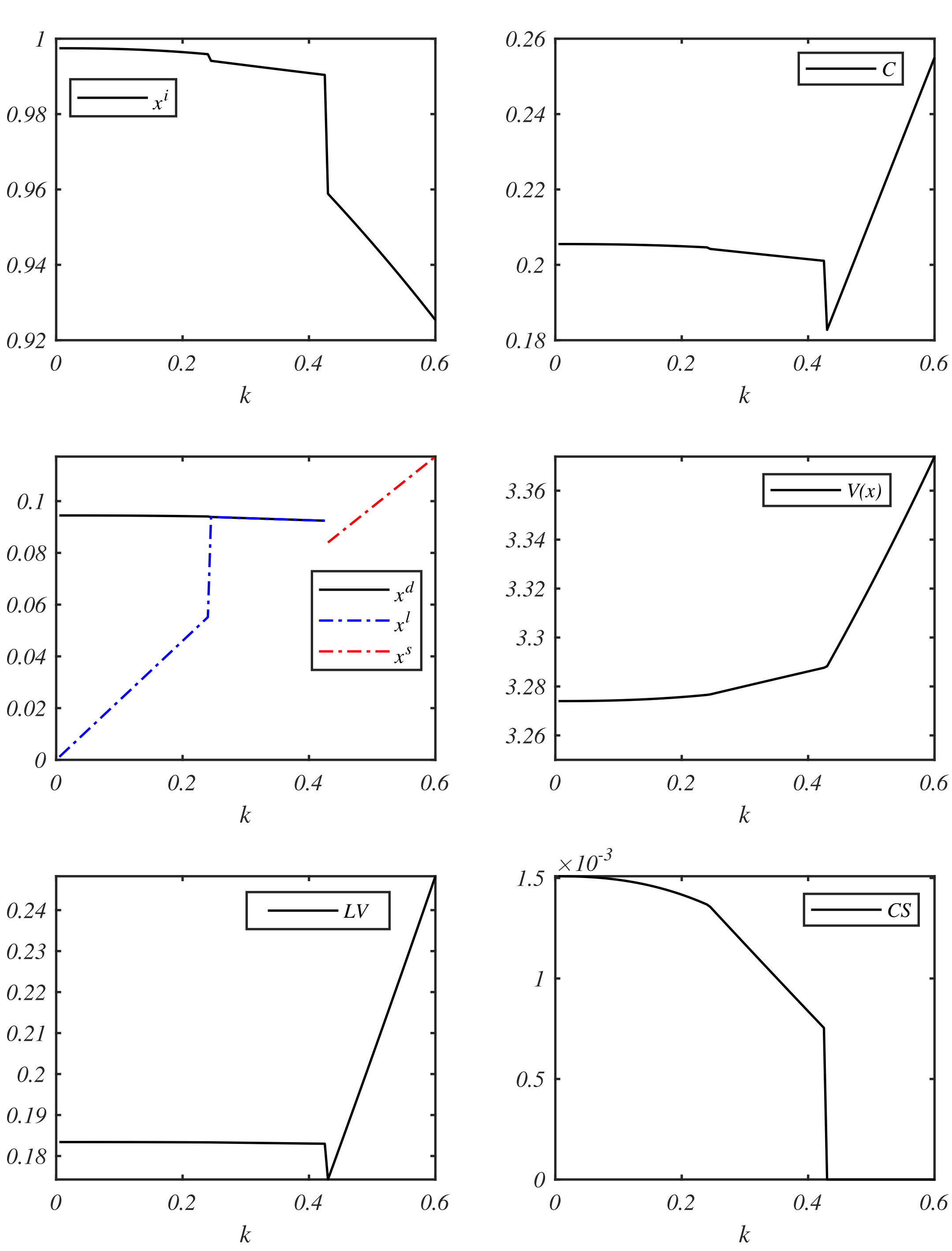

Figure 3: Comparative statics with respect to investment reversibility k. The figure plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS. The firm chooses risky debt with reorganization bankruptcy for $k \leq 0.24$, risky debt 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.

