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Optimal Leverage, its Benefits, and the Business Cycle

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Abstract

We study the effect of the business cycle on optimal capital structure choice and the benefit to leverage. We propose a regime switching model with a state-dependent cash flow process to capture macroeconomic risk in a firm's cash flow. Our model is parsimonious but still realistic and allows for a wide range of analysis. We find pro-cyclical optimal leverage ratios, benefits to leverage, and costs of operating at a non-optimal leverage. If macroeconomic risk decreases, i.e. earnings become more stable and growth rates less volatile, optimal leverage and its benefits increase due to lower default risk. The regime switching property of EBIT traces observed EBIT paths closely and is applicable to a wide range of corporate valuation models. Our model offers novel empirically testable implications, such as higher tax benefits after the change in macroeconomic risk since the late 1980s and common capital structure adjustments in recessions and around turning points.

Keywords: capital structure; macroeconomic risk; regime switching; benefit to leverage

JEL classification: E44; G12; G32

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1 Introduction

The business cycle is essential for understanding corporate financing decisions. To analyze how the macroeconomic risk affects optimal leverage ratios, we propose a structural model of optimal capital structure that incorporates changing macroeconomic conditions through the firm's cash flow channel. Our model is parsimonious but at the same time realistic and allows for a wide range of analysis. We show that optimal leverage and its benefits vary pro-cyclically, and a reduction of macroeconomic risk lowers optimal leverage ratios but influences benefits to leverage only marginally. The costs that a corporation faces if it operates at a non-optimal leverage are higher in recessions.

In contrast to previous approaches, we model earnings before interest and taxes (EBIT) with a stochastic process that depends on the business cycle. In expansions EBIT follow a positive trend while in contractions they decrease on average. The turning points of the economy are determined stochastically by a Markov chain. Following Goldstein, Ju, and Leland (2001) and the trade-off theory, the firm chooses its optimal financing mix by balancing tax benefits and default costs which in turn depend on the macroeconomic conditions. As a result we find that optimal capital structures and benefits to leverage strongly differ in expansions and recessions.

Our model shows that optimal leverage choice varies pro-cyclically with the business cycle. In expansions firms choose a higher amount of debt for financing their investments, while they turn to equity financing in contractions. Positive growth expectations decrease a firm's default risk and increase its debt capacity. In contrast, default is more likely in recessions and the firm behaves optimal by choosing a higher amount of equity to reduce default risk.

The benefit to leverage, defined as the ratio of the levered and unlevered firm value, is pro-cyclical as well. Estimating the parameters of our model to reflect S&P500 firms, we find that by issuing debt the unlevered asset value of the firm is increased by 5% in expansions and by 4% in contractions. Despite increasing default risk, tax shields are important means to maximize shareholders wealth in contractions. In expansions the levered firm value is 23% higher than in recessions, but the benefits increase only by 1%. Hence, benefits account for only a small fraction of the gain in the levered firm value.

If managers want to determine their firm's optimal leverage ratios, they need to precisely assess the present state of the economy and the expected growth rate of EBIT. If they fail to identify the present conditions, they come to a non-optimal leverage choice. Firms operating at a non-optimal leverage ratio face costs of being over- or underlevered. We find that these costs are higher in recessions than in expansions. In recessions marginal default costs increase more rapidly with outstanding debt which makes being overlevered more costly in this state. If managers issue too little debt in a contraction, then they miss a substantial amount of tax benefits which are an important way to create shareholder value since earnings will decline on average. For a small deviation from the optimum, the costs are only a small fraction of the levered firm value, but if the optimum changes due to a switch of the state, then the firm faces high costs. If capital structure adjustments are costly, then the firm adjusts their leverage more often at turning points of the economy, because there it is more likely that the increase in value exceeds the adjustment costs. Besides this finding, leverage adjustments should generally be more common in recessions because the costs of being over- or underlevered are higher in this state.

As observed by Stock and Watson (2002), macroeconomic risk has changed over time. After the 1980s, recessions became milder and economic growth less volatile. This shift in macroeconomic conditions affects corporate financing policies. Our model shows that mild recessions and less volatile growth rates lead to higher levered firm values, because the loss of cash flows in recessions is smaller. As a response optimal leverage increases due to a reduction in default risk. However, the benefits to leverage are hardly affected by the changing conditions. The fraction of the levered firm value that corresponds to the benefits to leverage varies only slightly. If firms behave optimal they can keep the benefits to leverage at the same level, independent of the state of the economy.

Our theoretical results on pro-cyclical leverage ratios explain recent empirical findings by Korteweg (2010) who assesses a significant positive difference in optimal leverage ratios over the business cycle. Our findings are also in line with Covas and Den Haan (2010) who come to the result of pro-cyclical debt issuances. In their empirical study, Korajczyk and Levy (2003) analyze observed leverage ratios on the basis of financial constraints and state that financially unconstrained firms have countercyclical leverage ratios. Our model addresses optimal rather than observed leverage ratios, which are not necessarily identical. For example, according to the trade-off theory a profitable firm operates at a high optimal leverage ratio. But over time high retained earnings decrease the observed leverage constantly, so that observed and optimal ratios do not correspond to each other. In our model optimal leverage is not affected by the historic outcomes, it reflects the optimal leverage choice at a certain point in time.

