The Value in Waiting to Issue Debt

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Working Paper

ABSTRACT

This paper addresses the zero-leverage puzzle, the observation that many firms do not issue debt and thus seem to forego sizable debt benefits. By considering the real option of issuing debt, small and risky firms have incentives to postpone debt issuance, even when standard trade-off theory predicts that these firms should have leverage. Thus, the value of debt-free firms should include an option component whose value is derived from future debt issuance benefits. The paper proposes a model of optimal timing for issuing debt and finds empirical support for the model's predictions.

Keywords: Real options, Capital structure

JEL classification: G32

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I. Introduction

This article provides an explanation for the zero-leverage puzzle. Based on the trade-off theory, a firm financed with debt saves on taxes, while it faces the debt costs associated with financial distress. Firms issue debt and net a positive gain by trading off costs and benefits. However, zero-levered firms seemingly ignore significant tax advantages associated with debt financing. I propose that this behavior is due to the value in waiting to issue debt and postponing debt costs. I present a simple model for a firm's optimal issuance with optimal leverage and default, and find the factors that increase the propensity to remain zero-levered: high volatility, high debt costs, low tax levels, low payout rate, and small size. I verify the factors empirically on a sample of zero-leverage (ZL) firms with estimating a survival and a choice model and an out-of-sample test on levered firms.

The trade-off theory identifies debt as a preferred source of financing. However, Strebulaev and Yang (2013) and Bessler, Drobetz, Haller, and Meier (2013) document a significant number, and an increasing trend, of firms with zero leverage. On average, 10% of firms had no debt every year between 1962 and 2009. At first glance, this evidence is inconsistent with standard trade-off models. It is also striking given that Korteweg (2010) reports net debt benefit averaging 5% of firm value between 1994 and 2004. The potential gain is positive, 1.8% on average, even for ZL firms that supposedly face more issuance costs in form of financial constraints.[1] Thus, it seems that ZL firms "leave considerable amount of money on the table by not levering up" (Strebulaev and Yang, 2013).

I model a ZL firm that holds a valuable real option for issuing debt according to a classical trade-off model. The real-option value reflects the hesitation that managers feel to restructure the capital because of the uncertain future of the firm and debt costs. Managers only exercise this option when doing so makes up for the loss of optionality, or insurance value of not having debt; should firm value suddenly decline, not issuing debt postpones exposure to non-recoverable costs. I show that a small amount of non-convex costs, which may not exceed benefits of immediate issuance, is sufficient to create value in waiting and ZL policy. Thus, even when standard trade-off theory predicts firms should have leverage, debt-free firms can exist without any additional indirect bankruptcy costs.

Viewing debt issuance through a real option lens determines the factors that increase the option value and make firms more likely to have zero leverage: small size, low payout rate, low tax rate, and high debt costs (bankruptcy and issuance). Most importantly higher asset volatility increases the insurance value of the option to issue debt later. Intuitively, there is a volatility threshold in this article's model, similar to the optimal exercise policy of American options.[2] The threshold separates issuing and non-issuing firms. Above this volatility, firms prefer not to issue and wait

[1] The value is for non-dividend paying ZL firms that are more likely to face financial constraints (Korteweg, 2010).

[2] Calculating the volatility boundary for a given asset value is equal to calculating a threshold in the asset's value for a given volatility. Increasing the option value increases (decreases) the asset (volatility) threshold.

because option values increase in the underlying asset's volatility.

These implications of the model are consistent with the earlier evidence on ZL firms and I test them empirically. Consistent with Bessler et al. (2013), a volatility comparison of ZL and levered firms shows that it is higher for ZL firms, both in overall and in size-ranked subsamples. Then, I estimate a hazard model for the duration that firms stay debt-free. I also look at a binary-choice model to opt in or out of a ZL policy determined by firm characteristics in 1996-2012 period. Both models verify that the earlier five factors increase the duration and likelihood of remaining debt-free as the theoretical model predicts. In the choice model, re-interpreting the latent factor yields the volatility threshold that separates ZL and non-ZL states of the firms. In the same period, I run an out-of-sample test of the choice model on levered firms and observe a reasonable performance in predicting their choice of becoming levered. The choice model passes robustness checks over the subsample of firms with positive payout and an alternative proxy for ZL firms.

In more detail, my model is based on original trade-off models with endogenous default policy and capital structure, where I add the waiting option and small fixed costs to produce non-convexity. The firm is debt-free, considers optimally replacing some equity with debt and is motivated solely by tax savings. Traditional models focus on the amount of debt to be issued, conditional on immediate issuance. Instead, I consider a schedule of optimal debt amounts to be conditional on a possible issuance moment. In a nutshell, the mechanism can be understood from the following example: consider an all-equity firm valued at \$100 in a Bernoulli trial. If the firm restructures its capital by optimally replacing part of its equity with debt now, it gains \$6 in tax savings and bears \$5 in expected distress costs. But, if the same optimal restructuring in the future yields net gains of \$10 with 80% chance and \$0 with 20% chance, the firm prefers to hold the real option valued at \$8. The market also incorporates this in its assessment of the firm's value. Thus, the firm remains debt-free and deviates from the traditional optimal leverage caused by the real option value.

I analyze three cases and derive five hypotheses for testing the model's implications empirically. Case I is based on Leland (1994) that represents the static trade-off with the option to issue a consol bond. In Case I with reasonable parameters, the traditional setup predicts a minimum optimal leverage of 50%, but considering the value of waiting reduces the optimal leverage to zero for the same model. Without the real option, this model requires 100% of the firm's value lost at default and a very low tax rate to produce ZL policy. Case II shows that the results requires the costs' non-convexity by replacing the fixed bankruptcy cost with an issuance cost in the earlier model. Case III is based on Leland (1998) that represents dynamic trade-off with debt rebalancing, rollover, and issuance costs. Due to issuance costs in rebalancing, having very small leverage, or debt, with very frequent rebalancing is not optimal. With similar parameters but without a real option, the same model generates ZL policy when the bankruptcy cost increases from 30% to 80%.

In the trade-off literature, existing studies explain the ZL phenomenon by proposing additional costs or restrictions to issue debt that makes the overall costs greater than tax benefits. For instance Strebulaev and Yang (2013) introduce the firm owners' aversion to losing the firm to debtholders without leaving a legacy for descendants. Luciano and Nicodano (2008) examine the cost of lost guarantees for the parent company that already guarantees subdivision's debt. Sundaresan and Wang (2006) points out the cost of lost growth options if the entrepreneur leaves the firm at default. Sufi (2009) finds that it is costly for some firms to issue debt because of financial constraints to access credit markets. This article shows how the real option character of debt issuance explains ZL without assuming additional high bankruptcy or issuance costs that seem to be required by the trade-off theory. Thus, under weaker conditions, debt-free firms can exist. Moreover, ZL firms compose an important subsample of all firms in the leverage analysis and most of the traditional trade-off models are unsuccessful in explaining ZL policy. This article provides a means of reconciling ZL firms with trade-off theory that is embeddable in earlier models, dynamic or static, by combining it with the real-option theory.

This article also complements the literature related to financial flexibility. Recently, DeAngelo, DeAngelo, and Whited (2011) show that financially-constrained firms retain part of their debt issuance capacity to ensure the financing of future projects. Kisser (2013) suggests a similar motivation for cash holdings. Despite these considerations, Strebulaev and Yang (2013) find that one-third of ZL firms pay out some of their cash, either through share repurchases or cash dividends. The ratio is 43% in 1996-2012 period.[3] These firms not only pay higher taxes by replacing interest payments with dividends, but also appear less likely to be financially constrained. The model here helps reconcile the existence of such firms with the flexibility arguments. Although payouts are exogenous in the model, I show that a dividend-paying firm may very well remain optimally unlevered.

The contributions of this paper to the empirical studies on ZL firms are three. First, this paper analyzes the determinants of the duration that ZL firms stay unlevered. Second, in the choice model, the paper re-interprets the underlying factor to derive the volatility boundary between ZL and non-Zl states. The median of the volatility boundary is 41% (59%) which is below (above) 55% (48%), the median of volatility in ZL (non-ZL) firm-quarters. Third, the out-of-sample test cross-sectionally verifies the validity of the binary-choice model in predicting the choice for levered firms.[4]

The rest of the paper is organized as follows: section two models the firm and the optimal strategy to issue debt. Section three test the model predictions empirically. Finally, Section four concludes .

[3]For earlier works, see Gorbenko and Strebulaev (2010), Gamba and Triantis (2008), Hennessy and Whited (2005),and Trigeorgis (1993). For this literature, explaining ZL firms, especially with dividend payments, is "perhaps the most significant challenge."(Denis, 2012)

[4]I am grateful to Elkamhi, Ericsson, and Parsons (2012) for kindly sharing their data on estimated volatility of levered firms.

II. Model

Consider a firm with an unlevered asset-value process, ν, following Geometric Brownian Motion (GBM) with constant volatility under physical measure. The firm has no debt and is an all-equity firm. Current asset value is ν_0 and the firm's managers determine when to issue debt based on the state of the firm which is determined by its value. I leave more details about debt, e.g. debt structure and benefits, to the cases analyzed later. Since the asset captures the random shocks from one source of risk, the value process under equal risk-adjusted (risk-neutral or RA) measure also follows the GBM process with a drift changed to the risk-free rate:

$$\frac{d\nu}{\nu} = (\mu - \delta)dt + \varepsilon dW^p \quad \Leftrightarrow \quad \frac{d\nu}{\nu} = (r - \delta)dt + \varepsilon dW^q \tag{1}$$

Where δ is the asset payout rate, μ is the expected growth rate of the process, ε is the volatility, and r is the risk-free rate. Both processes W^p (physical shocks) and W^q (RA shocks) are standard Brownian motions. All the parameters are exogenous including the payout rate. The model does not have an endogenous payout rate for simplicity. An endogenous payout rate probably will be zero to maximize the total firm value, but I do not consider this case in my analysis.

In the model, debt, once issued, replaces equity and changes the capital structure of the firm. Equity holders receive the cash-in-flow of debt issuance, but it does not change their wealth before and after the issuance. However, the issuance creates an extra value in the form of debt benefits from tax savings less debt costs according to trade-off theory. The extra value is lucrative for equity holders and adds to their wealth after the issuance because they gain more in the form of their equity appreciation. Thus, debt is solely issued to save on taxes and has no other benefits such as financing new projects, in the model.

Another way of looking at the replacement is from the eyes of the firm's managers who have complete objectives, similar to the shareholders', aligned to increase the firm's value. Prior to debt issuance, they manage the firm with the unlevered value. They are indifferent as to whether the firm finances with debt or equity, since the financing method does not affect the operations of the firm. However, they care about the extra gain from debt benefits. In a Modigliani and Miller (1958) framework, tax savings from interest payments and debt costs are the frictions. Prior to issuing debt, they manage an unlevered firm, but, after issuing debt, they manage the same firm with an extra value added by debt benefits. From the managers' point of view, issuing debt (replacing equity with debt to be more accurate) is similar to a positive NPV project. The tax savings are equal to present value of future incomes, and the debt costs are the present value of future possible costs. The real-option value quantifies the hesitation that managers feel to restructure the capital because of the uncertain future of the firm and riskiness of its assets. For the managers, the question is when, or at which state, to wait no longer to implement this positive NPV project. The answer is the state with the largest expected gain from issuing debt, the time when the net gain is higher than the option value.

In this framework, I explain where the mystery is and how the proposed solutions in the literature work so far. If the debt benefits are positive in many states, then it is mysterious why some firms do not issue debt at these states to enjoy the extra value while others do. The empirical works that find positive net gain from issuing debt for ZL firms highlight the mystery. then, one solution is to invalidate the assumption: to make debt benefits negative and show hidden or ignored costs of debt. Inflating debt costs by adding other costs, such as debt overhang or family-legacy concerns, is one strategy. Another strategy is to consider constraints on issuing debt, also categorized as costs. However, there is no need to inflate the costs or add barriers and a weaker assumption is to have non-convex costs in this paper. Throughout this article, debt issuance is profitable at all the analyzed states. The model determines states that have positive debt benefits and no-issuance as the optimal strategy.

The model keeps some of the assumptions in the classical models: a) debt issuance has a long life due to its long maturity. A short-term debt has high costs such as rollover risk and covenants. Since it adds an extra dimension to the model's complexity, this paper does not consider optimal maturity. b) debt is irreversible due to no downward restructuring. The irreversibility assumption naturally holds as long as the costs to buyback debt are higher than default or issuing new debt. Default is not uncommon and there is also empirical evidence about the irreversibility assumption (for example see Korteweg (2010)).

Since debt issuance has real option properties, I follow the real-option analysis as discussed in McDonald and Siegel (1986) and Dixit and Pindyck (2012). There is a border state beyond which debt is issued and this state is equal to an unlevered asset value triggering debt issuance, ν_I. Figure 1 explains the model structure. The firm has no debt below this threshold and before being reached for the first time by the value process. Only after the unlevered value process crosses the threshold does the firm exercise the real option of debt issuance and expose itself to debt costs such as the cost of default. Thus, this article answers another concern about firms' ignoring debt benefits. Actually, they do not ignore the value in the debt benefits; they merely prefer to keep the option inactive. Prior to crossing the threshold, the firm benefits from simply holding the inactive real option. The market takes the value of this inactive option into account for the firm's valuation. Thus, the total value of an all-equity firm is the unlevered value plus the inactive option value, and no value is left on the table.

Insert Figure 1 about here.

For the time being, the debt benefit is a function, $DB(\nu)$, of the unlevered firm value, ν, at each point in time. The condition for activating the real option, i.e. issuing debt, is the subject of interest. This condition addresses only the question of what the optimal threshold is. Later, in different cases, I will focus on some very commonly used debt structures for modeling and provide results that are more accurate. For the optimal exercise strategy, I need first to evaluate the option at each state; I use the approach of Ericsson and Reneby (1998). The option's value before the exercise point is the value of a contingent claim paying \$1 at the threshold times the debt benefit for the unlevered firm value at the threshold. The claim satisfies the next partial differential equation (PDE) with the boundary condition as \$1 at the threshold. Solving for the option value yields:

$$
\begin{aligned}
&\frac{1}{2}\varepsilon^2\nu^2 F_{\nu\nu} + (r-\delta)\nu F_\nu - rF = 0 \\
&DB(\nu) = TS(\nu) - DC(\nu) \\
&W(\nu) = DB(\nu_I)(\frac{\nu}{\nu_I})^{\beta_1} \qquad \nu \le \nu_I
\end{aligned}
\tag{2}
$$

where F_ν is the partial derivative of the function with respect to the asset value, DB is the debt benefit, TS is the tax savings, DC is the debt costs, and W is the option to wait. The option's formula has two elements: the last part is the value of the contingent claim, and the first part is the total debt gain at issuance. In the Dixit and Pindyck (2012)'s sense, the first part of the debt benefit is the project revenues, TS; and the last part is the project costs, DC. Analogical to an American call option, TS is similar to the value of stock, DC is similar to the exercise price, and $TS - DC$ is the options payoff. Simply put, the waiting option calculates the market expectations about when the firm issues debt and discounts its benefits. As the market includes the expectation in the firm valuation, the total firm value before issuing debt is the unlevered value, ν, plus the option held for issuing debt, W. The optimal debt issuance threshold is set to maximize total value. Solving the implied first order, or the smooth pasting, condition results in:

$$
\frac{\partial(\nu + W(\nu))}{\partial \nu_I} = 0 \quad \Rightarrow \quad \frac{\partial DB(\nu_I)}{\partial \nu_I} = \beta_1 \frac{DB(\nu_I)}{\nu_I}
\tag{3}
$$

I solve for the threshold numerically given that the debt-benefit function is known. The value for β_1 is close to one, and with no asset payout rate it is one. Above, the left-hand side (LHS) of the last equation is the marginal gain in benefits of waiting for the firm's value to increase one dollar. The right-hand side (RHS) is the average actual debt gain per each dollar of the firm's value at the current level. For the firm's value below the threshold, the marginal gain on waiting to increase is higher than the average gain on exercising the option. Thus, managers prefer to wait and issue debt at higher firm value. The threshold is the point at which the marginal and average gains on the debt value match. If the equation is re-arranged, the marginal benefit divided by the average benefit has to match β_1. The ratio is the unlevered-asset elasticity of the net benefits. Below the threshold, the elasticity is larger than one and waiting is more beneficial. Beyond the threshold, not exercising the option creates loss for the firm because the average gain surpasses the marginal gain and waiting has no benefits. Figure 2 illustrates the concept.

Insert Figure 2 about here.

Note that the larger the ratio of ν_I/ν_0, the longer the waiting for the process to hit the threshold. The conditions for the asset threshold to exist are the conditions for Equation 3 to have a solution. However, the asset threshold may exist but fall below the current asset value at all times. This situation means that there is no value in waiting to issue debt. Thus, not only should the optimal asset threshold exist but it should also lie above the current asset level, $\nu_0 < \nu_I \iff Elasticity(\nu_0) > \beta_1 = Elasticity(\nu_I)$. Under this condition, there can be cases with feasible debt issuance (positive net gain) but zero leverage (the optimal strategy is waiting). In Section II.A, I first solve the above model for a very simple case to show that the model is plausible and such cases exist. Then, in Proposition 1, I formally characterize the general properties of the cases with a profitable but not optimal debt issuance.