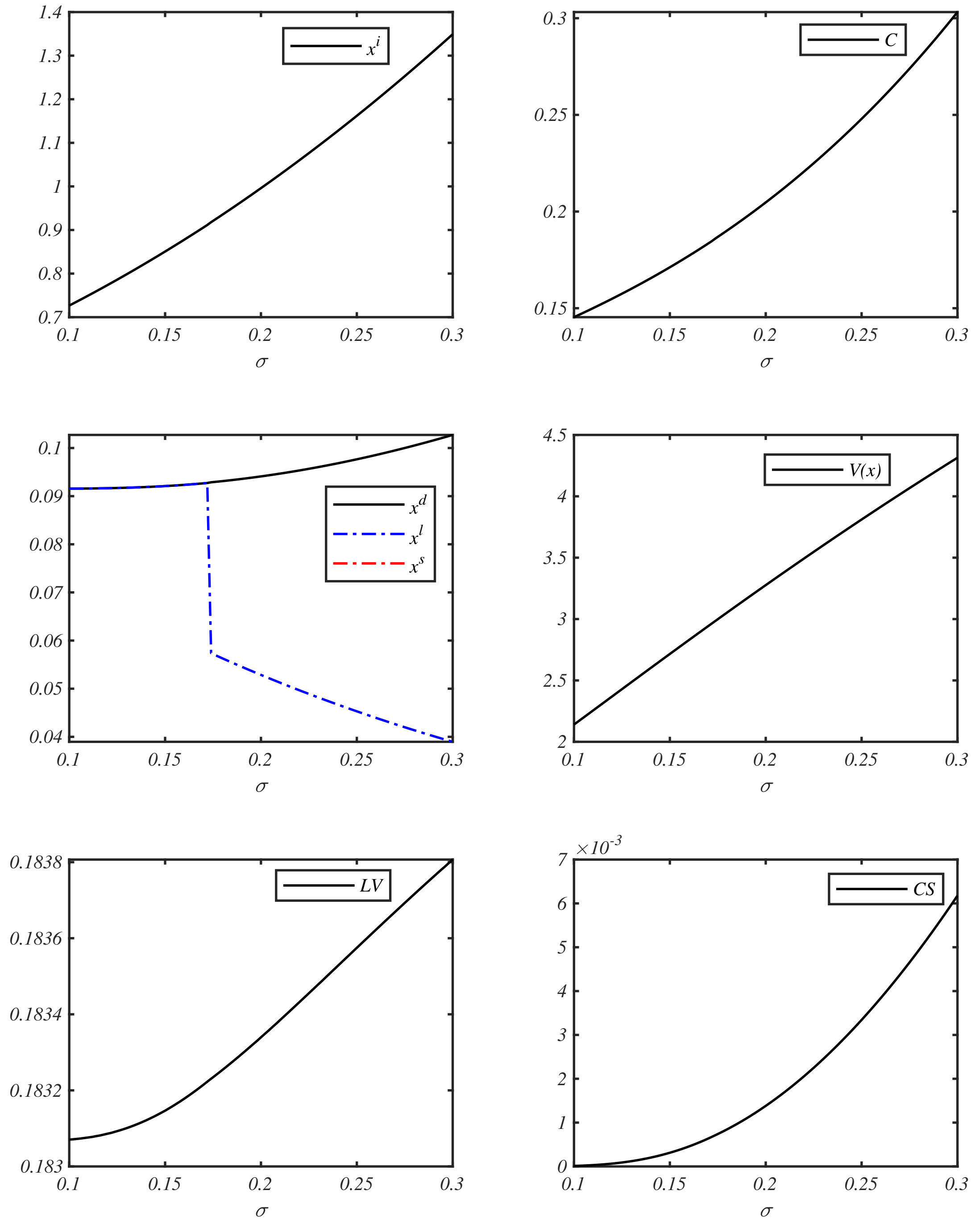

Figure 4: Comparative statics with respect to volatility σ. The figure plots the investment threshold x^i, coupon C, exit thresholds x^d, x^l, x^s, firm value $V(x)$, leverage LV, and credit spread CS. The firm chooses risky debt with liquidation bankruptcy for $\sigma \leq 0.172$ and risky debt with reorganization bankruptcy for $\sigma > 0.172$. In all the regions, EBC is binding.