The main distinction of our model to previous approaches is that the firm faces unlimited downward risk once a recession sets in. In constrast, modeling EBIT with a geometric Browian motion multiplied with a state variable that switches between two values to reflect macroeconomic risk (e.g. Hackbarth, Miao, and Morellec (2006)) implies that the economic outlook at the beginning of a recession is rather bright. Once the firm has survived the jump down to a much lower EBIT level at the start of a recession, the upside potential from jumping back to the old level is huge. This leads to the counterintuitive implication that the economic outlook at the beginning of a recession is even brighter than in the middle of an expansion. Hence, the assumption that drift rates rather than the level of EBIT switch is the central distinction in our model. It is mainly responsible for the fact that we find pro-cyclical rather than counter-cyclical leverages to be optimal.

Two independent, recent papers construct a similar framework but have a different focus. Chen (2010) uses regime switching processes to model a firm's cash flow, the outcome of the economy, and the consumer price index. His analysis focuses on credit spreads and default rates Bhamra, Kuehn, and Strebulaev (2009) combine a structural model with a consumption-based asset pricing model to explain leverage ratios at aggregated and individual levels. Their approach integrates the effect of the business cycle in the aggregate consumption and through an additional systematic volatility component. In our analysis we examine the optimal leverage choice, the benefit to leverage, costs of being over- or underlevered and changing macroeconomic conditions. Our approach focuses on the effect of state dependent EBIT, not of the consumption in the economy. Moreover, our approach is more parsimonious and we are able to trace the observed effects closely back to our state dependent earnings process.

The rest of the paper is organized as follows: In section 2 we define the economy of the model and in section 3 we use the contingent claims valuation technique to derive analytical functions for the levered firm and debt value. In section 4 we estimate the model's parameters and analyze implications on optimal leverage, the benefit to leverage, and changing macroeconomic conditions. Finally, section 5 concludes. Derivations are contained in the appendix.

2 The model

We consider a continuous time economy with a representative firm and two possible states of the economy, i.e., expansion ($i = 1$) or recession ($i = 2$). All agents know the present state i_0 at all times and its characteristics. The transition from one state to the other is given by a Markov chain M_t with Poisson transition probabilities. The rate of leaving the present state i in the infinitesimal time interval $\mathrm{d}t$ is denoted λ_i. All agents are risk neutral and discount cash flows with the constant risk free rate r. Corporate earnings are taxed at the constant tax rate τ and management acts in best interest of shareholders.

Upon this economy, we consider an infinitely-lived firm whose assets generate stochastic EBIT x_t. Because of different earning perspectives in different states of the economy, x_t follows a geometric Brownian motion that changes its drift and volatility components at turning points of the economy, called regime-switching-process:[1]

$$\begin{aligned} \mathrm{d}x_t &= \mu_i x_t \,\mathrm{d}t + \sigma_i x_t \,\mathrm{d}W_t, \quad \text{where} \quad i = 1,2 \\ &\mu_1, \mu_2 \in \mathbb{R}, \quad \sigma_1, \sigma_2 > 0, \quad x_0 > 0 \end{aligned} \tag{1}$$

Uncertainty is modeled through the complete probability space $(\Omega, \mathcal{F}, \mathcal{P})$, where the σ-algebra $\mathcal{F}$ is generated by the Markov chain M_t and standard Brownian motion $(W_t)_{t\geq 0}$. The probability measure $\mathcal{P}$ is the product of the distribution of $\mathrm{d}W_t$ and M_t. To obtain a realistic setting of EBIT across the business cycle, we assume $\mu_1 > 0$ and $\mu_2 < 0$, i.e. the expected earnings growth is positive in an expansion and negative in a recession. The risk of deviation from the present EBIT-trend μ_i is reflected through the state dependent volatility component σ_i. The present value of expected perpetually generated after-tax EBIT is the value of the firm's unlevered assets $u(x)$.

Since the firm's EBIT is subject to taxation at the constant tax rate τ, the firm has incentives to issue debt in order to generate tax benefits and to create a levered firm value $v(x)$ exceeding the unlevered asset value $u(x)$. We consider a stationary debt environment according to Leland (1998) where a firm initially issues a certain amount of debt with principal P, fair coupon C. Throughout time a constant fraction m of outstanding debt is retired continuously and replaced by the same amount of debt with the same coupon and retirement rate, so that the outstanding amount of debt P is constant over time. Debt is issued at par so that the principal P equals the initial market value of debt $d(x_0)$ and the firm has to pay the fair coupon that incorporates the risk of the volatile EBIT process. The value of shareholders equity $e(x)$ is the residual claim to the levered firm value $v(x)$ after subtraction of the market value of debt $d(x)$.

The issuance of debt bears default risk. We incorporate an endogenous default decision according to Leland and Toft (1996), where the decision to default belongs to the shareholders and default is triggered if EBIT x_t falls beneath state dependent default thresholds, K_1 and

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[1] For details on regime-switching-processes see Guo (2001)

K_2. The thresholds correspond to the point where shareholders optimally stop injecting funds into the firm because the cost of remaining active equals its benefits. Since the benefits are state dependent and higher in an expansion due to the positive difference in the growth rates $\mu_1 - \mu_2$, we find that $K_1 < K_2$. In words, the firm will default earlier in a recession than in an expansion. When default occurs, bondholders receive the unlevered asset value less default costs and equity becomes worthless. Default costs are reflected through a state dependent recovery rate $0 < \alpha_i \leq 1$, so that the payment to bondholders in case of default corresponds to $d(x) = \alpha_i u(x)$, i denoting the present state at time of default.