A. Case I: Single consol bond with optimal default policy and leverage

In this section, first I explain Case I briefly with some of the main calibration results. Then, I derive valuation formulas and show more calibrations to produce the hypotheses for the empirical tests. At the end, I provide a proposition to determine the conditions for the debt benefit function that creates the value in waiting.

Consider an all-equity firm holding the option to issue a consol bond only once with continuous coupon payments, C. Just to keep it simple, there are no rollover risk, no maturity, no liquidity, no rebalancing, no transaction costs and no conflicts of interests. The only debt cost in the case here is the bankruptcy cost. Once debt is issued, the proceedings replace equity. The optimal leverage determines the level of the debt coupon at the time of issuance. The optimal default policy, however, is set after the issuance and adjusts the default state. The default state, or its equivalent unlevered asset level, is the state that the shareholders stop serving the coupons.

To make both optimal decisions, i.e. leverage and default, managers need to know the total firm value for all the possible choices. For any possible default policy and coupon rate, I derive value of debt, equity, and debt benefits. Then, it is trivial to find the optimal default and debt structure policy. Up to this point, the structure of the problem is similar to Leland (1994). Both optimal policies yield the debt-benefit function in Equation 3 to calculate the unlevered asset threshold. I keep the current firm value, ν_0, constant for now. If the current firm value is constant, the threshold turns into a volatility value above which waiting is optimal. It is similar to the asset value threshold below which waiting is optimal if the volatility is constant. One is calculable, keeping the other constant, and there is an equivalency relation between them (see Figure 5).

More intuitively, consider two firms with the same value while one has riskier assets (assets with higher volatility) than the other. The low-risk firm issues debt right away because the gain is large and waiting option is valued less. The riskier firm prefers to wait because the option is more valuable than the immediate gain; when a firm is riskier, it is more likely to become zero-levered. Thus, there is a volatility threshold that separates firms that issue and do not issue in the model based on the volatility of their assets (see Figure 3a). Model calibrations to plausible values create Figure 3b.

Insert Figure 3 about here.

In Figure 3a, everything is constant except the volatility level. The vertical dashed line shows the volatility threshold beyond which firms prefer to wait. The figure also compares the optimal leverage of the real-option model with similar models that do not take into account the value in waiting. While traditional models consider the optimal leverage to remain above 50%, the real-option model implies zero leverage for high volatility firms. In addition, the same model produces ZL policy only with very large debt costs and low tax savings. Figure 3b shows how the volatility threshold changes as a function of the PBC rate. Firms with high asset volatility stay in the dark area where it is feasible but not optimal to issue debt. The borderline between the dark and light areas represents all the volatility threshold points. Figure 3a is a cut on Figure 3b at PBC rate of 30% highlighted by the lines.

The calibration result is close to values that are later estimated in the empirical section and range between 50-70% for the volatility boundary. However, the model does not imply that every firm with a volatility higher than the boundary follows the no-debt policy. It only applies to the firms not passed the boundary before. Since the boundary changes with the firm's situation, a firm issues debt under favorable circumstances; but later circumstances change and the boundary drops, while the firm has already issued debt. The calibration uses the average risk-free and payout rate as 5% and 3% to match the averages of data in 1996-2012 period. The total bankruptcy rate ranges from 30% to 45%, depending on the optimal default policy. Classically, this rate is between 0-20% (see e.g. Bris, Welch, and Zhu (2006)); but Elkamhi et al. (2012) argue that it is slightly above 50%, if financial distress costs before filing for bankruptcy are also included. The selected range is in the middle of the two. The graph does not change much if the range remains between 10-20%; the threshold gets close to 60% for the volatility. The tax rate is 25% and lower than the 35% corporate tax rate, similar to Leland (1998), for accommodating lost benefits due to personal taxes.

Now that I have presented the main findings in the Case I, I will focus on the details. The trade-off has only two elements of tax saving and bankruptcy cost in Case I. Both of these elements relate to the default policy of the firm, especially the bankruptcy cost. The default policy is the constant unlevered asset level at which the firm goes bankrupt (ν_B). The level determines the proportional bankruptcy cost, $\alpha\nu_B$. This policy determines also the RA probability of default at any value of the firm. The probability is crucial for measuring both tax savings and bankruptcy cost. Thus, optimal default policy is an inseparable part of the trade-off analysis in this framework. Shareholders decide about bankruptcy; and Leland (1994) derives the optimal barrier to file for bankruptcy. By assumption, the current firm value is above the barrier, $\nu_B < \nu_0$. After determining the optimal default policy, I calculate the optimal leverage at any issuance point; and, at the end, I set the optimal issuance threshold. While these events chronologically happen in reverse order, the modeling strategy is actually to move backwards.

The procedure begins with formulating debt, equity, tax saving, and bankruptcy cost values. They are all claims defined on the unlevered asset value. In general, any claims with continuous payments, C, satisfies the following partial differential equation (PDE):

$$\frac{1}{2}\varepsilon^2\nu^2 F_{\nu\nu} + (r-\delta)\nu F_\nu + F_t - rF + C = 0 \tag{4}$$

where F is the claim's value, and the subscripts are partial derivatives with respect to the value. The boundary conditions depend on the payoff of the claims at thresholds and maturity. For perpetual claims, the PDE becomes time-homogeneous and the time dimension drops. Thus, Equation 4 turns into:

$$\frac{1}{2}\varepsilon^2\nu^2 F_{\nu\nu} + (r-\delta)\nu F_\nu - rF + C = 0 \tag{5}$$

and the general solution is:

$$F = A_0 + A_1\nu^{\beta_1} + A_2\nu^{-\beta_2} \tag{6}$$

where

$$\beta_1 = \frac{\sqrt{h^2+2r}-h}{\varepsilon} \qquad \beta_2 = \frac{\sqrt{h^2+2r}+h}{\varepsilon} \qquad h = \frac{r-\delta-(\frac{1}{2}\varepsilon^2)}{\varepsilon} \tag{7}$$

The first claim is debt. The bankruptcy and the firm's value approaching infinity set the boundary conditions.

$$D(\nu) = \frac{C}{r} + (((1-\alpha)\nu_B - K)^+ - \frac{C}{r})(\frac{\nu}{\nu_B})^{-\beta_2} \tag{8}$$

where D is the debt value, K is the fixed bankruptcy cost, and α is the PBC rate for the asset given default ($1-\alpha$ is the "asset" recovery rate, not to be confused with the bond's recovery). The last term in the above equation is the discounted RA default probability. Due to limited liability, bankruptcy costs cannot exceed the asset value at default. In order to simplify, I make the PBC rate and the fixed cost small enough to satisfy this requirement.[5] Thus, I drop the positive part of the payoff, $(.)^+$, at default from the debt formula.

[5] The condition is $K \leq (1-\alpha)\frac{C-\tau C}{r}(\frac{\beta_2}{1+\beta_2})$

Here, an assumption influences the model and requires discussion. The default cost has two components: a fixed default cost and a cost proportional to the firm's value at default. When there is the fixed default cost, as long as the debt benefits are positive, the classical trade-off model still suggests that debt issuance is feasible and optimal. Thus, having the fixed default cost or the decomposition of the bankruptcy costs is irrelevant in the trade-off theory for answering the question "To issue or not to issue?" The positivity of benefits is only important. However, I consider cases in which it is not optimal to issue debt, even if doing so would yield a positive benefit, depending on the cost structure. Technically, the fixed cost assumption creates concavity in the debt cost structure. Conversely, it creates convexity in the benefit function of debt and makes it possible to treat the benefit as a real option possible. In addition, it is common to define a fixed default cost in the literature (see Anderson and Sundaresan (2000) or Dotan and Ravid (1985)).

Boundary conditions (see Appendix .A) for all other securities yield the values as follows:

$$TS(\nu) = \frac{\tau C}{r}(1 - (\frac{\nu}{\nu_B})^{-\beta_2}) \tag{9}$$

$$BC(\nu) = (\alpha \nu_B + K)(\frac{\nu}{\nu_B})^{-\beta_2}) \tag{10}$$

$$E(\nu) = \nu + TS(\nu) - BC(\nu) - D(\nu) \tag{11}$$

where TS is the tax savings, τ is the tax rate, BC is the bankruptcy cost, and E is the equity value. The only missing value so far is the optimal default barrier, ν_B. Since the shareholders choose the barrier, they set it to maximize their equity value. Mathematically, this is equivalent to solving the first order condition (FOC) that yields the value for the barrier:

$$\frac{\partial E}{\partial \nu_B} = 0 \Rightarrow \nu_B = \frac{C - \tau C}{r}(\frac{\beta_2}{1+\beta_2}) \tag{12}$$

The default barrier does not depend on bankruptcy cost because the equity holders do not incur the cost at default. The model is capable of capturing costs paid by the shareholders at default, when the shareholders and debtholders split the cost (see Appendix.F), but for now the focus is on the simple case.

Next, I analyze the optimal leverage set by the managers. It is technically to choose the optimal coupon ($C^* : \partial(E + D)/\partial C|_{C=C^*} = 0$). The optimal coupon, before or after the issuance, is the same (see Appendix.D), as long as the policy for the issuance is known. Analyzing the optimal coupon *ex post* is easier.

After determining the optimal leverage,[6] I reach the point at which I can tune the value in

[6]The optimal issuance threshold for the case of all possible coupon rates without following optimal leverage is

waiting more accurately. This means using Equation 3 to numerically calculate the optimal asset threshold, ν_I, after getting the debt-benefit function $(DB(\nu) = TS(\nu) - BC(\nu))$ for each asset level. The waiting is associated with ν_I/ν_0. A ratio smaller than one means no waiting. Above one, the larger the ratio the longer the wait.

Numerical calculation of the optimal issuance boundary produces the comparative statics about the waiting. I first focus on the asset's risk. Figure 4 shows the increasing trend of waiting with respect to the asset risk because higher volatility adds value to the option. The result is similar to the classical exercise policy of an American call option where the exercise threshold increases in volatility. In Figure 4, the waiting also increases in the default costs. In the classical exercise policy of an American call, the result is equivalent to increasing the call's exercise price. Both results produce the next two hypotheses. All these hypotheses rely on a very simple intuition: a higher expected default cost, due to either high default chance (for high asset risk) or high bankruptcy costs, increases the real-option value and makes managers more patient to avoid the costs:

Hypothesis 1: *The duration and probability for a firm to follow the ZL policy increases when the firm's asset volatility is higher (H1).*

Hypothesis 2: *The duration and probability for a firm to follow the ZL policy increases when the firm's debt costs are higher (H2).*

The contour graph for Figure 4 at point one creates Figure 3b. The contour graph also can yield H1 and H2. In Figure 3b, the waiting (the dark) area widens in the default costs that implies H2. In addition, as volatility increases for a given PBC rate, the firm moves to dark area which implies H1. Later, other figures result in relevant hypotheses in a similar way. From now on, instead of three-dimensional graphs, I report the contour graphs to derive the hypotheses. It is because the contour graphs not only are precise and have information about the ZL policy, but also they depict the behavior of the volatility (and, equivalently, the asset) threshold.

Insert Figure 4 about here.

As mentioned in the introduction, for any given asset value, a boundary for the volatility exists. It is similar to an American call exercise where the asset value is constant and investors decide to exercise the option depending on the asset's volatility with respect to the volatility threshold. Because of the equivalency (see Figure 5), wherever I mention the relationship, I also express parallel expressions in terms of the asset threshold. For example, the volatility (asset) threshold above (below) which managers prefer to wait for debt issuance decreases (rises) in the bankruptcy-cost rate, ceteris paribus. Any increase in other default costs, e.g. fixed default cost, also results in lower (higher) threshold for volatility (asset value).

presented in Appendix .B. The appendix also intuitively explains how to find the optimal coupon at the end.

$$ZL = \begin{cases} 1 & \text{if} \quad \nu_0 < \nu_I(volatility, ...) \Leftrightarrow \varepsilon > \varepsilon_i(size, ...), \\ 0 & \text{if} \quad Otherwise \end{cases} \tag{13}$$

Insert Figure 5 about here.

Next, I analyze the tax effect. Even if net debt benefits are positive, a decrease in tax payments or rate makes the tax shield from interest payments less interesting for the firm and managers become more patient. Therefore, the volatility (asset) threshold decreases (increases) with a decreasing tax rate. Figure 6 shows this relation that results in the next hypothesis.

Hypothesis 3: *The duration and probability for a firm to follow the ZL policy increases when the tax rate is lower (H3).*

Insert Figure 6 about here.

Another case is the asset payout rate (see Figure 7). It is easy to see that a high payout rate decreases the drift of the asset process. Low drift implies a lower value for waiting. Hence, it pushes the volatility (asset) threshold upwards (downwards). Payout can take many forms, such as dividend payments to the shareholders or share repurchases.

Hypothesis 4: *The duration and probability for a firm to follow the ZL policy increases when the payout rate is lower (H4).*

Insert Figure 7 about here.

The figure also shows that dividend payment and ZL policy does not contradict. This prediction seems coherent with the empirical literature: both Strebulaev and Yang (2013) and Korteweg (2010) show that there exist ZL firms that pay dividends. Nevertheless, the propensity of dividend-paying firms to become zero-levered falls as the dividend rate increases; the dark area shrinks.

The last hypothesis is with respect to the firm's size. The managers wait until the firm's value, ν_0, increases so that the firm passes from the wait strategy area to the issue strategy area. Figure 8 shows that size decreases the waiting. As in Figure 9, The volatility (asset) value above (below) which managers prefer to wait for debt issuance increases with the current unlevered value of the assets (volatility), ceteris paribus.

Hypothesis 5: *The duration and probability for a firm to follow the ZL policy increases when the firm's size is lower (H5).*

Insert Figure 8 about here.

Insert Figure 9 about here.

This defines a proper capital structuring strategy for the growth path of the firm. When the firm is small and young, it is better to wait to issue debt, even if it is feasible to do so. This helps the firm to avoid exposure to the bankruptcy costs. The higher the risk, the higher the waiting period to increase the distance to default. Then, when the firm becomes bigger and matures enough to reduce the default chance and its cost, it is time to issue debt.

After the presentation of all Case I results, I formally express the general properties of all the possible cases having a feasible, but not optimal debt issuance. This generalizes the cases to support the existence of the dark area in the first graphs. If a model has assumptions matching with the proposition below, there is value in waiting to issue debt:

PROPOSITION 1: *There exists an interval for the asset volatility values ($\varepsilon_i < \varepsilon < \varepsilon_{max}$) such that it is feasible to issue debt but not optimal, under some assumptions.*

Proof. Appendix .C provides the assumptions and the proof for the proposition. □

ε_{max} is the maximum volatility to have a feasible debt issuance and ε_i is the volatility threshold above which waiting to issue debt is optimal. All the borderlines in the contour plots numerically calculate ε_i because it is hard to derive an explicit formula for the threshold:

$$ZL = 1 \quad when \quad \varepsilon > \varepsilon_i(size, payoutrate, etc.), \quad and \quad ZL = 0, \quad otherwise \tag{14}$$

where ZL is an indicator taking one, if the firm is debt-free. I will estimate this level, ε_i, in the empirical section. Therefore, I assume that the debt structure of ZL firms in data matches with the assumptions in Proposition 1. The next two cases are further examples of the model with similar assumptions: having non-convex debt costs and the option to wait.

B. Case II: Transaction cost

So far, there is no transaction friction in the model to explain the ZL phenomenon. In Case II, almost all the assumptions are identical to the earlier case, except the fixed bankruptcy cost is dropped and the fixed issuance cost, κ, is added to the model. It is common in the literature to have issuance and transaction costs as in Fischer, Heinkel, and Zechner (1989), Hackbarth, Hennessy, and Leland (2007), or Hackbarth and Mauer (2012). Doing so shows that the idea of treating debt issuance as a real option only requires concave debt cost structure and works well with other costs in the literature. To have a very simple structure for the concave cost, the firm incurs a fixed one-time issuance cost.

All the formulas are similar to the previous case (see equations 8, 10, and 9), with fixed default cost set equal to zero ($K = 0$). Only the equity formula has an extra term denoting the fixed issuance cost. Optimal default and leverage also follow the same logic:

$$E(\nu) = \nu + TS(\nu) - BC(\nu) - D(\nu) - \kappa \tag{15}$$

$$\nu_B : \frac{\partial E}{\partial \nu_B} = 0, \quad C^* : \frac{\partial (E + D)}{\partial C}|_{C=C^*} = 0 \tag{16}$$

The debt-benefit function is $DB(\nu) = TS(\nu) - BC(\nu) - \kappa$. Again, I use Equation 3 to calculate the issuance threshold. This calculation creates graphs similar to Section II.A (see Figure 10). The constant issuing cost, κ, is \$1. With respect to a reasonable value for PBC rate (see Figure 3a), the cost is smaller than 2% of the debt's market value. The cost is variable depending on volatility and PBC rate because the market value of debt is variable. The transaction cost is much smaller when it is compared to the face value of the perpetuity, C^*/r, because the coupon rate increases dramatically with a higher PBC rate and volatility. The cost is close to Hennessy and Whited (2007) that use 1.09% debt flotation following Altinkilic and Hansen (2000). Other results are similar, and I report only the figure that focuses on the volatility and bankruptcy cost. As expressed in Hypothesis 2, this figure implies a negative relationship between the PBC rate and the volatility threshold. An equivalent model without the real option requires an issuance cost 7.5 times higher (\$7.5 or maximum 15%) than the cost at the current level to create ZL policy at 30% PBC rate.[7]

Insert Figure 10 about here.