All claims, such as the levered firm value $v(x)$, the unlevered asset value $u(x)$, debt value $d(x)$, and equity value $e(x)$ are state dependent functions of EBIT x_t, which is denoted by the index i:

$$v(x_t) = \begin{cases} v_1(x_t) & \text{if } i_t = 1 \\ v_2(x_t) & \text{if } i_t = 2 \end{cases} \tag{2}$$

Initially managers choose the outstanding amount of debt P to maximize the levered firm value $v(x) = v_{i_0}(x)$ and hence the shareholders wealth. The maximum is achieved when the marginal tax benefits equal the default cost. Since the value of the levered firm $v(x)$ depends on the present state, the maximization problem has two solution, namely for each possible present state one solution:

$$\max_P v_i(x) \quad i = 1, 2 \tag{3}$$

We define leverage as the ratio of debt and the levered firm value $l_i = d_i(x)/v_i(x)$. l_1 is the leverage in an expansion, l_2 in a recession, and l_i^* is the optimal ratio that maximizes the levered firm value in the corresponding state i. The benefit to leverage is defined as $b_i = \frac{v_i(x) - u_i(x)}{u_i(x)}$ and refers to the present value of the expected future benefits of issuing debt in $t = 0$. Since the firm value can be split up into the value of unlevered assets and the benefits, the maximization of the levered firm value is equivalent to the maximization of the benefits.

3 Valuation of corporate securities

In this section we construct a static contingent claims valuation model with the basic characteristics of Hackbarth, Miao, and Morellec (2006) to derive closed form solutions for the value of the firm's unlevered asset value, the levered firm value, its outstanding amount of debt, and the value of shareholder's equity. All claims are denoted as functions of EBIT x_t and dependent on the state $i = 1, 2$.

If the default threshold in expansions K_1 is lower than in recessions K_2, we have three disjoint regions that can be analyzed separately. We define the region $x \leq K_1$ as the default region. Here, the firm is liquidated in both states. Second, $K_1 < x \leq K_2$, defines the transient region where the firm is active in state one, but liquidated in state two. Third, the action region $K_2 < x$, where the firm is active in both states. As shown in section 4, the case of $K_1 < K_2$ is sufficient and hence we will not discuss other scenarios.

3.1 Unlevered asset value

Following Mello and Parsons (1992) the value of unlevered assets $u(x)$ corresponds to the present value of a perpetual claim to after-tax EBIT.

$$u(x) = \mathbb{E}\left[\int_t^\infty e^{-r(s-t)}(1-\tau)x_s \, \mathrm{d}s \;\middle|\; x_0 = x, i_0 = i\right] , \quad i = 1, 2 \tag{4}$$

It can be compared to the value of the firm that does not issue debt. An application of Itô's Lemma to each state of the economy yields a set of ordinary differential equations for the value of unlevered assets u_i:[2]

$$\frac{1}{2}x^2\sigma_1^2 u_1'' + \mu_1 x u_1' - r u_1 + \lambda_1(u_2 - u_1) + (1-\tau)x = 0 \tag{5}$$
$$\frac{1}{2}x^2\sigma_2^2 u_2'' + \mu_2 x u_2' - r u_2 + \lambda_1(u_1 - u_2) + (1-\tau)x = 0 \tag{6}$$

The equation consists of three parts: first, a linear Black-Scholes operator $\frac{1}{2}x^2\sigma_i^2 u_i'' + \mu_i x u_i' - r u_i$ captures the change of the unlevered firm value due to the movement of the Brownian motion. The second part $\lambda_i(u_j - u_i)$ is the change in values arising from a regime shift multiplied by the rate of leaving state i. The third part $(1-\tau)x$ represents the perpetual claim to after-tax EBIT.

Under the boundary conditions

$$\lim_{x\to 0} u_i(x) < \infty \text{ and } \lim_{x\to\infty} \frac{u_i(x)}{x} < \infty \ , \tag{7}$$

the solution to (5) and (6) is

$$u_1(x) = w_1 \cdot x \quad \text{ and } \quad u_2(x) = w_2 \cdot x \ . \tag{8}$$

with the constants w_1 and w_2 given by

$$w_1 = -\frac{(1-\tau)(\mu_2 - r - \lambda_1 - \lambda_2)}{(\mu_1 - r - \lambda_1)(\mu_2 - r - \lambda_2) - \lambda_1\lambda_2} \ , \tag{9}$$
$$w_2 = -\frac{(1-\tau)(\mu_1 - r - \lambda_1 - \lambda_2)}{(\mu_1 - r - \lambda_1)(\mu_2 - r - \lambda_2) - \lambda_1\lambda_2} \ . \tag{10}$$

The unlevered asset value is a linear function of the present level of EBIT. The constant coefficients w_i incorporate the growth rate in the present state μ_i and the possible switch to the other state with a different growth rate. Intuitively, for the considered scenario with $\mu_1 > \mu_2$, we find that $u_1(x) > u_2(x)$. Moreover, the unlevered asset value is independent of

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[2] The derivation of the differential equations is contained in the appendix A.1.

the volatility σ_i of EBIT because it is the expected value of the process, reflecting the future drift not the volatility.

3.2 Value of corporate debt

The state dependent value of all outstanding corporate debt d_i $(i = 1, 2)$ is the present value of the continuous coupon payment C and retirement of the principal mP as long as the firm is solvent. Upon default bondholders receive the state dependent unlevered asset value diminished by the recovery rate α_i. In the default region the firm is liquidated in both states which leads to a debt value of $\alpha_i w_i x$. In the transition region $(K_1 < x \leq K_2)$ the firm is active in state one but defaults in state two. Therefore, the value of outstanding debt in state two is $d_2(x) = \alpha_2 w_2 x$. An application of Itô's lemma[3] in state one yields a set of differential equations for $d_1(x)$:

$$\frac{1}{2}x^2\sigma_1^2 d_1'' + \mu_1 x d_1' - (r+m)d_1 + \lambda_1(\alpha_2 w_2 x - d_1) + C + mP = 0 \ . \tag{11}$$

The structure of the equation matches (5) and (6). Note that in the transient region $\alpha_2 w_2 x$ corresponds to $d_2(x)$ and the constant payment $C + mP$ is the absolute outstanding coupon plus the retirement of the principal.

In the action region $(K_2 < x)$ the firm is active in both states. Itô's lemma yields in analogy to (5) and (6) a set of differential equations:

$$\frac{1}{2}x^2\sigma_1^2 d_1'' + \mu_1 x d_1' - (r+m)d_1 + \lambda_1(d_2 - d_1) + C + mP = 0 \tag{12}$$

$$\frac{1}{2}x^2\sigma_2^2 d_2'' + \mu_2 x d_2' - (r+m)d_2 + \lambda_2(d_1 - d_2) + C + mP = 0 \tag{13}$$

In order to obtain continuous solution functions for $d_i(x)$, we use continuity conditions at

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[3] The exact derivation is contained in the appendix A.2.

$x = K_1$ and $x = K_2$:

$$d_1(K_1) = \alpha_1 w_1 K_1 \tag{14}$$

$$d_2(K_2) = \alpha_2 w_2 K_2 \tag{15}$$

$$\lim_{x \to K_2^-} d_1(x) = \lim_{x \to K_2^+} d_1(x) \tag{16}$$

In addition, at $x = K_2$ we require a smooth fit of $d_1(x)$ to obtain a $\mathcal{C}^1$-function outside of the default region.

$$\lim_{x \to K_2^-} d_1'(x) = \lim_{x \to K_2^+} d_1'(x) \; . \tag{17}$$

Solving (11), (12), (13) subject to (14) - (17), we receive explicit functions for the value of state dependent corporate debt:

Theorem 1: Value of corporate debt

If a firm's EBIT is given by (1), its debt structure by (C, m, P), and the default policy by $K_1 < K_2$, then the value of corporate debt $d(x)$ is state dependent and satisfies:

$$d_1(x) = \begin{cases} \alpha_1 w_1 x & \text{for } x \leq K_1 \\ A_1 x^{\gamma_1} + A_2 x^{\gamma_2} + \frac{C+mP}{r+m+\lambda_1} + \frac{\alpha_2 \lambda_1 w_2 x}{r+m+\lambda_1-\mu_1} & \text{for } K_1 < x \leq K_2 \\ A_3 x^{\beta_1} + A_4 x^{\beta_2} + \frac{C+mP}{r+m} & \text{for } K_2 < x \end{cases} \tag{18}$$

and

$$d_2(x) = \begin{cases} \alpha_2 w_2 x & \text{for } x \leq K_2 \\ b_3 A_3 x^{\beta_1} + b_4 A_4 x^{\beta_2} + \frac{C+mP}{r+m} & \text{for } K_2 < x \end{cases} \; . \tag{19}$$

where $\beta_1, \beta_2 < 0$, $\gamma_1 > 0$, $\gamma_2 < 0$, $b_3 < 0$, $b_4 > 0$ and A_1, A_2, A_3, A_4 are the coefficients determined by the boundary conditions (14) - (17). The derivation and explicit formulas of the exponents and coefficients are contained in the appendix A.2.

In the action region the value of corporate debt consists of two parts: First, $\frac{C+mP}{r+m}$ is the risk-free value of perpetual debt. Second, the negative sum $A_3x^{\beta_1} + A_4x^{\beta_2}$ reflects the discount of the risk-free value due to default risk and a possible regime shift. In state one the default risk can increase because the drift can switch from $\mu_1 > 0$ to $\mu_2 < 0$. In contrast, a switch from state two to state one decreases default risk because on average EBIT x moves further away from the default threshold K_i due to the positive drift μ_1. With increasing x the exponential terms vanish and the whole expression converges to the value of risk-free debt $\frac{C+mP}{r+m}$. Given the structure of the differential equations, we can express the discount due to default risk in an recession by multipyling the singel terms of the default risk in an expansion by b_3 and b_4 respectivly. In the transient region ($K_1 < x \leq K_2$) a switch from state one to state two results in a sudden default which is reflected by the increased discount rate $r + m + \lambda_1 - \mu_1$ of the perpetual debt claim. The additional term $\frac{\alpha_2\lambda_1 w_2 x}{r+m+\lambda_1-\mu_1}$ incorporates the default value in state two. The analytical formulas extend those of Leland (1994) by the terms of the transient region and the different exponents in the transient and action region.