C. *Case III: Optimal leverage, default, debt rebalancing, and rollover with issuance costs*

All the previous sections use a very basic model to explain the concept of the value in waiting. Without adding further complications, the models are as simple as possible merely to convey the idea of waiting. However, I extend the concept to more elaborate and realistic models through relaxing some assumptions and adding features. For example, the basic model restricts the firm to issuing a consol bond only once. It seems there is an infinite transaction costs for issuing debt after the first issuance. This property raises questions about whether the other assumptions drive some the results. Although the answer to this concern is partly addressed with the proof of Proposition 1, I extend the model to more advanced cases that show the wait for issuance applies to other models with different assumptions.

Here, the idea is to use Leland (1998)'s model with some alterations for tractability. In brief, the model has proportional bankruptcy costs and optimal decisions about debt rollover, debt re-

[7] A 30% PBC rate without a fixed bankruptcy cost creates similar results as Case I with 15% to 20% PBC rate.

balancing, leverage, and default policy, as in Leland (1998). I drop optimal risk shifting and cash-flow-triggered default for the sake of simplicity, even though these assumptions increase the debt cost, its concavity, and the likelihood of choosing the ZL policy. The model involves the option to wait and non-convex debt costs in form of the extra fixed issuance cost, κ, at the time of rebalancing and issuance. The model in Leland (1998) considers real option of rebalancing debt in the future and optimal leverage. Adding the non-convex cost assumption to Leland (1998)'s model would still result in issuing debt right away, if the net benefit is positive. This is because in optimizing the leverage, choosing no debt is a special and degenerate case in the leverage optimization; the debt benefit function changes in the zero-coupon case. This case needs to be handled separately using the optimal timing formulas presented in this paper.

As in the original Leland (1998)'s model, the model in Case III has continuous issuance and retirement of debt. The firm retires old debt at a continuous rate m (the average debt maturity is $M = 1/m$) and issues new debt with coupon c and face value p. But, in sum, the firm has outstanding debt with coupon payments C and face value P at any point of time. Due to the rollover, the total debt service is the overall coupon rate, C, plus the net partial principal repayment, mP. The debt rollover creates a continuous but small transaction cost at rate k_2 times the retired principal of debt, mP. The debt structure remains the same until the firm either decides to rebalance debt upwards at a higher asset value, ν_U, or file bankruptcy, at value ν_B.

In order to start this debt structure at the time that firm decides to issue debt, the model assumes that the firm issues a lump-sum debt with the same face value, P, and average maturity, $1/m$. According to this assumption, every infinitesimal part of the total debt has a different face value similar to the later debt structure. Thus, the debt structure remains homogeneous over time even at issuance. As a result of initiating the rolling-debt structure, the model is simplified and any complications in formula derivation at the time of issuance are avoided.

At the time of rebalancing and issuance, the cost is the rate, k_1, times the principal of debt issued plus the fixed cost, κ; and it is larger than the rollover cost. These costs keep growing at the same rate, $\phi = \nu_U/\nu_0$, as the firm passes the rebalancing point. At the rebalancing point, the new debt is issued at a new face-value that is proportional to the earlier principal, ϕP and its cost is $\phi(\kappa + k_1 P)$; at the first issuance, the cost is $\kappa + k_1 P$. Technically, higher costs imply less discrete rebalancing as indeed happens in reality. The small fixed issuance cost acts as in the earlier model and creates a convex debt-benefit function.

Optimal decisions about the amount of debt, P,[8] debt issuance, ν_I, and debt rebalancing, ϕ, are taken by managers to maximize the firm's value. The shareholders set the default policy in

[8] I assume the coupon rate is the risk-free rate times the principal P. Otherwise, managers would issue a consol bond to avoid rollover risk, if both coupon and face value were optimized.

such a way that it maximizes the equity value. On the time line of events, after the issuance is decided, capital structure decisions (choosing ϕ and P) are made before determining default policy (choosing ν_B) in line with Goldstein, Ju, and Leland (2001) .

Details about derivation of the formulas are in Appendix .E; only the outcomes are shown here:

$$\nu_B < \nu < \nu_U \begin{cases} D(\nu) = \dfrac{C + mP}{r + m} + A_D \nu^{y_1} + B_D \nu^{-y_2}, \\ \\ TS(\nu) = \dfrac{\tau C}{r} + A_T \nu^{\beta_1} + B_T \nu^{-\beta_2}, \qquad BC(\nu) = A_B \nu^{\beta_1} + B_B \nu^{-\beta_2} \\ \\ RC(\nu) = k_1 P + \dfrac{k_2 m P}{r} + \kappa + A_R \nu^{\beta_1} + B_R \nu^{-\beta_2} \\ \\ DB(\nu) = TS(\nu) - BC(\nu) - RC(\nu), \qquad E(\nu) = \nu + DB(\nu) - D(\nu) \end{cases} \tag{17}$$

$$\nu \leq \nu_I, \qquad W(\nu) = DB(\nu_I)(\frac{\nu}{\nu_I})^{\beta_1}$$

This case also shows that the idea is easily expandable to cases that are more complicated. The condition in Equation 3 repeats itself in this case as well. The relation determines how to find the threshold in different cases. In the cases that are more general, having this relation requires the contingent claim paying \$1 at default to have a power-function form. However, a stronger induction requires analyzing more complicated cases such as credit-downgrade costs (see Elkamhi et al. (2012)) or stochastic volatility (see Lotfaliei (2012)).

The comparative statics of the model are very similar to those in the first case. A similar contour line for volatility threshold emerges here with a steeper slope and a narrower dark area compared to the earlier cases. The line changes position depending on other firm characteristics, such as transaction costs. Figure 11 shows the results of the calibration and can be compared to Figure 3b. In the same graph for having the same volatility threshold at 30% PBC rate, a model without the real option requires a PBC rate of 80% to generate ZL policy. Other resulting graphs are also similar and have been omitted for brevity. In sum, the idea is not model dependent and is expandable to more complicated cases.

Insert Figure 11 about here.

III. Empirical Analysis

The empirical section begins with describing the data. A very preliminary look at the descriptive statics supports the hypotheses. Next, I compare volatility of ZL and levered firms to show a higher volatility for ZL firms as theory predicts. In the main empirical analysis, I test the factors suggested by the theory on the time that ZL firms remain unlevered and verify theoretical predictions. Then, I estimate a PROBIT model and find that all the five hypotheses are approved. I re-interpret the choice model to derive the volatility boundary from the underlying choice factor in PROBIT. Finally, I check the robustness of the model in an out-of-sample test and subsample analysis where I find better results.

A. Data

In this section, I empirically analyze ZL firms and test the theory from the previous section. The analysis mainly focuses on the simple hypotheses generated in Case I and verified in the consecutive cases. I gather all the data for ZL firms between 1996 and 2012. ZL firms exist for a longer period, but only for this period I have access to their options data. I do not lose many ZL firms by doing so when I compare them with the sample of all levered firms. I define market leverage as the debt ratio to the approximate asset value, the book value of debt plus the market value of equity. ZL firms are firms with no debt in the short or long term (Compustat codes DLTTQ and DLCQ). The choice of ZL-firm criteria is similar to Strebulaev and Yang (2013).

I collect all the firm-quarters observations matching this criteria and drop from the sample utility and financial firms, firms with an equity market cap (defined as total shares times share value, CSHOQ*PRCCQ) lower than $9 million, and non-US firms. Then, I combine, using CUSIPs, these firm-quarters with the Optinmetrics data set of 91-days call-option-implied volatilities. I trim the Optionmetrics for volatility below 0 and above 20. So far, data has only ZL firm-quarters. Using GVKEYs of the firms in this joint database, I go back to COMPUSTAT and the Optionmetrics and acquire all firm-quarter observations for the firms in the list. Consequently, the sample has data of firms that remain ZL during the period or switch between levering up and remaining zero levered; each firm-quarter is flagged with a ZL indicator. Later, I compare this sample with another sample that includes only levered firm-quarters. Therefore, there are two samples: a) the sample of all firm-quarters for only the firms that have zero leverage at least in one quarter (1327 global company keys), and b) the sample of all firms with leverage (5683 global company keys). The first sample is the basis for most of the inferences, especially the survival analysis and estimating the binary choice, because they are closer to the boundary of choosing the ZL policy. The second sample serves for out-of-sample tests and anecdotal comparisons.

For ZL firm-quarters in the main sample, the option-implied volatility from the Optionmetrics represents the asset volatility to test H1. There is no volatility delevering. The ratio of other liabilities to the total assets is small and has an average close to ten percent for firm-quarters with no debt. The same average is close to twenty percent when the same firms switch from the ZL policy. I only delever volatility of firm-quarters with debt, using the debt-asset ratio and not the liability-asset ratio. Delevering volatility with all the liabilities reduces it for firms that switch from the ZL policy to issue debt, and strengthen the arguments for ZL firms' higher volatility. For the levered-firm sample, the second dataset, reported asset volatility already takes the leverage into account. Bessler et al. (2013) use realized equity volatility for ZL firms and delever it for levered firms. Strebulaev and Yang (2013) use earnings volatility. Using implied volatility has two advantages. First, it is forward looking and reflects any changes in the market beliefs not reflected in realized or historical volatility. It is also instantaneous and does not need long time-series of data, compared to earnings volatility.[9] I transform volatility in the regressions to be able to estimate the volatility threshold when I re-interpret regression results.

The tangibility of the firm's assets in book terms (PPENTQ/ATQ) is one of the proxies for debt costs to test H2. For empirical inference, I assume firms with higher tangible assets face lower proportional bankruptcy costs. For another bankruptcy-cost proxy, I follow the idea in Sundaresan and Wang (2006) and use firms' growth opportunities indicated by the firm's book-to-market (BM) ratio (ATQ / (Market cap+LTQ)). BM ratio proxies for the fixed cost of default, K. Consider two firms with all equal properties, including the firm's value and PBC rate. One has more growth opportunities than the other does. The firm with more growth opportunities loses more, if default occurs, because it gives up more investment opportunities at default when the entrepreneur leaves the firm. This cost makes managers patient to issue debt and decreases the volatility threshold. Therefore, firms with low asset BM ratios, more growth opportunities, are more patient in issuing debt. The volatility (asset) value above (below) which managers prefer to wait for debt issuance increases (drops) in the BM ratio of the assets, ceteris paribus.

To derive the tax effect for testing H3, I multiply both profitability of the firm and the tax ratio. Highly profitable firms that face high tax ratios are more likely to pay more taxes and become less patient to follow ZL policy. The ratio of the firm's operating income before depreciation (OIBDPQ) to the market value of the firm (Market cap+LTQ) indicates the profitability. The tax ratio is the ratio of total income taxes (TXTQ) to the net income or loss (NIQ). I winsorize the tax ratio in 5% and 95% because the ratio in very rare cases takes extreme values when the net income or loss is close to zero. For H4 where low asset's payout rate means higher value for waiting, I use the equity payout rate, the sum of dividend yield (DVPSPQ/PRCCQ) and share repurchase rate (PRSTKCY/Market cap). I also define a dummy variable for marking the firms that have positive equity payout as dividend payers. Total debt plus the equity market cap ((DLTTQ + DLCQ)+

[9] I also check inferences on volatility without delevering, and the results do not change. Similar results also emerge using realized volatility for the same period.

Market cap) is the total size of the firm that tests H5 with a logarithm transformation. In order to control for the firms seeking financial flexibility, I include the proportion of cash holdings and short-term investments (CHEQ/Market cap) of the firms' assets. High cash holdings imply high propensity for the firms to look for financial flexibility. Table I has the first sample's descriptive statistics.

Table I- Descriptive statistics: merged Compustat and Optionmetrics data, 1996-2012. ZL (Zero-Leverage) is equal to one if long-term (DLTTQ) and short-term (DLCQ) debts are both zero for the firm-quarter and zero otherwise. Volatility is 91-day call-option-implied volatility. For non-ZL firm-quarters, it is delevered. Market cap is shares outstanding times the share price (CSHOQ*PRCCQ). Size is total debt plus the equity market cap ((DLTTQ + DLCQ)+ Market cap). Tangibility is the ratio book tangible assets (PPENTQ) to the total assets (ATQ). B/M ratio is the book assets (ATQ) to market value of assets (book liabilities [LTQ] and equity market cap). Profitability is the ratio of the firm's operating income before depreciation (OIBDPQ) to the market value of the firm (Market cap+LTQ). The tax ratio is the ratio of total income taxes (TXTQ) to the net income or loss (NIQ). The payout rate is the dividend yield (DVPSPQ/PRCCQ) plus the share repurchase rate (PRSTKCY/Market cap). Cash holdings is the ratio of cash and short-term investments to the market cap (CHEQ/Market cap).

ZL	Obs	Variable	Median	Mean	Std. dev.	5th %tile	95th %tile
No	12110	Volatility	48.2%	52.4%	22.7%	24.2%	93.7%
		Tangibility	12.0%	18.5%	18.4%	2.0%	59.5%
		B/M ratio	0.49	0.53	0.29	0.14	1.05
		Profitability	1.4%	1.1%	2.6%	-3.0%	4.0%
		Tax rate	42.9%	34.8%	31.2%	-20.8%	86.7%
		Payout rate	0.0%	5.1%	17.3%	0.0%	26.4%
		Size	848	3,291	14,173	131	10,480
		Cash	13%	19%	21%	1%	56%
Yes	12217	Volatility	54.9%	59.2%	23.5%	29.8%	102.6%
		Tangibility	8.9%	14.4%	15.1%	1.2%	47.1%
		B/M ratio	0.40	0.46	0.30	0.11	1.01
		Profitability	1.1%	0.7%	2.7%	-3.6%	3.7%
		Tax rate	40.0%	32.9%	30.8%	-19.9%	80.3%
		Payout rate	0.0%	5.1%	15.6%	0.0%	25.8%
		Size	541	2,996	19,860	95	7,848
		Cash	16%	21%	19%	3%	59%

Insert Table I about here.

A glimpse at the median and mean of variables to compare ZL and non-ZL states signals results that model predicts. The ZL firm-quarters have higher volatility, higher bankruptcy cost proxies (low tangibility and BM ratio), low tax ratio, and are of smaller size. Compared to the all-levered sample, the balanced number of firm-quarters in each category provides better conditions to derive the boundary separating ZL and non-ZL states. It is because their passage reveals where the boundary is. Hence, the statistical analysis focuses on ZL firms to estimate the model while it also controls the fixed effect of firms; all-time levered firms never hit the boundary and only provide limited information about it. In the next sub-section, the analysis answers the question: "What changes in the firm's characteristics determine the time spent as ZL firm and trigger hitting the boundary and issuing debt?"

B. Results

First, I compare the volatility of ZL firms with the larger sample of levered firms to show that ZL firm-quarters have higher asset volatility. However, this is only a preliminary analysis. The levered firm sample has equity-implied asset volatility, and the ZL sample has option-implied asset volatility. Equity on a levered firm's assets is similar to a call option on a ZL firm's equity. They can be compared because both show volatility for the assets. Their average volatility is two times higher than the average for levered firm-quarters in the same period. In addition, only 40% of ZL firm-quarters have volatility lower than 50%, while 80% of levered firm-quarters fall below this value (see Figure 12).

Next, I sort ZL and levered firm-quarters into deciles based on their size and find higher volatility for ZL firms. There is a negative correlation between volatility and size; large firms seem to have lower volatility with respect to small firms. The endogeneity in size-volatility relationship may imply that the difference in ZL and levered firms' volatility is created by their size difference. To address this concern, I control for firms' size with size deciles to compare asset volatility in both groups. For deciles, Figure 13 compares both averages of volatility and size. For ZL firm-quarters, average volatility is high and average size moves slightly to left and gets smaller as the size rank increases. Analogous to what happens in the model, the main result is that the average volatility of ZL firms is clearly higher than that of their levered counterpart.

Insert Figure 12 about here.

Insert Figure 13 about here.