3.3 Levered firm value

The value of the levered firm is the present value of a claim to after tax EBIT plus the tax shield as long as the firm is solvent. In default it is the liquidation value less default costs. It can be treated as the solution to a system of differential equations constructed in the same way as in the case of corporate debt. Because of the different growth perspectives of EBIT in different states, the levered firm value $v_i(x)$ ($i = 1, 2$) is state dependent as well.

In the transient region the firm defaults in state two but remains active in state one. Hence, we have a single equation for the value of the levered firm in the transient region ($K_1 < x \leq K_2$):

$$\frac{1}{2}x^2\sigma_1^2 v_1'' + \mu_1 x v_1' - r v_1 + \lambda_1(\alpha_2 w_2 x - v_1) + (1-\tau)x + \tau C = 0 \ . \tag{20}$$

In the action region the firm is active in both states and satisfies the equations

$$\frac{1}{2}x^2\sigma_1^2 v_1'' + \mu_1 x v_1' - r v_1 + \lambda_1(v_2 - v_1) + (1-\tau)x + \tau C = 0 \ , \tag{21}$$

$$\frac{1}{2}x^2\sigma_2^2 v_2'' + \mu_2 x v_2' - r v_2 + \lambda_1(v_1 - v_2) + (1-\tau)x + \tau C = 0 \ . \tag{22}$$

The respective continuity and smoothness conditions read

$$v_1(K_1) = \alpha_1 w_1 K_1 \ . \tag{23}$$

$$v_2(K_2) = \alpha_2 w_2 K_2 \ . \tag{24}$$

$$\lim_{x \to K_2^-} v_1(x) = \lim_{x \to K_2^+} v_1(x) \ , \tag{25}$$

$$\lim_{x \to K_2^-} v_1'(x) = \lim_{x \to K_2^+} v_1'(x) \ . \tag{26}$$

Solving (20) - (22) subject to (23) - (26) gives theorem 2:

Theorem 2: Value of the levered firm

Under the same assumptions as in theorem 1, the value of the levered firm $v(x)$ is state dependent and in each state given by:

$$v_1(x) = \begin{cases} \alpha_1 w_1 x & \text{for } x \le K_1 \\ B_1 x^{\hat\gamma_1} + B_2 x^{\hat\gamma_2} + \frac{\tau C}{r+\lambda_1} + \frac{\alpha_2 \lambda_1 w_2 x}{r+\lambda_1-\mu_1} + \frac{(1-\tau)x}{r+\lambda_1-\mu_1} & \text{for } K_1 < x \le K_2 \\ B_3 x^{\hat\beta_1} + B_4 x^{\hat\beta_2} + w_1 x + \frac{\tau C}{r} & \text{for } K_2 < x \end{cases} \tag{27}$$

and

$$v_2(x) = \begin{cases} \alpha_2 w_2 x & \text{for } x \le K_2 \\ \hat b_3 B_3 x^{\hat\beta_1} + \hat b_4 B_4 x^{\hat\beta_2} + w_2 x + \frac{\tau C}{r} & \text{for } K_2 < x \end{cases} \tag{28}$$

where $\hat\beta_1, \hat\beta_2 < 0$, $\hat\gamma_1 > 0$, $\hat\gamma_2 < 0$, $\hat b_3 < 0$, $\hat b_3 > 0$, and B_1, B_2, B_3, B_4 are the coefficients derived from the boundary conditions (23) - (26). Explicit formulas of the exponents and coefficients and the derivation of the formula are contained in the appendix A.2.

The structure of the functions in theorem 2 is identical to those in theorem 1. The value of the levered firm is the state dependent value of unlevered assets $w_i x$ plus the tax shield τC. In the action region ($K_1 < x$) the tax shield is independent of the present state, but the liquidation value incorporates the present state and the switch to the other. In the transient region the tax shield is discounted at higher rate $r + \lambda_1$ because a switch from state one to state two would result in a loss of the tax shield. Again, the negative sum $B_3 x^{\hat{\beta}_1} + B_4 x^{\hat{\beta}_2}$ reflects the discount due to default risk and a possible state switch. In state two the subtraction is larger than in state one due to the higher default risk through the prevailing negative trend μ_2.

3.4 Equity value

The value of a levered firm's equity is the present value of the residual claim to the levered firm value after deducing payments to bondholders.

Theorem 3: Equity value

Under the same assumptions as in theorem 1, the value of equity $e(x)$ is state dependent and given by

$$e_i(x) = \begin{cases} 0 & \text{for } x \leq K_i \\ v_i(x) - d_i(x) & \text{for } K_i < x \end{cases} \qquad i = 1, 2\ . \tag{29}$$

In case of liquidation the bondholders receive all that is left of the unlevered firm value and, hence, equity becomes worthless. Outside of the default region the residual claim is positive and increasing in EBIT. In the transient region a sudden state switch from state one to state two results in a total loss for the shareholders. Since the value of corporate debt is bounded, the growth of the equity value converges to the growth of the firm value for large

x. Debt and levered firm value satisfy smoothness conditions at the upper default boundary K_2 and hence equity does so as well.