Now, the main statistical analysis begins. First I test earlier hypotheses on the time that ZL firms remain debt-free and, then, I estimate the binary choice model and the volatility threshold. For each firm in the ZL-firm sample, I derive the number of quarters that a firm remains debt-free prior to having debt. In the survival analysis[10] terms, I consider issuing debt as a failure. If a firm switches between ZL and non-ZL states multiple times, I consider each case a data point. The average quarters remaining ZL is 7.3 and there are 1655 observations. It shows that only a small number of firms switch between ZL and non-ZL states given 1327 firms in the sample. Although

[10] I use LIFEREG procedure in SAS to estimate the parameters

the theory is developed for only issuing once, I assume that similar intuition and mechanism apply for moving back and forth between ZL and non-ZL states. I do a subsample analysis only for the first-time that a firm switches from ZL to non-ZL states and similar results emerge (it can be provided upon request). I pick the firm characteristics at the first quarter that the firm begins to follow ZL policy as independent variables. To control for the time effect in the analysis, I also add dummies for the years that the firm is in ZL state. I run a survival analysis with exponential disturbance in form of:

$$\begin{aligned} \text{ZL duration} \propto\ & a_0 + a_1 \log(\text{volatility}) + a_{2a}\text{Tangibility} + a_{2b}\text{BM ratio} \\ & + b_1\text{Profitability} + b_2\text{Tax Ratio} + a_3\text{Profitability} \times \text{Tax Ratio} \\ & + a_{4a}\text{Div. dummy} + a_{4b}\text{Payout Rate} + a_5 \log(\text{size}) + b_3 \text{ cash} \end{aligned} \tag{18}$$

Table II- Survival analysis: I estimate ZL duration $\propto a_0 + a_1\log(\text{volatility}) + a_{2a}\text{Tangibility} + a_{2b}\text{BM ratio} + b_1\text{Profitability} + b_2\text{Tax Ratio} + a_3\text{Profitability} \times \text{Tax Ratio} + a_{4a}\text{Div. dummy} + a_{4b}\text{Payout Rate} + a_5\log(\text{size}) + b_3$ cash. a_1 is positive and significant as in H1, a_3 is negative and significant as in H3, and a_5 is negative and significant as in H5. a_{2a} is positive and significant as in H2 in the last regression only. As in H2 and H4, a_{2b}, and a_{4b} have the right sign but are not significant seemingly due to low power. a_{4a} is not significant. The p-values test the null hypothesis that the coefficient is zero.

Parameter	Estimate	p-value	Estimate	p-value	Estimate	p-value
Intercept	1.38	0.0%	1.3763	0.0%	1.20	0.0%
log(Volatility)	0.24	5.7%	0.2437	4.7%	0.30	0.9%
Tangibility	-0.34	13.4%	-0.3375	13.5%	-0.48	2.5%
B/M ratio	-0.26	14.0%	-0.2623	13.1%	-	-
Profitability	2.99	5.2%	2.9766	5.2%	-	-
Tax	-0.01	91.9%	-	-	-	-
Profit×Tax	-7.81	11.6%	-8.02	7.9%	-	-
Div. Payer dum.	0.00	97.4%	-	-	-	-
Payout rate	-0.41	17.9%	-0.41	14.2%	-	-
log(Size)	-0.08	1.2%	-0.08	1.0%	-0.07	3.8%
Cash	1.32	0.0%	1.32	0.0%	0.98	0.1%
Annual dummies	yes		yes		yes	

Insert Table II about here.

There is evidence to support at least four hypotheses with 10% confidence: High volatility (H1), low tax payments (H3), debt cost effects (H4), and small size (H5) increase the time spent as ZL firm. For the payout (H2), the variables at least have the right sign as model predicts. However, they are not significant and it can be due to low power of the test. Firms with high cash holdings and profitability spend more time with no debt which seems coherent with the financial flexibility explanation.

This is a very simple approach and some of the information is lost between the first quarter and the quarter that the firm takes leverage. The simplicity has limitations of low power and some lost information. In order to make up for the loss, I take the average of firm characteristics for all the ZL quarters rather than the first ZL quarter and find similar results.

For further investigation, I test the hypotheses in a choice model that I estimate in PROBIT[11]. The regression has the form of:

$$\begin{aligned}\Pr(\text{ZL}) \propto\ & a_0 + a_1\log(\text{volatility}) + a_{2a}\text{Tangibility} + a_{2b}\text{BM ratio} \\ & + b_1\text{Profitability} + b_2\text{Tax Ratio} + a_3\text{Profitability} \times \text{Tax Ratio} \\ & + a_{4a}\text{Div. dummy} + a_{4b}\text{Payout Rate} + a_5\log(\text{size}) + b_3\ \text{cash}\end{aligned} \tag{19}$$

The choice model estimates the propensity to have no debt and the table below shows the results of the estimation:

Insert Table III about here.

For hypothesis testing, Table III shows that all hypotheses are not rejected. Acceptable coefficients are significant and have the right sign. Similar to theoretical model's predictions and the real-option intuition, higher volatility, higher debt costs, lower tax payments, lower payout rate and smaller size increase the likelihood of following a ZL policy. Volatility and size solely contribute to half of the pseudo R-squared of the model.

In the regression with no size variable, it seems that profitability absorbs its effect. It has implications for the financial policy of profitable firms. Without controlling for size, profitable firms are more likely to issue debt because they are larger and the likelihood of ZL policy decreases in size. If the size effect for profitable firms are controlled, then there are two separate channels that affect their debt issuance decision. One is the pecking order channel where ZL firms prefer to use their internal funds and do not issue debt; it makes the profitability sign positive in the regression. Another channel is the tax channel, where the firm is less likely to follow ZL policy, if it pays high taxes. The interaction between profitability and tax ratio seems missing in earlier empirical analysis. This contributes to the debate over the role of profitability in the leverage decisions. For the levered firms, Strebulaev (2007) provides a brief review on the profit-leverage relationship and explains a possible regression's results with simulations. His explanation relies on the unchanged debt levels in between of debt rebalancing points for the profitable firms. If the equity value for a levered profitable firm increases, constant debt level implies a decreasing leverage and negative profitability-leverage relation. However, the explanation does not apply when the firm already has zero leverage. The pecking order and tax channels that are mentioned above can explain the

[11] I use QLIM procedure in SAS to estimate the parameters

Table III- PROBIT regression results : I estimate Pr(ZL) $\propto$ a_0 + $a_1$log(volatility) + a_{2a}Tangibility + a_{2b}BM ratio + b_1Profitability + b_2Tax Ratio + a_3Profitability $\times$ Tax Ratio + a_{4a}Div. dummy + a_{4b}Payout Rate + $a_5$log(size) + b_3 cash. All the hypotheses are supported by the results: High volatility (a_1), high debt costs(a_{2a}, a_{2b}), low tax payments (a_3), low payout rate (a_{4b}) and small size (a_5) increase the propensity to remain ZL. Only a_{4a} that is related to H2 has a different sign. The p-values test the null hypothesis that the coefficient is zero.

Parameter	Estimated Coefficients for each statistical model									
Intercept	1.51	1.96	1.65	2.10	0.23	0.43	1.50	1.92	1.39	1.85
p-value	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
log volatility	0.34	0.58	-	-	-	-	0.30	0.50	0.22	0.40
p-value	0.0%	0.0%	-	-	-	-	0.0%	0.0%	0.0%	0.0%
Tangibility	-0.52	-0.43	-0.57	-0.53	-0.55	-0.53	-0.51	-0.42	-0.49	-0.40
p-value	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
B/M ratio	-1.00	-1.04	-1.06	-1.13	-0.79	-0.83	-0.96	-0.98	-0.87	-0.90
p-value	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%
Profitability	1.56	1.80	0.79	0.72	-1.69	-1.98	-	-	-	-
p-value	0.0%	0.0%	0.0%	9.4%	0.0%	0.0%	-	-	-	-
Tax rate	0.26	0.39	0.21	0.29	0.09	0.13	-	-	-	-
p-value	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	-	-	-	-
Profit×Tax	-4.72	-6.09	-4.48	-5.59	-0.06	-0.49	-	-	-	-
p-value	0.0%	0.0%	0.0%	0.0%	95.8%	68.4%	-	-	-	-
Div. Dum.	0.30	0.29	0.25	0.23	0.12	0.10	0.31	0.31	-	-
p-value	0.0%	0.0%	4.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-	-
Payout rate	-0.10	-0.11	-0.09	-0.11	-0.03	-0.04	-0.10	-0.11	-	-
p-value	7.7%	4.0%	0.0%	5.0%	61.2%	48.0%	7.1%	3.7%	-	-
Log(Size)	-0.16	-0.15	-0.20	-0.22	-	-	-0.15	-0.14	-0.13	-0.12
p-value	0.0%	0.0%	0.0%	0.0%	-	-	0.0%	0.0%	0.0%	0.0%
Cash	0.84	0.79	0.83	0.80	0.92	0.91	0.74	0.66	0.69	0.62
p-value	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Year dummy	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Pseudo R2	10.80%	13.19%	9.84%	11.15%	5.48%	6.25%	10.42%	12.42%	8.98%	11.04%

relationship between profitability and ZL policy.

In the PROBIT regression, only the dividend payment dummy does not have the right sign and it seems coherent with ownership concentration of ZL firms as proposed by Strebulaev and Yang (2013). If the firm's dividends are the most important source of income for entrepreneurs, they require some payments for their consumption regardless of the financial policy of the firm. Tax ratio also has a positive sign. Tax ratio for the firms with net loss creates a tax shield for the future, even if it is positive. This can be the reason for its positive sign. As soon as the tax ratio is multiplied by the profitability, both change signs that supports H3. Results remain the same among different statistical models. Results do not change when annual dummies to control for time effect are included or when the same regression is run cross-sectionally on data every year. The results are also robust to the error distribution in the estimation method, and Logistic regression inferences are similar. They are not reported here for brevity.

In order to re-interpret the choice results, I use another representation of the PROBIT model that is equivalent to the previous equation:

$$\mathrm{ZL} = \begin{cases} & a_0 + a_1 \log(\text{volatility}) + a_{2a}\text{Tangibility} + a_{2b}\text{BM ratio} \\ 1 \quad \text{if} & +b_1\text{Profitability} + b_2\text{Tax Ratio} + a_3\text{Profitability} \times \text{Tax Ratio} \\ & +a_{4a}\text{Div. dummy} + a_{4b}\text{Payout Rate} + a_5\log(\text{size}) + b_3 \text{ cash} > 0, \\ 0 \quad \text{if} & \mathit{Otherwise} \end{cases} \tag{20}$$

The equation here is very similar to Equation 13. This equation matches the standard PROBIT setup where the underlying choice factor is compared with zero. I use the similarity to derive the volatility boundary and re-interpret the results that makes sense according to the theoretical model. In econometric terms, volatility is the latent variable revealing the choice of the firm. I transform the estimated model to derive the estimated boundary:

$$ZL = 1 \quad if \quad \text{volatility} > exp([a_0 + a_{2a}\text{Tangibility} + \ldots + b_3 \text{ cash}]/a_1) = threshold \tag{21}$$

The new formula is close to the graphs in the theoretical section where I show the volatility threshold as function of other variables. For example, H2 states that lower payout increase the ZL likelihood. Equivalent to H2, I expect a_{4b}/a_1 to be negative and the volatility (asset) threshold decrease (increase) for the firms with lower payout. The results are valid based on the new re-interpretation.

Moreover, the volatility boundary is easily calculable from the exponential transformation. The median estimated volatility boundary for ZL firm-quarters is 42% (below their median volatility of 55%), while the same median is 58% for firm-quarters with leverage (above the median volatility of 48%). It is equivalent to ZL firm-quarters located at the right of the threshold in Figure 3a and non-ZL firm-quarters are located at the left. Thus, ZL firms have higher volatility compared to the estimated boundary (55% $\geq$ 42%), but the same firms have lower volatility with respect to their boundary when they switch to have debt (48% $\leq$ 58%). In addition, this result means when firms decide to take on debt, they have on average a higher boundary, compared to the boundary of ZL firms (58% $\geq$ 42%), due to changes in determinant variables, such as size and debt costs.

C. Robustness check

C.1. Out-of-sample test

The out-of-sample (OOS) test checks how the regression analysis extends to other samples cross-sectionally. The test analyzes the overall prediction error of the choice model and the results support the model. Table IV shows the results. To create this table, I apply the model estimated in Table III to the sample provided by Elkamhi et al. (2012). A perfect model predicts that all the levered firm-quarters will choose no ZL policy and will show no error. The error rate in the regression model is the ratio of the firm-quarters predicted to have no leverage to all the levered firm-quarters. OOS has a parsimonious prior that considers all the firm-quarters are zero levered. It is biased because the number of ZL firm-quarters in the first sample is larger than non-ZL firm-quarters. The marginal contribution of asset volatility to ZL prediction is about 8%, which is close to 7,200 firm-quarters.

Table IV- Out-of-sample test errors : I try the regression model in the first column of Table III over a sample of all levered firms. Errors are the percentage of the firms predicted to have zero leverage by the statistical model. None of the models have yearly dummies. The first model on the left has all the variables. Second model does not have volatility in addition. Third model does not have volatility, tangibility, BM ratio, profitability, tax ratio, profitability$\times$tax ratio. The last three columns also have an intercept.

Out-of-sample test	Obs.	all variables	No volatility	No volatility, debt costs & tax	Only cash & size	Only size	No variables
error	90319	16.86%	24.97%	62.60%	61.02%	62.84%	100.00%

Insert Table IV about here.

C.2. Zero-interest proxy and the subsample of firms with payout

Table V shows all the robust results similar to the earlier PROBIT with slightly higher R-squared. I check the robustness of the results for a different ZL proxy and in a subsample. Earlier, I used the definition proposed in Strebulaev and Yang (2013) for ZL firm-quarters. An alternative proxy is ZL firm-quarters that also pay no interest on their balance sheet (ZI). ZI firm-quarters are within current ZL firm-quarters. Using the new proxy not only does not change the inferences but also makes them more stronger. The profitability sign flips contrary to the earlier results and is important in profitability-leverage relationship. This result implies that the firms with no tax shield from interest payments are more sensitive to an increase in their income because they are more likely to pay higher taxes. Therefore, once the size effect is controlled, the tax trade-off channel seems more important to them when it is compared to the pecking order channel that are explained earlier.

The inferences are robust in the subsamples as well. An important subsample is the sample of ZL firms that additionally have positive payout, either in the form of dividends or share repurchases. These firms are more likely to be financially flexible and show the most puzzling behavior among the ZL firms. I check the same hypotheses that model predicts on these firms, and robust results emerge.

Insert Table V about here.

IV. Conclusion

In this paper, I show that the real-option value of debt issuance provides an explanation for the zero-leverage puzzle. I calculate the theoretical value in waiting and demonstrate that this is more likely to exceed the positive issuance gain for small, young, and risky firms. Even with a positive net gain, managers intuitively prefer to wait and postpone tax savings in order to avoid exposure to bankruptcy costs as if the real option mechanism acts as an amplifier. However, the value of the firm should include the real-option component. Therefore, I extend the inaction area from real-option literature, e.g Bloom (2009), to the trade-off and capital structure theory.

This study contributes to earlier studies on the ZL phenomenon. Some studies look for the levels of debt-related costs that are making the net benefits negative. However, I show that even if debt issuance is feasible with positive net benefits, some firms prefer to wait. Thus, zero leverage and positive immediate net gains from debt issuance can coexist. For the same reason, dividend payments and zero-leverage policies are not contradictory. In this sense, this article complements the financial flexibility literature.

Empirically, I find support for the theoretical predictions of the model. I find the factors that explain the time to remain ZL according to the theoretical prediction. An estimation of a binary-choice model for firms with zero-leverage shows that most of the factors determined theoretically increase the propensity to stay debt-free: High asset volatility, high debt costs, low tax payments, low payout rate, and small size. The out-of-sample test validates these factors as determinants of

Table V- Regression results on the subsamples of ZL firms Pr(ZL) $\propto a_0 + a_1$log(volatility)+ a_{2a}Tangibility + a_{2b}BM ratio + b_1Profitability + b_2Tax Ratio + a_3Profitability $\times$ Tax Ratio + a_{4a}Div. dummy + a_{4b}Payout Rate + $a_5$log(size) + b_3 cash. All the hypotheses are supported by the results: High volatility (a_1), high debt costs(a_{2a}, a_{2b}), low tax payments (a_3), low payout rate (a_{4b}) and small size (a_5) increase the propensity to remain ZL. Only a_{4a} that is related to H2 has a different sign in the second subsample. a_{4b} is not significant in the first subsample. The p-values test the null hypothesis that the coefficient is zero.

Parameter	Estimated Coefficients for each statistical model			
	Firms with payout		Firms with no interest payments	
N obs	10,542		24,327	
Intercept	1.99	2.27	0.77	0.66
p-value	0.0%	0.0%	0.0%	0.0%
log volatility	0.38	0.61	0.11	0.23
p-value	0.0%	0.0%	0.0%	0.0%
Tangibility	-0.37	-0.27	-0.79	-0.73
p-value	0.0%	0.0%	0.0%	0.0%
B/M ratio	-1.24	-1.27	-1.36	-1.40
p-value	0.0%	0.0%	0.0%	0.0%
Profitability	3.00	2.89	-0.91	-0.80
p-value	0.7%	0.4%	4.3%	7.7%
Tax rate	0.16	0.24	0.20	0.27
p-value	0.7%	0.4%	0.0%	0.0%
Profit×Tax	-5.93	-5.97	-6.32	-7.19
p-value	0.7%	0.7%	0.0%	0.0%
Div. Dum.	-	-	0.13	0.12
p-value	-	-	0.0%	0.0%
Payout rate	-0.07	-0.09	-0.12	-0.13
p-value	18.6%	11.1%	5.5%	4.2%
Log(Size)	-0.17	-0.16	-0.15	-0.14
p-value	0.0%	0.0%	0.0%	0.0%
Cash	0.97	0.94	1.13	1.11
p-value	0.0%	0.0%	0.0%	0.0%
Year dummy	No	Yes	Yes	No
Pseudo R2	12.38%	14.22%	12.34%	13.21%

the no-leverage policy.

An interesting extension of this paper would be to consider volatility risk. If the amount of priced volatility risk varies across firms for given levels of volatility, then cross-sectional variation in debt issuance policies would follow. Another extension of the paper would be a mix of project inception and financing with debt: Financing choices for large versus small projects and high-risk versus low-risk projects.

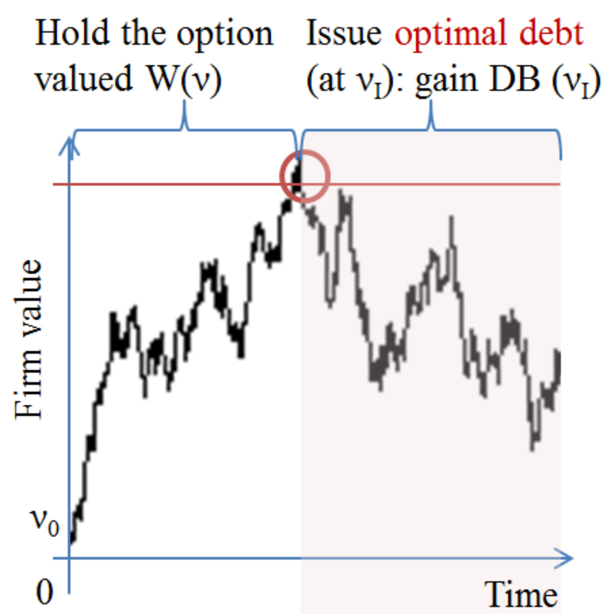


Figure 1. The model

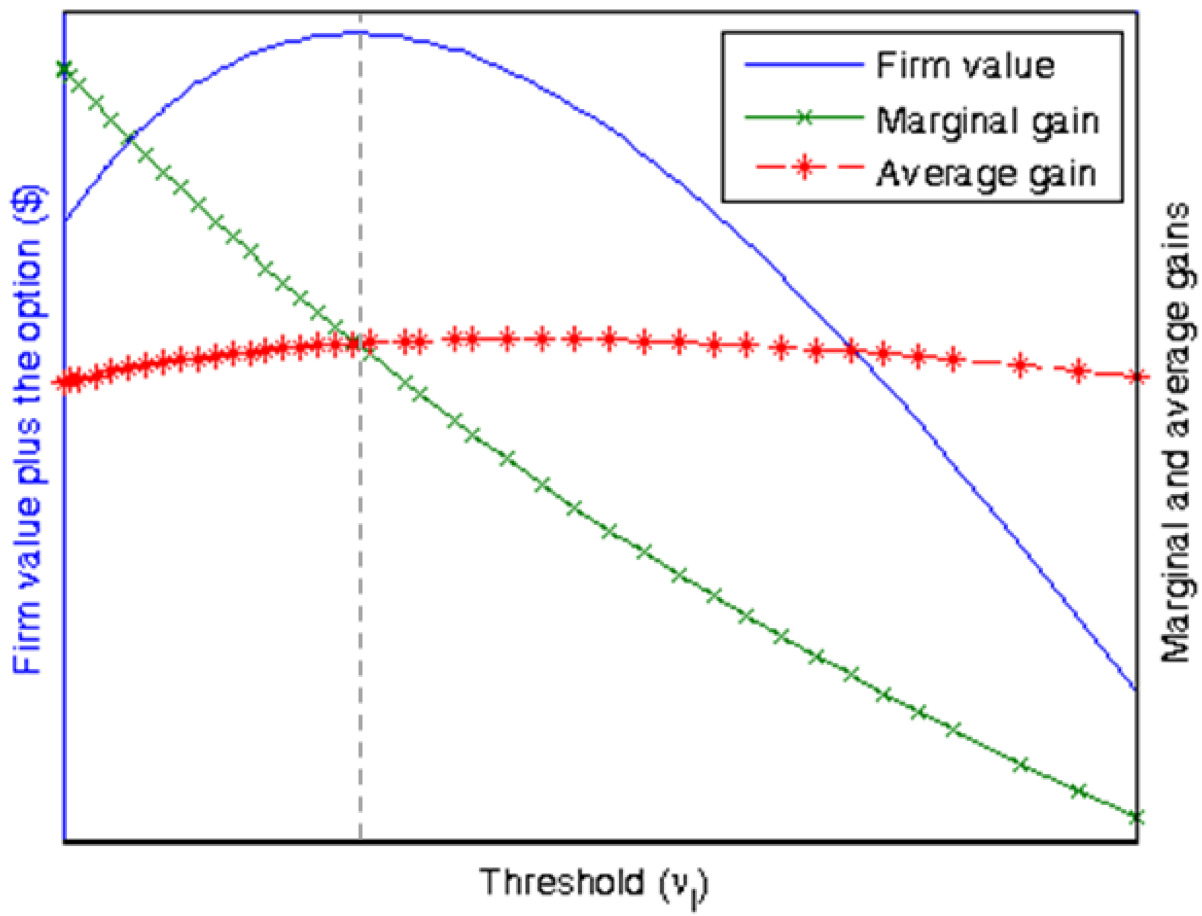
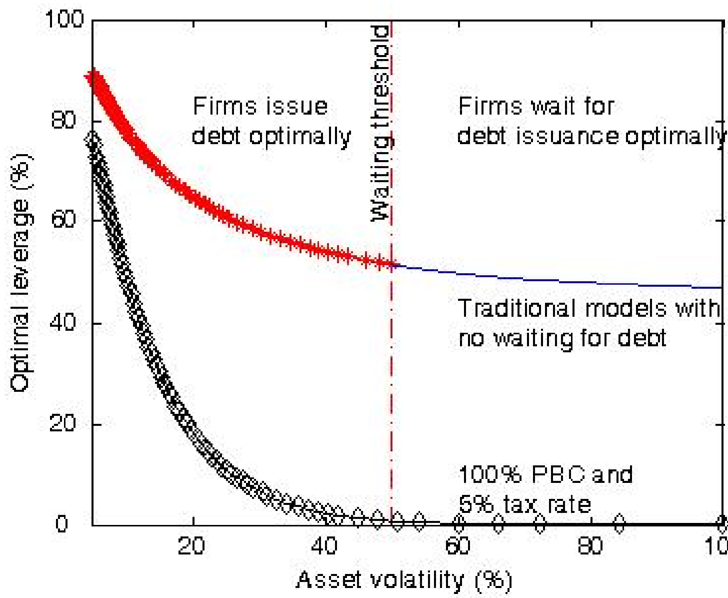
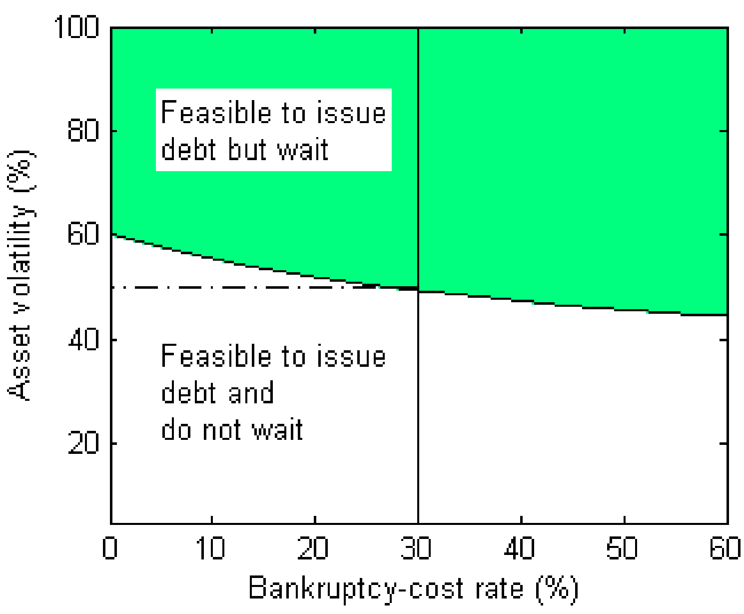


Figure 2. The optimal threshold and its derivation
The X-axis has different values for the threshold, and the Y-axis has the total value at each threshold point. The total value is the unlevered value, ν, plus the option, $W(\nu)$. The optimal threshold is the point that maximizes the total firm value, or where marginal and average debt gain meet. As soon as the firm's value increases to this point, the wait is over and the firm issues debt.



(a) The cross section of volatility for firms with 30% Proportional Bankruptcy cost (PBC) rate.
The X-axis shows the firm's asset volatility. The Y-axis shows the optimal leverage. Proportional Bankruptcy-cost (PBC) rate is the portion of the firm's assets lost in default. Firms on the left of the threshold issue an optimal amount of debt. Firms at the right wait even if the model with no real-option consideration prescribes debt issuance. The plain line shows the leverage without the real option assumption. All other parameters are as in Figure 3b. The line with diamonds shows the same model that generate ZL policy without the real option.



(b) Comparative statics of the model for volatility and PBC rate
The X-axis shows the PBC rate. The Y-axis shows the firm's asset volatility. Firms in the dark area have more incentive to wait to issue debt, even though issuing debt would have a positive net value. Firms in the white area simply issue debt. Other model parameters are: the risk-free rate is 5%, the asset payout rate is 3%, the tax rate is 25%, the constant default cost is \$2, and the firm's value is \$100. Firms follow the optimal default and leverage. The debt issuance maximizes the net debt benefit.

Figure 3. Some of the main results of the model in Case I

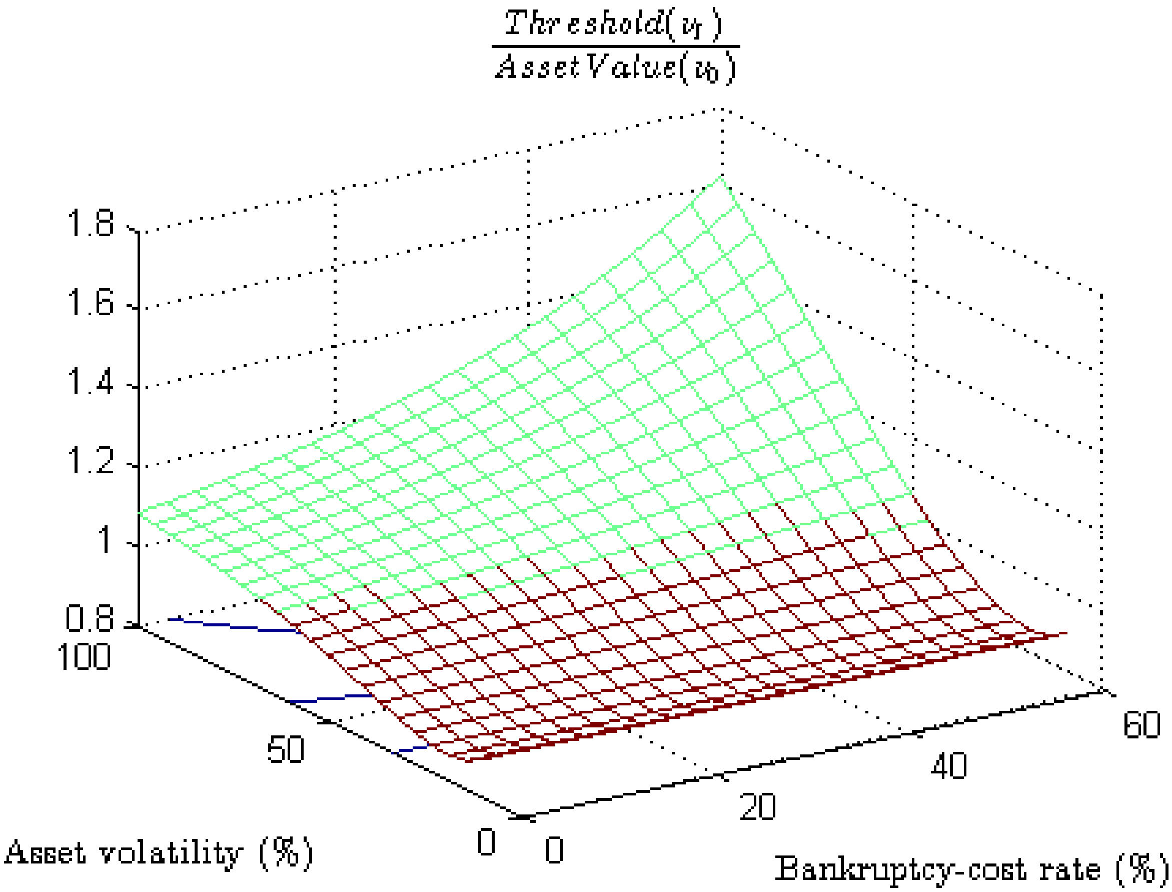


Figure 4. The ratio of the optimal threshold to the current asset value as a function of the asset risk and the PBC rate

The optimal threshold increases with the asset risk and bankruptcy costs. All the values above 1 imply that the firm waits to issue debt, but below 1 the firm issues debt. The risk-free rate (r) is 5%, the payout rate (δ) is 3%, the asset value (ν_0) is \$100, the fixed bankruptcy cost (K) is \$2, and the tax rate (τ) is 25%.

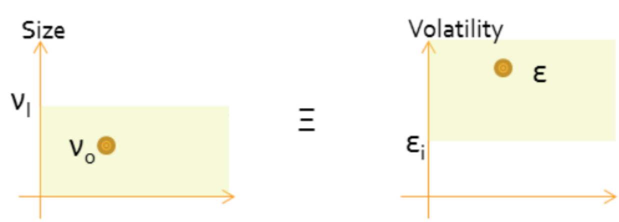


Figure 5. The equivalency of asset (ν_I) and volatility (ε_i) thresholds

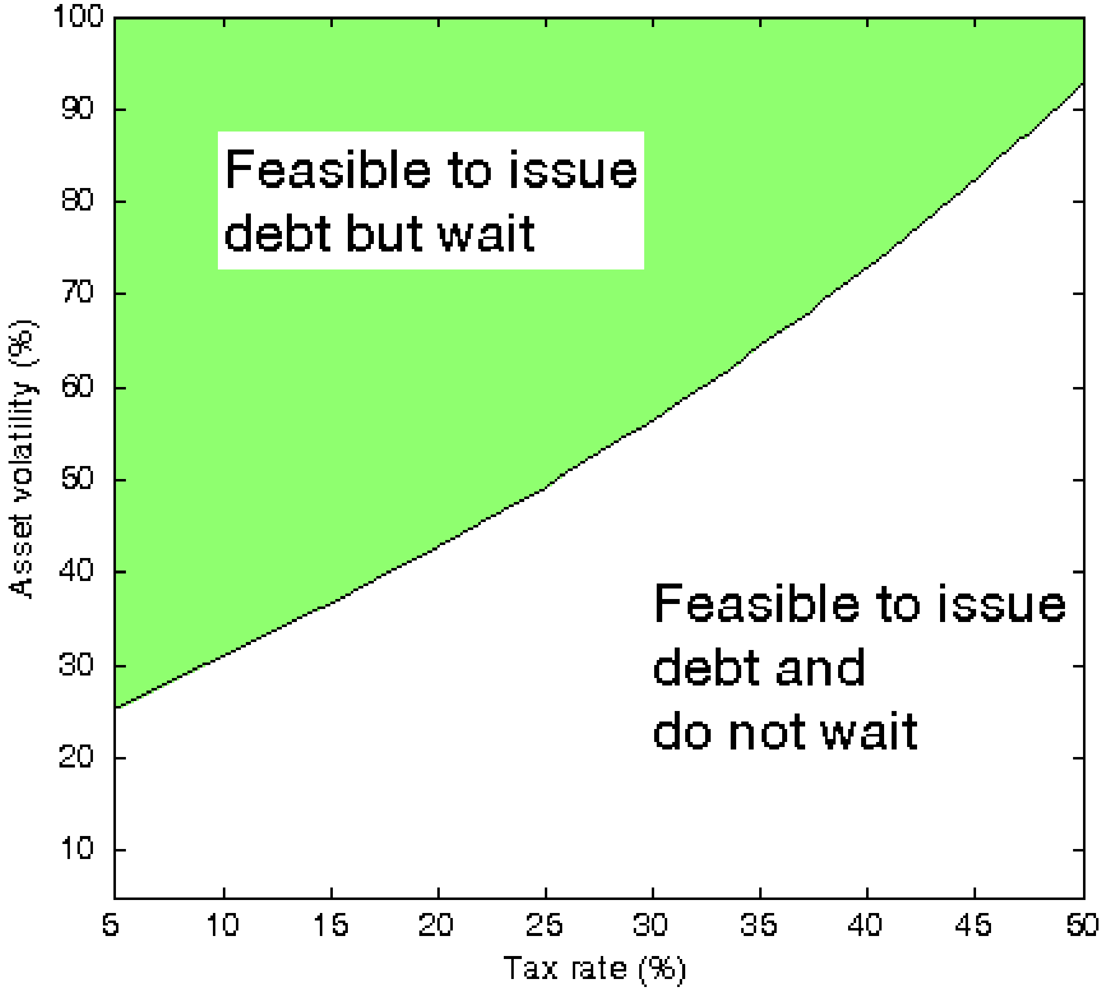


Figure 6. Comparative statics of the model for volatility and tax rate
The X-axis shows the tax rate. The Y-axis shows the firm's asset volatility. Firms in the dark area have more incentive to wait to issue debt, although issuing debt has a positive net value. Firms in the white area simply issue debt. Other model parameters are: the risk-free rate is 5%, the payout rate is 3%, the constant default cost is $2, PBC rate is 15%, and the firm's value is $100. Firms follow the optimal default and leverage.