3.5 Coupon size, default policy and optimal capital structure

In $t = 0$ the management has to decide about the hight of the principal that will be issued. The fair coupon C that the firm has to pay for its debt obligations depends on the principal P, the present state i_0, and the default thresholds K_1, K_2 because as show in theorem 1 and 2 the discount of corporate securities depends on the business cycle. For a given set of P, x_0, K_1, K_2 we can find the fair coupon by solving the debt-at-par equation for C numerically:

$$d_{i_0,C,P,K_1,K_2}(x_0) = P \ . \tag{30}$$

Since management acts in the best interest of shareholders, we employ a smoothness condition according to Leland and Toft (1996) in each state

$$\left.\frac{\partial e_i(x)}{\partial x}\right|_{x=K_i} = 0 \qquad i = 1, 2 \ . \tag{31}$$

Equation (31) guarantees that default is triggered at the point where marginal increase of equity value is zero. The value of equity $e(x)$ is an implicit function of the coupon C and in turn the value of debt $d(x)$ depends on the default thresholds K_1 and K_2. When solving (31) for a given principal P iteratively, C has to be determined in every step by solving (30).

Being able to determine the optimal default thresholds and the fair coupon, we can derive an optimal capital structure by maximizing the levered firm value. The optimal leverage ratio is the solution to the problem:

$$\max_{0<P<v_{i_0}} v_{i_0}(x_0) \text{ s.t. } (30), (31) \qquad i_0 = 1, 2. \tag{32}$$

Table 1: Summary of the calibrated parameters used in the benchmark case. The parameters are estimated on aggregated S&P500 date.

growth rate of EBIT	μ_1	0.04
	μ_2	-0.15
volatility of EBIT	σ_1	0.20
	σ_2	0.25
rate of leaving a state	λ_1	0.20
	λ_2	0.65
recovery rate	α_1	0.8
	α_2	0.6
risk-free rate	r	0.05
corporate tax rate	τ	0.15
retirement rate of debt	m	0.0

For each i_0 we receive an optimal principal P, a fair coupon C, and two distinguishable default thresholds K_1 and K_2. We denote the solution to (32) with $v_i^*(x)$ and define the optimal leverages by $l_i^* = d_i^*(x)/v_i^*(x)$. There are two different optimal capital structures, one for state one and one for state two.

4 Implications for optimal capital structure

In this section we focus on the structural estimation of the parameters of the model and the implication for corporate financing policies. We call the set of estimated parameters benchmark scenario. Table 1 summarizes the estimated parameters.

4.1 Parameter estimation

The parameters λ_1, λ_2 that determine the transition of the states of the economy are estimated to fit stylized facts on the state of the US-economy after the 1960ies. An average recession lasts for 5 years[4] which corresponds to $\lambda_1 = 0.2$. Being currently in an expansion, then the probability of entering a recession within one year is about 18% and within two

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[4] The average length of state i is given by $1/\lambda_i$.

years 33%[5]. We choose a conservative setting by assuming that the average length of a recessions is much shorter and set the rate of leaving the recession to $\lambda_2 = 0.65$. In this manner a recession lasts on average for 1.54 years and the probablility of leaving a recession within one year is 48% and 73% within two years. In the long run about 76% of time is spend in an expansion an 24% in a contraction. Firms' EBIT follows the positive drift on average longer than the negative one.

We calibrate the EBIT-process x_t to fit the annually aggregated EBIT of S&P500 firms. We do not use firm level data for calibration because the difference in trends across the business cycle is more pronounced in aggregated data. An observation year is regarded to be a recession if at least six month of the fiscal year is considered as a recession by the monthly NBER recession indicator. Otherwise, the year belongs to an expansion. Using annual Compustat data from 1962 to 2006, we observe a positive average growth rate of the aggregated S&P500 EBIT in expansions and a negative growth rate in recessions. Due to our assumption that investors are risk neutral, we choose $\mu_1 = 0.04$ and $\mu_2 = -0.15$. Uncertainty in form of a volatility is intuitively higher in recessions. We choose $\sigma_1 = 0.2$ and $\sigma_2 = 0.25$. We set the initial level of EBIT to the arbitrary value $x_0 = 10$. All results in percent, especially the optimal leverage ratios and the benefit to leverage, do not vary in x_0.

In line with Gilson (1997) and Andrade and Kaplan (1998) who report defaults costs of 20% to 40 %, we choose a recovery rate in an expansion of $\alpha_1 = 0.80$ and in a recession $\alpha_2 = 0.60$. In line with previous research we set the corporate tax rate τ to 15% and the risk free rate of interest r to 0.05 approximating the historical average of a short term US government bond.