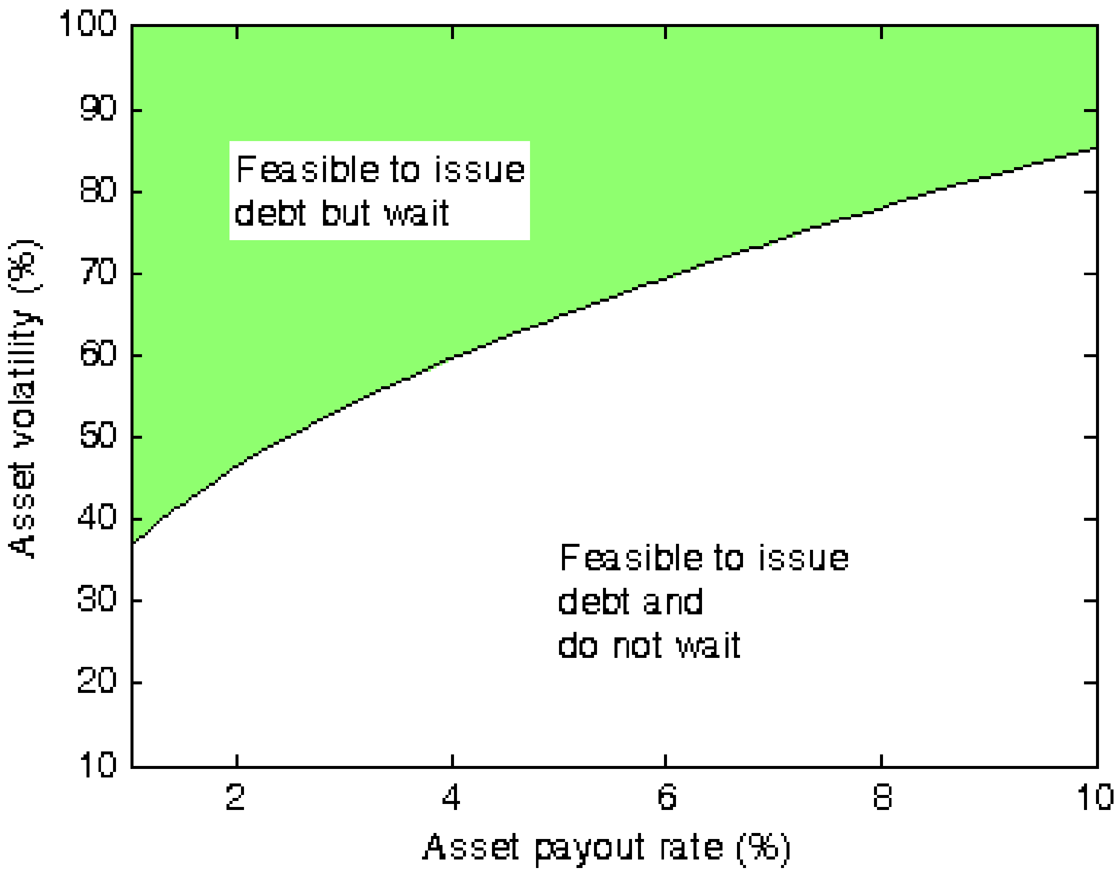


Figure 7. Comparative statics of the model for volatility and asset payout rate
The X-axis shows the payout rate of the asset. The Y-axis shows the firm's asset volatility. Firms in the dark area have more incentive to wait to issue debt, although issuing debt has a positive net value. Firms in the white area simply issue debt. Other model parameters are: the risk-free rate is 5%, the tax rate is 25%, the constant default cost is \$2, PBC rate is 15%, and the firm's value is \$100. Firms follow the optimal default and leverage.

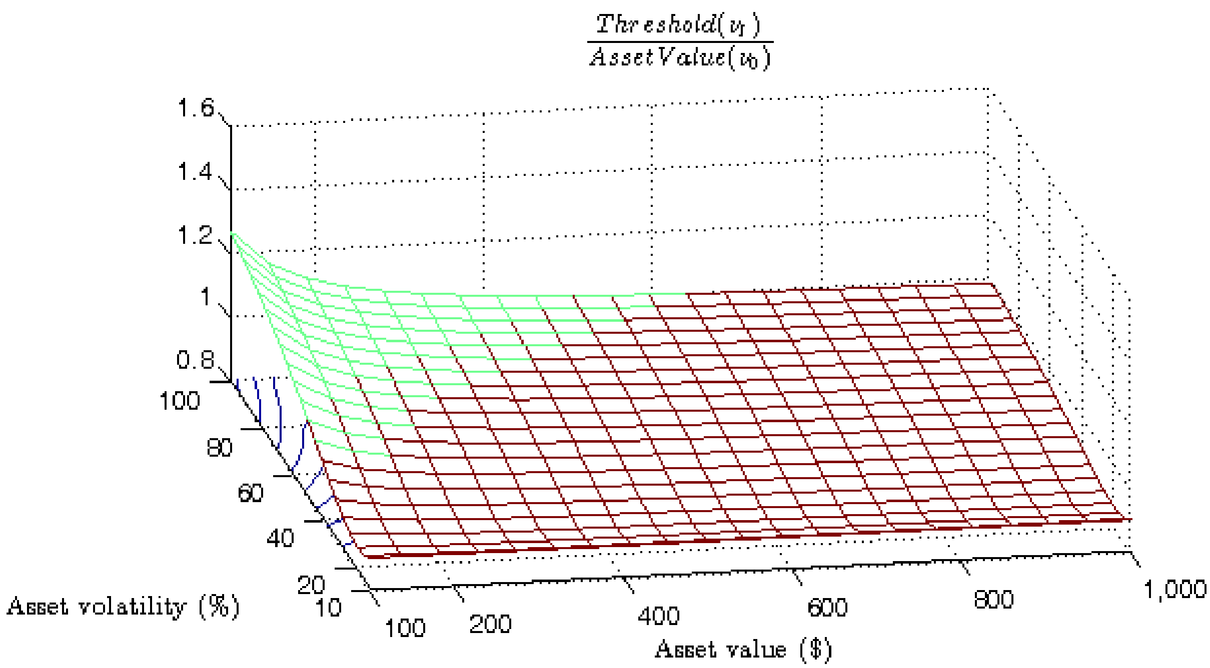


Figure 8. The ratio of the optimal threshold to current asset value as a function of the asset risk and current asset value,ν_0

The optimal threshold increases with the asset risk. All values above 1 imply that the firm waits to issue debt, but below 1 the firm issues debt. The risk-free rate (r) is 5%, the payout rate (δ) is 3%, the fixed bankruptcy cost (K) is \$3, the PBC rate is 15%, and the tax rate (τ) is 25%. Compared to earlier figures, the increase in the fixed cost recompenses slightly the loss in the relative fixed cost (K/ν_0) because of the increasing range of asset value.

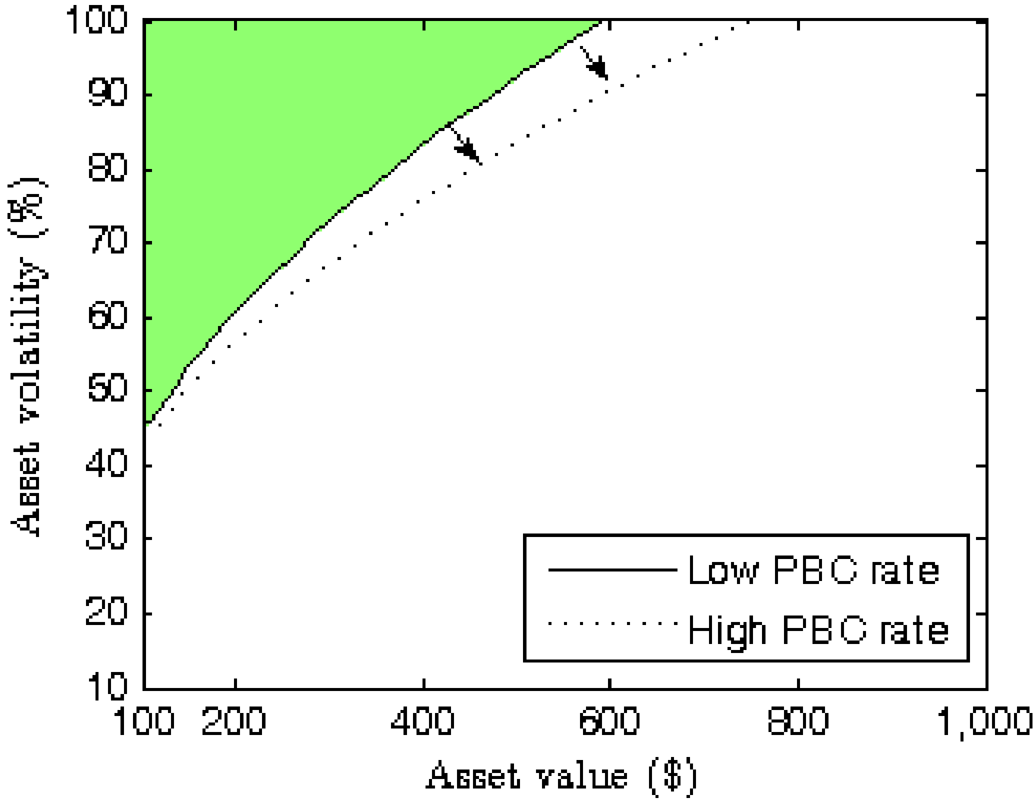


Figure 9. Comparative statics of the model for volatility and unlevered asset value
The X-axis shows the current value of the firm's asset, ν_0. The Y-axis shows the firm's asset volatility. Firms residing in the dark area have more incentive to wait to issue debt, although issuing debt has a positive net worth. Firms in the white area prefer to issue debt and not to wait. Other model parameters are the risk-free rate is 5%, the asset payout rate is 3%, the tax rate is 25%, the constant default cost is $3, and the PBC rate is 15% (low) or 25% (high). Firms follow the optimal default, leverage, and issuance.

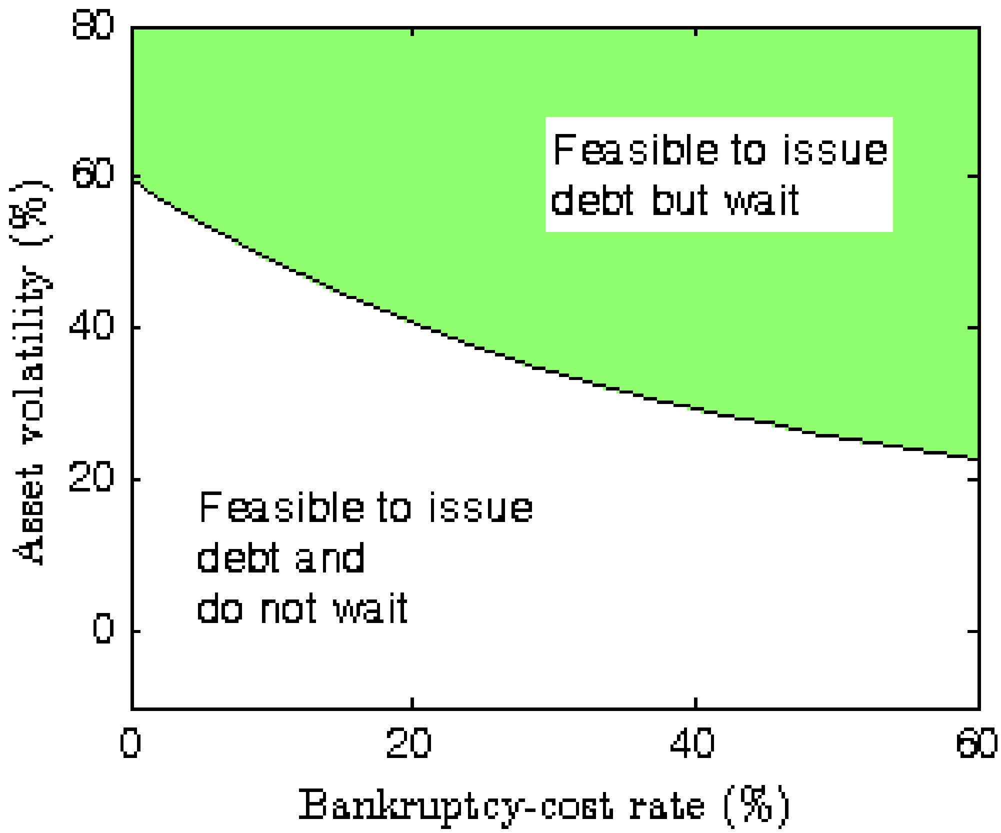


Figure 10. Comparative statics of the model for volatility and Proportional Bankruptcy-cost rate (PBC rate) in Case II
The X-axis shows the PBC rate of the firm's asset given default. The Y-axis shows the firm's asset volatility. Firms in the dark area have more incentive to wait to issue debt, although issuing debt has a positive net value. Firms in the white area simply issue debt. Other model parameters are: the risk-free rate is 5%, the asset payout rate is 3%, the tax rate is 25%, the constant issuing cost, κ, is \$1 and the firm's value is \$100.

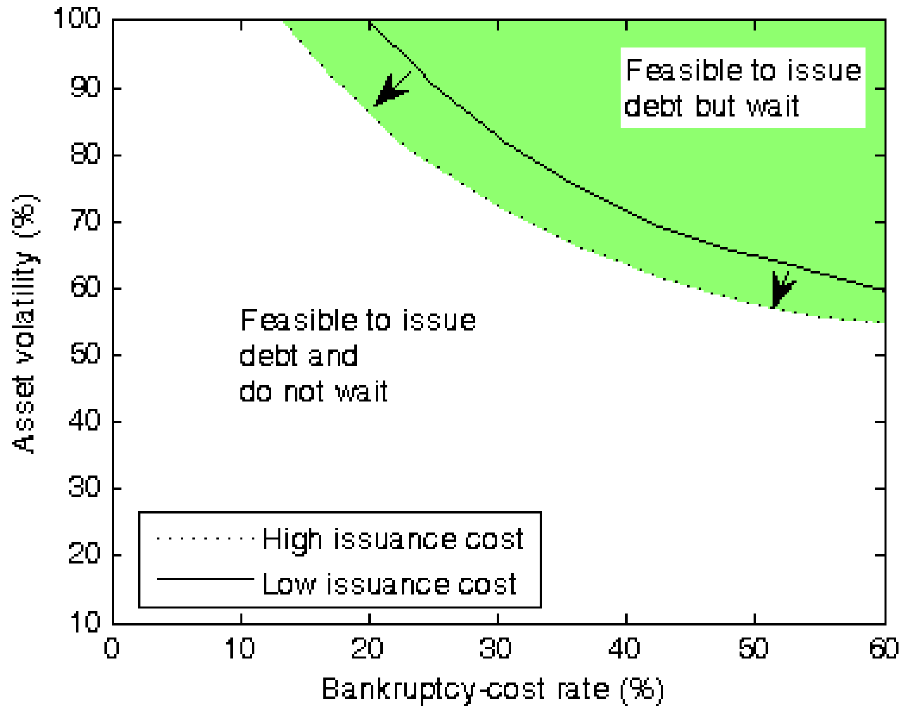


Figure 11. Comparative statics of the model, with rebalancing option, for volatility and PBC rate

The X-axis shows the PBC rate of the firm's asset given default. The Y-axis shows the firm's asset volatility. Firms in the dark area have more incentive to wait to issue debt, although issuing debt has a positive net value. Firms in the white area prefer to issue debt and not to wait. Other model parameters are the risk-free rate is 5%, the asset payout rate is 3%, the tax rate is 25%, the constant issuance cost is 2%, the variable issuance cost is 0.9%, the debt rollover cost is 0.5% and the firm value is $100.