Figure 1 shows the path of aggregated S&P 500 EBIT. The graph displays the stylized facts of the regime switching process. During expansions there is a positive growth in EBIT while in recession the growth rate is negative. Without the regime switching ability it is not possible to characterize certain periods as recessions. The possibility of increasing and

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[5] The cumulative distribution function of the exponential distrubution $F_{\exp}(t)$ gives the probability that the event of a state switch occures up to time t: $F_{\exp}(t) = 1 - e^{-\lambda_i t}$.

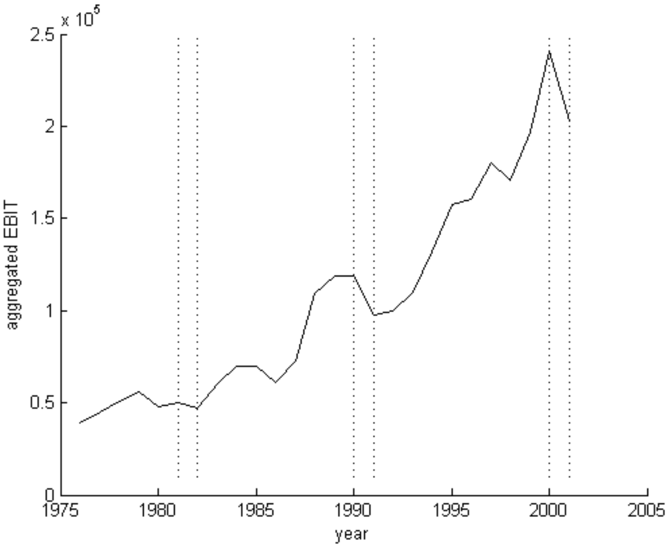


Figure 1: Aggregated EBIT of S&P500 firms from 1975 to 2001. Recession years classified by NBER are 1981-1982, 1990-1991, and 2001.

decreasing EBIT would be constant throughout time and independent of the business cycle.

4.2 Pro-cyclical leverage and benefits

The results of our benchmark scenario in table 2 show that optimal leverage is pro-cyclical. In expansions the firm chooses to finance 50% of their capital needs with debt and 50% to be equity. The positive growth of EBIT last on average 60 month which pushes EBIT on average further away from the default thresholds and reduces default. When after an average expansion a state switch to a recession occurs, then, despite the negative EBIT growth, default is unlikely because the distance between EBIT x_t and the default threshold K_2 has increased during the expansion. In contrast, if the present state is already a recession, then the firm chooses an optimal leverage ratio of 46%. On average EBIT loses 15% continuously within one year, which leads to lower debt capacity and interest coverage. Management chooses to finance a larger fraction with equity because additonal debt would increase default risk and reduce the levered firm value.

The benefit to leverage is pro-cyclical. In an expansion the unlevered firm value of 184.02

is increased through debt issuance of 96.23 by 5%. These benefits are obtained in two ways. First, in the present expansion the firm generates high tax shields and second, when the next recession enters, the firm has the same amount of debt outstanding but on average at a higher EBIT level. In this manner the tax benefits remain high in the upcoming recession. In contrast, if the present state is already a recession, the unlevered asset value of 157.34 is increased through the debt issuance of 72.15 only by 4%. Now, the firm cannot afford operating at a high leverage ratio and misses tax benefits compared to an expansion. As the expansion sets in tax benefits become more secure but are much lower compared to those that could be generated if the present state was already an expansion. Our values roughly reflect the estimates of benefits to leverage by Graham (2000). Figure 2a shows the levered firm value in dependence of the chosen leverage. First the levered firm value increase in both states due to rising tax benefits. At some point the marginal default costs exceed the additional tax benefits leading to negative net benefits which result in a decreasing firm value. The point where marginal default costs exceed marginal tax benefits is smaller in a recession leading to the observed pro-cyclical leverage. The choice of operating at a lower leverage ratio reflects a more conservative financial policy.

As long as managers choose a principal where the levered firm value exceeds the unlevered firm value, they create (not necessarily optimal) shareholder value. The points where the solid and the dashed line hit the dotted lines, are the barrier to the region where managers destroy shareholder value, because the levered firm is smaller than its unlevered value. This barrier is pro-cyclical, i.e. in an expansion this point is reached at an leverage of 0.81 and in an recession at 0.74. Because of the positive growth expectations of EBIT in expansions, the levered firm value still exceeds the unlevered value at a higher leverage level.

The value of equity is counter-cyclical. This does not imply a higher value for shareholders in recessions, it rather reflects the choice of financial sources. In our model the costs of choosing equity financing are lower, but on the other hand there are no benefits in form of tax shields. The change in shareholders' wealth is reflected through the unlevered firm value

Table 2: Results on state dependent capital structure using the parameters from the benchmark scenario.

claim		$i = 1$ expansion	$i = 2$ recession
optimal leverage	l_i^*	0.50	0.46
benefit to leverage	b_i^*	0.05	0.04
levered firm value	$v_i(x_0)$	192.86	157.34
debt value	$d_i(x_0)$	96.23	72.15
equity value	$e_i(x_0)$	96.63	85.19
unlevered firm value	$u_i(x_0)$	184.02	150.72
coupon	$C_i(x_0)$	5.68	4.40
Ratio of default thresholds	R	0.97	0.97

and the change in benefits to leverage.