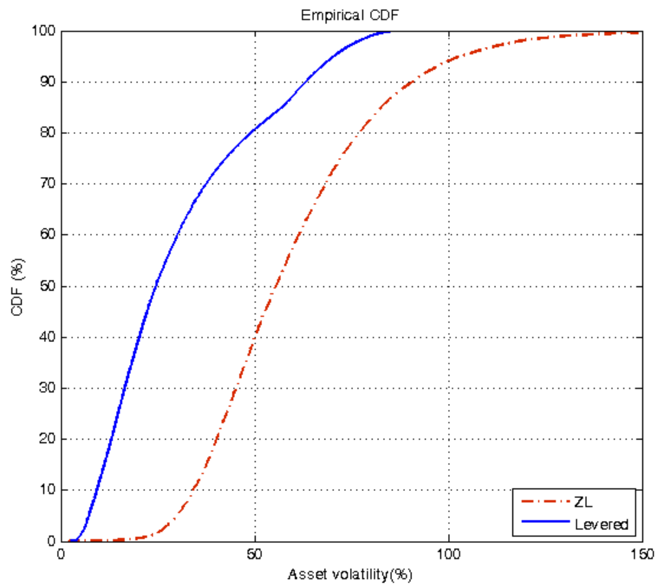


Figure 12. Empirical cumulative probability distribution comparison: Asset volatility of ZL and levered firms

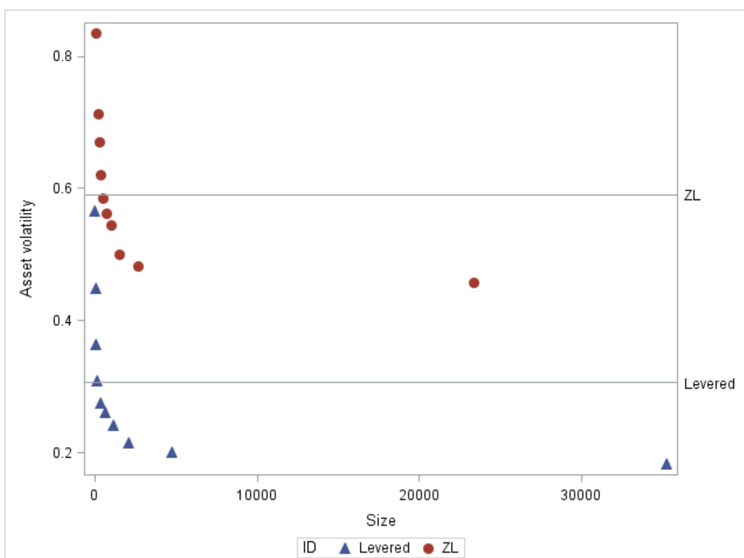


Figure 13. Average asset volatility comparison for size sorted firm-quarters: ZL versus levered

The X-axis indicates the average asset value. The Y-axis indicates the average volatility. I sort all the ZL and levered firm-quarters on the basis of their size and divide them into ten groups. Each point represents the average for each group. Circles represent levered firm-quarters, and "+" represents ZL firm-quarters. For example, the highest decile of ZL firm-quarters has a lower average size and a higher average volatility compared to its levered counterpart at the far right.

Appendices

Appendix A. Boundary conditions

The boundary condition for debt is:

$$\begin{aligned} D(\nu_B) &= ((1-\alpha)\nu_B - K)^+ \\ D(\nu \to \infty) &= \frac{C}{r} \end{aligned} \tag{22}$$

The boundary condition for tax savings is:

$$\begin{aligned} TS(\nu_B) &= 0 \\ TS(\nu \to \infty) &= \frac{\tau C}{r} \end{aligned} \tag{23}$$

The boundary condition for the bankruptcy cost is:

$$\begin{aligned} BC(\nu_B) &= \alpha\nu_B + K \\ BC(\nu \to \infty) &= 0 \end{aligned} \tag{24}$$

The boundary condition for debt benefits is:

$$\begin{aligned} &W(\nu_I) = DB(\nu_I) = TS(\nu_I) - BC(\nu_I) \quad W(0) = DB(0) = 0 \\ &DB(\nu) = TS(\nu) - BC(\nu) \quad \nu_I \leq \nu \end{aligned} \tag{25}$$

Appendix B. Optimal asset threshold as a function of coupon rate, and optimal coupon derivation

First, for any given perpetual coupon rate, I analyze the optimal asset threshold and waiting policy. Then, I check how marginal savings and costs determine the optimal coupon policy. Applying the optimal coupon to the previous analysis reveals the final decisions about the optimal issuance threshold.

Figure 14 shows the total firm value for any threshold when the coupon rate is constant. Each line denotes different firm characteristics. An optimal coupon is endogenous to parameters such as asset volatility or bankruptcy costs, but I exogenously keep the coupon rate constant here. The optimal threshold in the graph is the threshold value pointing to the largest firm value. Any elevation in parameters that increase the net benefits, such as tax rates, makes the managers impatient for issuing debt and decreases the threshold. On the other hand, an elevation in fixed default cost, the PBC rate, and any other values that increase the exposure to default costs encourages managers to postpone issuing debt.

Insert Figure 14 about here.

Among all the parameters, there is special interest in the volatility. Figure 15 gives the graph. Given a fixed coupon rate, the asset volatility changes the issuance threshold in an interesting way. The waiting increases and then suddenly begins to decline in extreme volatility values. The increase in volatility in turn increases the value of waiting while it also increases the value of the default option. It is worth mentioning that when the stockholders issue debt they lose the option to issue, but they gain the real option to default, which also has value. For a constant coupon, at low volatility levels the debt-issuance option is worth more than the default option. However, for very high asset volatility, the dynamic reverses. This generates a humped curve across the volatility stream.

This dynamic is only valid for the fixed-coupon cases. When the coupon is set endogenously, the trend tends to increase as volatility increases. The optimal coupon increases in volatility because debtholders demand higher coupons for riskier firms. Thus, with the optimal coupon, the optimal threshold moves along a diagonal plane that covers the increasing trend in both coupon and asset's volatility.[12]

Insert Figure 15 about here.

Now, I find the optimal coupon and show that the optimal coupon increases with the asset volatility. Intuitively, as the asset risk increases, debtholders demand a higher coupon. I look at the marginal savings and costs of the coupon for the firm. The marginal bankruptcy cost increases with the coupon because a higher coupon rate makes the firm more likely to default. The same reason decreases the marginal tax savings; as in default the tax savings are lost. An increase in the volatility flattens both tax savings and bankruptcy cost curves (see Figure 16) because a higher volatility means a higher chance to default for all the coupons. The elasticity of the tax savings is higher than the default costs' elasticity and, when both shift downwards, the optimal coupon shifts to the right. A similar analysis applies to the optimal leverage (see Leland (1994) for results). Only, the optimal leverage decreases with increasing volatility.

Insert Figure 16 about here.

[12] Consider a plane perpendicular to the X-Y plane (the coupon-volatility plane). Its intersection with X-Y plane creates a line with a positive slope and a negative intercept in X-Y plane. All the points on this line denote to endogenous coupon rates as a function of exogenous volatility. This plane also has an intersection with the 3D graph. This intersection creates a curve containing all optimal thresholds for the optimal coupons.

Appendix C. Proof for Proposition 1

Assumption 1: *The debt-benefit function (DB) is continuous and increasing in the unlevered firm value:*

$$\frac{\partial DB(\nu)}{\partial \nu} \geq 0 \tag{26}$$

This assumption means that, everything else being equal, the debt benefit increases if the firm's unlevered value increases. This is very intuitive since managers destroy the firm's value to gain on debt, if it is decreasing at any point. Another explanation to support this assumption is that the chance to default is decreasing in the firm's value. Thus, tax savings rise, default costs fall, and the debt benefits increase.

Assumption 2: *There exists a unique asset volatility level beyond which it is not feasible to issue debt and the debt benefit is strictly decreasing at this point:*

$$\exists! \varepsilon_{max} : DB(\varepsilon_{max}, \nu_0) = 0, \quad \frac{\partial DB(\varepsilon, \nu_0)}{\partial \varepsilon}|_{\varepsilon=\varepsilon_{max}} < 0, \tag{27}$$

Based on Assumption 2, there is a limit for the debt benefits of the firm. For volatility above this value, there is no positive value for issuing debt. For example, the fixed bankruptcy cost in the model results in such a condition. Without this assumption, firms benefit from issuing debt even under very high-risk levels that result in a default probability very close to one. An example of such cases is Leland (1994)'s model without fixed bankruptcy costs where firms with any asset risk level always benefit from debt issuance; only in limits of asset volatility to infinity, does the debt benefit trend towards zero from above. With a very tiny fixed bankruptcy cost, this assumption is valid and applies to Case I.

Assumption 3: *The debt-benefit function and its derivative are continuous in the asset volatility.*

Assumption 4: *There exists at least one asset volatility level to satisfy Equation 3 for the current unlevered asset value:*

$$\exists \varepsilon_x > 0 : J(\varepsilon_x) = 0, \qquad J(\varepsilon) = g(\varepsilon) - \beta_1 \frac{DB(\varepsilon, \nu_0)}{\nu_0}, \quad g(\varepsilon) = \frac{\partial DB(\varepsilon, \nu_0)}{\partial \nu_0} \tag{28}$$

The assumption here assures an existing solution to Equation 3. Now the assumptions above imply:

COROLLARY 1: *An asset volatility level, ε_i such that $\varepsilon_i = Max\{\varepsilon_x | J(\varepsilon_x) = 0\}$, exists and it is strictly smaller than ε_{max} ($\varepsilon_i < \varepsilon_{max}$).*

From Assumption 2, the debt benefit beyond the maximum feasible volatility is strictly negative ($\forall \varepsilon > \varepsilon_{max} : DB(\varepsilon, \nu_0) < 0$). Therefore, no asset volatility level satisfies Equation 3 beyond the maximum volatility because the debt value is strictly negative and the marginal debt benefit (the function g) is positive. ε_i exists (based on Assumptions 4 and 3), is unique, and cannot be bigger or equal to maximum volatility.

Now, I prove Proposition 1.

COROLLARY 2: *For asset volatility between* ε_{max} *and* ε_i *(*$\varepsilon_i < \varepsilon < \varepsilon_{max}$*):* $J(\varepsilon) > 0$.

First, consider:

$$\varepsilon_i < \varepsilon < \varepsilon_{max} : either \quad J(\varepsilon) > 0, \quad or \quad J(\varepsilon) < 0, \tag{29}$$

where the *either..or* statement holds. Otherwise, there exists an ε where $J(\varepsilon)$ equals zero, and it contradicts Corollary 1. However, the latter condition cannot hold:

$$\varepsilon_i < \varepsilon < \varepsilon_{max} : J(\varepsilon) < 0 \Rightarrow g(\varepsilon) - \frac{\beta_1}{\nu_0} DB(\varepsilon) < 0 \Rightarrow g(\varepsilon \to \varepsilon_{max}) < \frac{\beta_1}{\nu_0} DB(\varepsilon_{max}) = 0 \tag{30}$$

because it contradicts Assumption 1 (no value destruction by managers). Since $J(.)$ can only take positive values, this means that the marginal debt value is higher than the average debt benefits (the value in waiting is higher than in issuing), while the debt benefit for these volatility levels is positive (it is feasible to issue debt).

Appendix D. Proof for Proposition 2

I check if the optimal leverage (or coupon) *ex ante* is the same as the optimal leverage (or coupon) *ex post.* The answer is yes. In the model and prior to issuing debt, the issuance threshold depends on the optimal coupon rate. The optimal coupon rate also depends on the decision about the issuance threshold because a higher threshold implies a higher coupon rate. Managers decide about both parameters before the threshold is hit. After the issuance, however, managers decide only about the optimal coupon rate. The proposition here rules out any possibility that managers can chose a different post-issuance coupon rate.

PROPOSITION 2: *The optimal coupon (or leverage) prior to debt issuance is equal to the optimal coupon at the time of issuance.*

Proof. First, I check the FOC for optimal coupon at issuance. At issuance, the option is already exercised and the optimal coupon is set so that the total debt benefits are maximized:

$$C_p^* : \quad \frac{\partial DB(\nu_I, C)}{\partial C} = DB^C(\nu_I, C_p^*) = 0 \tag{31}$$

where C_p^* is the *ex post* optimal coupon, and DB^i is the partial derivative function with respect to i.

The FOC for the optimal coupon prior to issuance is more complicated. From Figure 15, the optimal threshold is a function of the coupon prior to issuing debt. Having this in mind, I derive the FOC for the optimal coupon *ex ante* (C_a^*):

$$C_a^*: \quad \frac{\partial W(\nu_I(C), C)}{\partial C} = 0 \quad = DB^C(\nu_I(C_a^*), C_a^*)(\frac{\nu}{\nu_I(C_a^*)})^{\beta_1} \tag{32a}$$

$$+\left[\nu_I^C(C_a^*)(\frac{\nu}{\nu_I(C_a^*)})^{\beta_1}\left(DB_I^{\nu}(\nu_I(C_a^*), C_a^*) - \beta_1\frac{DB(\nu_I(C_a^*), C_a^*)}{\nu_I(C_a^*)}\right)\right] \tag{32b}$$

Term 32b is equal to zero because of the optimality condition of the threshold to issue debt (see Equation 3):

$$DB^C(\nu_I(C_a^*), C_a^*) = DB^C(\nu_I, C_p^*) = 0 \iff C_a^* = C_p^* \tag{33}$$

because DB^C is strictly decreasing and $\nu_I(C)$ is strictly increasing in coupons. □

Appendix E. Derivation of the formulas for capital rebalancing

Figure 17 shows the setup for the problem.

Insert Figure 17 about here.

A PDE like the one in Equation 4, and solutions like those in Equation 6 apply to bankruptcy cost, rebalancing cost (RC), and tax savings. Only boundary conditions change for all $\nu_B < \nu < \nu_U$:

$$TS(\nu_B) = 0, \quad TS(\nu_U) = \phi TS(\nu_0), \quad TS(\nu) = \frac{\tau C}{r} + A_T\nu^{\beta_1} + B_T\nu^{-\beta_2} \tag{34}$$

$$BC(\nu_B) = \alpha\nu_B, \quad BC(\nu_U) = \phi BC(\nu_0), \quad BC(\nu) = A_B\nu^{\beta_1} + B_B\nu^{-\beta_2} \tag{35}$$

$$RC(\nu_B) = 0, \quad RC(\nu_U) = \phi RC(\nu_0), \quad RC(\nu) = k_1P + \frac{k_2mP}{r} + \kappa + A_R\nu^{\beta_1} + B_R\nu^{-\beta_2} \tag{36}$$

$$DB(\nu) = TS(\nu) - BC(\nu) - RC(\nu) \tag{37}$$

Following these conditions, coefficient values are:

$$CM = \left[\begin{array}{cc} \nu_B^{\beta_1} & \nu_B^{-\beta_2} \\ \nu_U^{\beta_1} - \phi\nu_0^{\beta_1} & \nu_U^{-\beta_2} - \phi\nu_0^{-\beta_2} \end{array} \right]^{-1} \tag{38}$$

$$\left[\begin{array}{c} A_T \\ B_T \end{array} \right] = CM \times \left[\begin{array}{c} -\tau C/r \\ (\phi - 1)\tau C/r \end{array} \right] \tag{39}$$

$$\left[\begin{array}{c} A_B \\ B_B \end{array} \right] = CM \times \left[\begin{array}{c} \alpha\nu_B \\ 0 \end{array} \right] \tag{40}$$

$$\left[\begin{array}{c} A_R \\ B_R \end{array} \right] = CM \times \left[\begin{array}{c} -k_2 mP/r \\ \phi(\kappa + k_1 P) + (\phi - 1)k_2 mP/r \end{array} \right] \tag{41}$$

However, for the debt value this changes slightly:

$$\frac{1}{2}\varepsilon^2\nu^2 D_{\nu\nu} + (r - \delta)\nu D_\nu - (r + m)D + (C + mP) = 0 \tag{42}$$

$$\begin{cases} D(\nu) = \dfrac{C + mP}{r + m} + A_D\nu^{y_1} + B_D\nu^{-y_2}, \\ \\ y_1 = \dfrac{\sqrt{h^2 + 2(r + m)} - h}{\varepsilon} \quad y_2 = \dfrac{\sqrt{h^2 + 2(r + m)} + h}{\varepsilon} \end{cases} \tag{43}$$

This initial condition and the solution for this equation are:

$$\begin{array}{l} D(\nu_B) = (1 - \alpha)\nu_B, \quad D(\nu_U) = P, \\ \left[\begin{array}{c} A_D \\ B_D \end{array} \right] = \left[\begin{array}{cc} \nu_B^{y_1} & \nu_B^{-y_2} \\ \nu_U^{y_1} & \nu_U^{-y_2} \end{array} \right]^{-1} \times \left[\begin{array}{c} (1 - \alpha)\nu_B - (C + mP)/(r + m) \\ P - (C + mP)/(r + m) \end{array} \right] \end{array} \tag{44}$$

The rest of the formulas are very similar to derivations for the simple case:

$$E(\nu) = \nu + DB(\nu) - D(\nu)$$
$$W(\nu) = DB(\nu_I)(\frac{\nu}{\nu_I})^{\beta_1}, \quad \nu \le \nu_I$$
$$\nu_B : \frac{\partial E}{\partial \nu_B} = 0$$
$$\phi : \frac{\partial DB}{\partial \phi} = 0, \quad \phi > 1 \tag{45}$$
$$P : \frac{\partial DB}{\partial P} = 0, \quad P \ge 0$$
$$\nu_I : \frac{\partial DB(\nu_I)}{\partial \nu_I} = \beta_1 \frac{DB(\nu_I)}{\nu_I}$$

Again, if ν_I is smaller than ν_0, then managers issue debt immediately.

Appendix F. Case IV: The bankruptcy cost split

In all the earlier cases, debtholders pay the default cost *ex post*. For many ventures and young firms, leaving entrepreneurs add value to the firm that has gone bankrupt. This inefficiency makes the cost split between equity holders (including entrepreneurs) and debtholders. This article's introduction has a list of these costs. For example, on the debtholder side, it is like the growth option of the firm losing value at default and being sold by debtholders at scrap value. An example on the equity holder side is the lost legacy of the entrepreneur at default. In order to capture these dynamics, I change the model in Case I and check its implications. Mathematically, the cost is split between debtholders and equity holders proportionally (ω represents the proportion paid by the shareholders). Limited liability applies only to debtholders.

Each claim's value is:

$$D_\omega(\nu) = \frac{C}{r} + ([\nu_B^\omega - (1-\omega)[\alpha\nu_B^\omega + K]]^+ - \frac{C}{r})(\frac{\nu}{\nu_B^\omega})^{-\beta_2} \tag{46}$$

$$TS_\omega(\nu) = \frac{\tau C}{r}(1 - (\frac{\nu}{\nu_B^\omega})^{-\beta_2}) \tag{47}$$

$\mathrm{BC}_\omega(\nu) = (\alpha\nu_B^\omega + K)(\frac{\nu}{\nu_B^\omega})^{-\beta_2})(48)$

$$E_\omega(\nu) = \nu + TS_\omega(\nu) - BC_\omega(\nu) - D_\omega(\nu) \tag{49}$$

The optimal default policy here yields a more general form.[13] Shutting down the sharing

[13] In order to drop the positive portion sign, $\omega K \le (1-\alpha)\nu_B^\omega$ holds .

generates the same results as in the case in the previous section. Equation 50 shows the barrier in the new model. As the portion paid by the shareholders gets higher, they lower the default barrier to avoid the cost paid at default. The same is true when their share is fixed and the PBC rate or the fixed default cost increases. This implies that any undesirable cost makes the shareholders postpone exercising the default option.

$$\frac{\partial E_\omega}{\partial \nu_B^\omega} = 0 \Rightarrow \nu_B^\omega = \frac{(C/r) - \tau(C/r) - \omega K}{(1+\omega\alpha)}\left(\frac{\beta_2}{1+\beta_2}\right) \tag{50}$$

Now I turn into the debt gain and its optional value. The real option value in this case is:

$$\begin{aligned} &DB_\omega(\nu) = TS_\omega(\nu) - BC_\omega(\nu) \\ &W_\omega(\nu) = DB_\omega(\nu_I^\omega)\left(\frac{\nu}{\nu_I^\omega}\right)^{\beta_1} \qquad \nu \leq \nu_I^\omega \end{aligned} \tag{51}$$

where, under the new model, ν_I^ω is the new threshold, DB_ω is the debt benefit, and W_ω is the real option value. The optimal threshold maximizes the option value and satisfies a similar equation, as before:

$$\nu_I^\omega \quad s.t. \quad \frac{\partial DB(\nu_I^\omega)}{\partial \nu_I^\omega}) = \beta_1 \frac{DB(\nu_I^\omega)}{\nu_I^\omega} \tag{52}$$

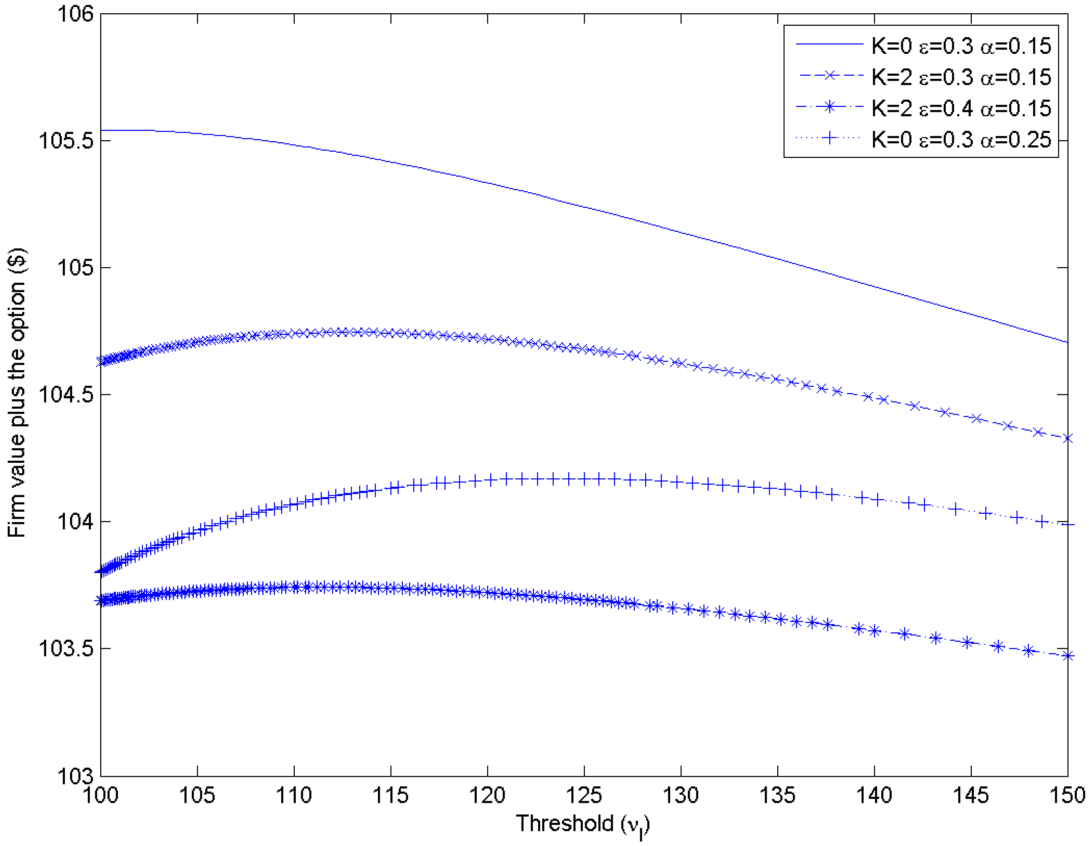


Figure 14. The total firm value as a function of different threshold values
The threshold is at the point maximizing the total firm value. The risk-free rate (r) is 5%, the asset value (ν_0) is \$100, the payout rate (δ) is 3%, the coupon (C) is \$5, and the tax rate (τ) is 15%. I analyze the fixed bankruptcy cost (K), the asset volatility (ε), and the PBC rate (α). The total firm value is the unlevered value, ν, plus the option, $W(\nu)$.

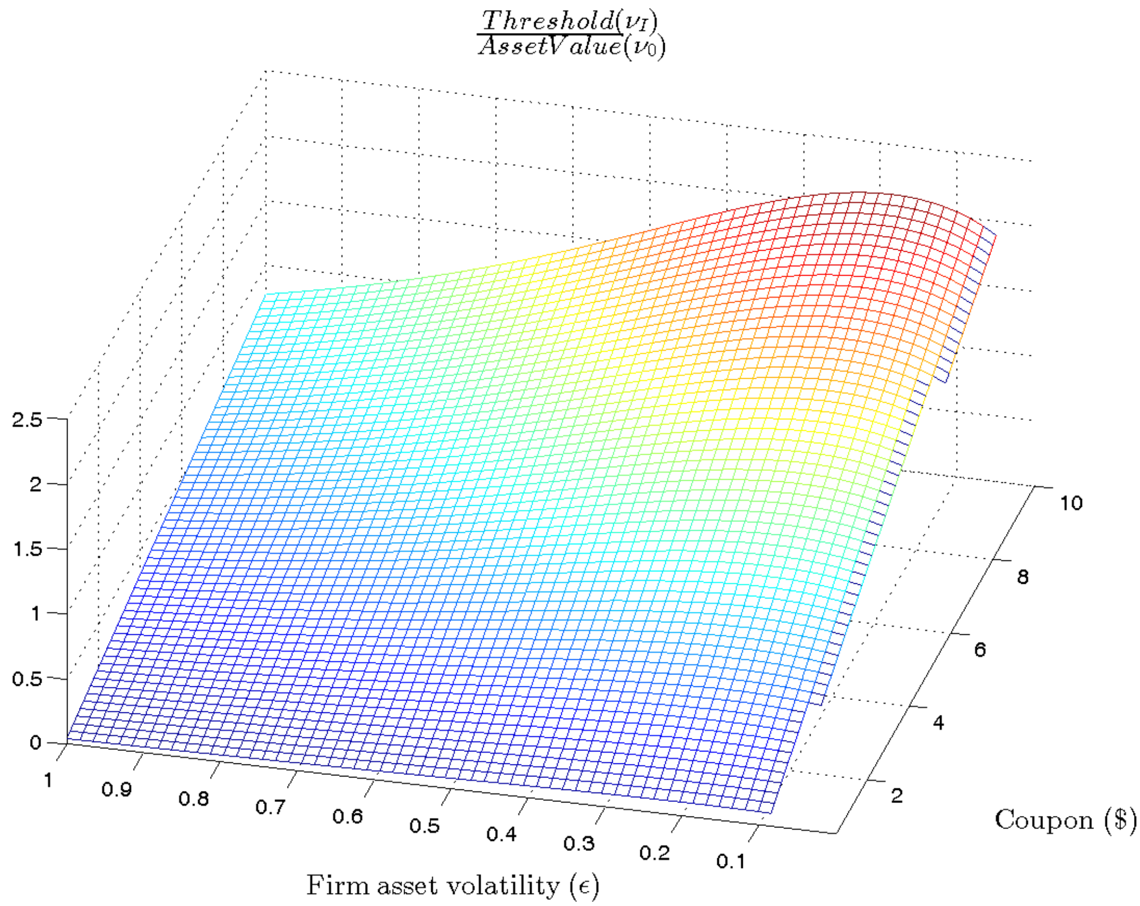


Figure 15. The optimal threshold as a function of volatility and coupon
The threshold increases with the coupon rate. The risk-free rate (r) is 5%, the payout rate (δ) is 3%, the asset value (ν_0) is $100, the PBC rate ($\alpha$) is 15%, the fixed bankruptcy cost (K) is 0, and the tax rate (τ) is 15%. I calibrate for the asset volatility (ε), and the coupon (C). Values below one indicate that debt is issued immediately.

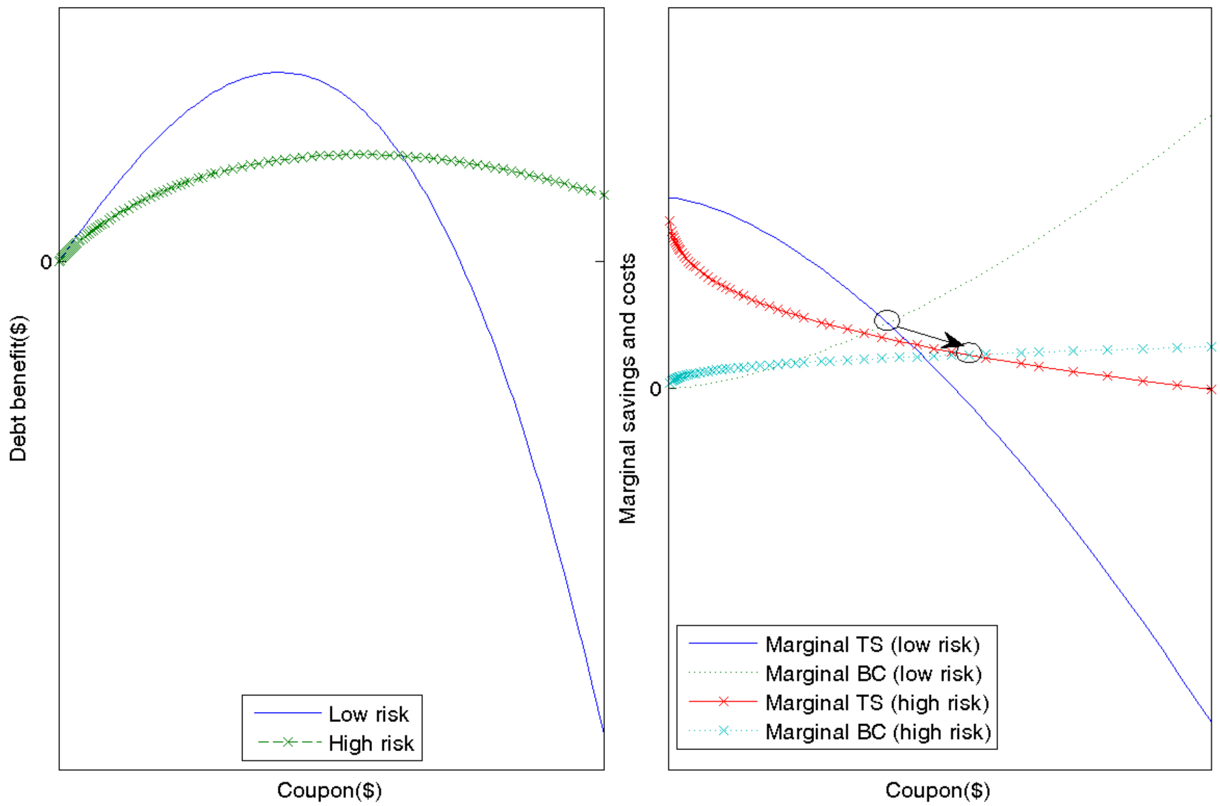


Figure 16. The optimal coupon and its derivation
The optimal coupon increases with the asset's risk. The left graph shows the debt benefits, and the right graph shows the behavior of marginal values. The intersection points on the right graph match the maximum points at the left graph. The flash shows the shift due to an increasing volatility.

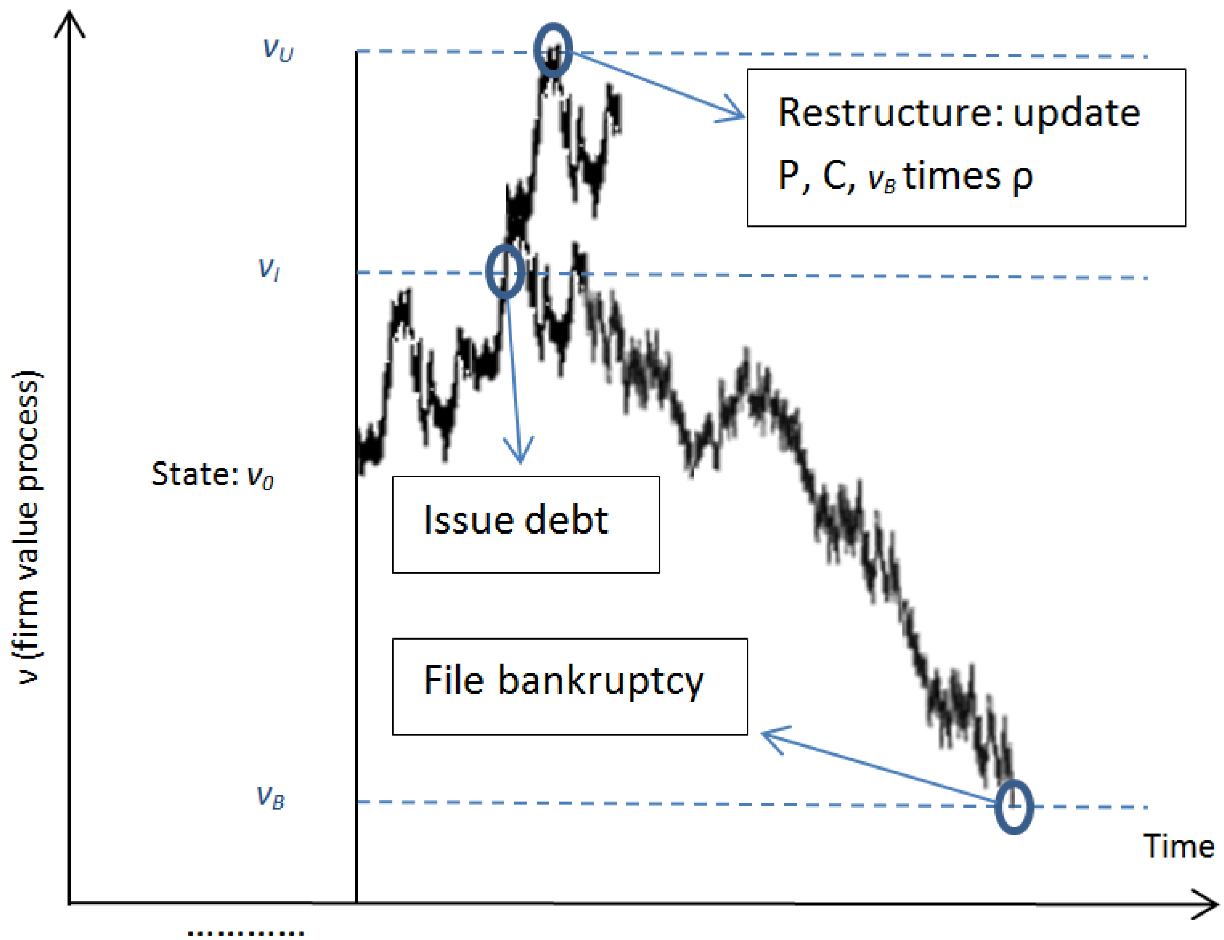


Figure 17. The setup of the problem

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