The default thresholds K_i are counter-cyclical as well. Firms default earlier in a recession than in an expansion due to the negative expected growth rate μ_2. In contrast, if a firm operates in an expansion at a EBIT level between the two thresholds, it will remain active because of the expected positive growth of EBIT over time. If a sudden state switch occurs, then all firms with EBIT in the range of $[K_1, K_2]$ are liquidated simultaneously, which refers to the default clustering described by Driessen (2005), Cremers, Driessen, and Maenout (2008), and Hackbarth, Miao, and Morellec (2006). The counter-cyclical default thresholds follow from the solution to equation (31) and are observed without initial split up into three regions in section 2.

Our theoretical implications explain various empirical findings on corporate capital structure. Korteweg (2010) calculates optimal leverage with help of an extended Modigliani and Miller (1958) setting and observes pro-cyclical leverage ratios and benefits. His empirically estimated benefits are lower than our predicted values, because our optimal leverage ratios are based on a risk-neutral setting. Covas and Den Haan (2010) find that debt issuances are pro-cyclical for most size-sorted US-firms. In contrast, Korajczyk and Levy (2003) state that leverage ratios are counter-cyclical. These findings do not contradict each other, because Korajczyk and Levy (2003) examine observed leverage ratios which do not correspond to optimal or target leverage ratios because of market frictions (Leary and Roberts (2005)).

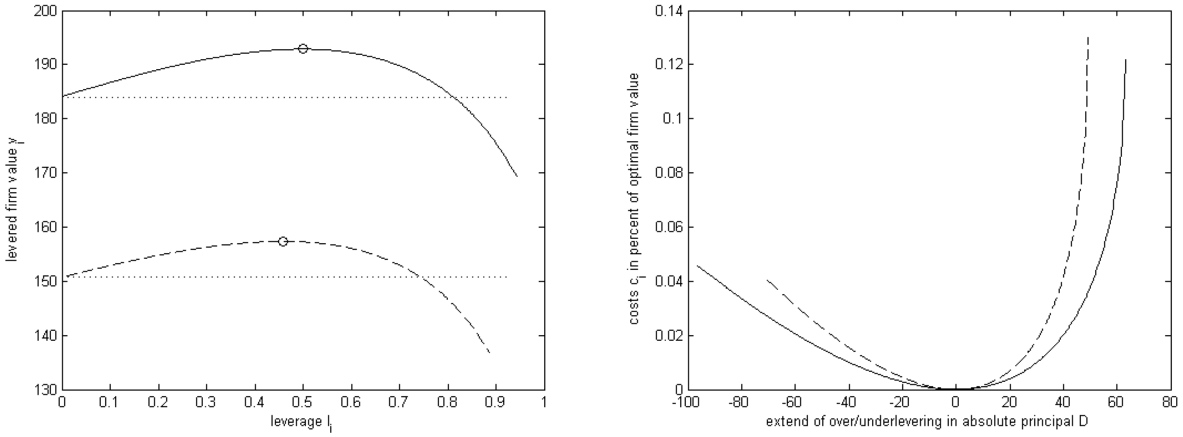
Retained earnings and temporary earnings shock change leverage ratios over time and the costs of returning to the optimum might exceed the benefits. In our model at the end of an expansion a firm operates at a leverage ratio that is substantially lower than the optimal recession-leverage due to the increased EBIT level. Hence, observed leverage ratios appear to be counter-cyclical while optimal leverage ratios remain pro-cyclical.

In other parsimonious trade-off models of capital structure (Hackbarth, Miao, and Morellec (2006)) optimal leverage is counter-cyclical. Their result is mainly driven by their assumed EBIT-process that is discontinuous at turning points. Their proposed EBIT process looses a fraction of its value in recession, but is restored to the old level in the next expansion. Implicitly the expected growth rate of EBIT in a recession is large because investors expect a positive jump. As well, in their model the growth rate in expansion is negative, because of the probability to a switch to a recession. In line with Nieuwerburgh and Veldkamp (2006) we model a "sharp and short" downturn and a "more gradual" resumption of the expansion to obtain a realistic setting.

4.3 Cost of being over- or underlevered

In this section we show that costs of operating at a non-optimal leverage are higher in recessions and that capital structure adjustments due to these costs are more common around turning points of the economy.

Often managers face the problem that they cannot infer the growth rate of their firm's EBIT exactly, nor do they know the present state with certainty. If they choose a leverage ratio based on an estimate that might deviate from the true value, they come to the problem of operating at a non-optimal leverage. For example, if the manager believes that the present state is an expansion, but in reality a recession has already started, then his chosen principal exceeds the optimal value. In this case the firm would be overlevered and face higher default costs. In contrast, if the firm chooses a principal that is too small, i.e. it underestimates its growth rate, the firm is underlevered and misses substantial tax benefits. In both cases the



(a) leverage and levered firm value

(b) costs of being over- or underlevered

Figure 2: Panel (a) shows the levered firm value in dependence of chosen leverage. All parameters correspond to the values in table 1. The solid line is the levered firm value in a expansion ($i = 1$), the dashed line in a recession ($i = 2$). The upper dotted line is the unlevered firm value in an expansion and the lower dotted line the unlevered firm value in a recession. The optimal levered firm values are marked with a circle. Panel (b) shows the costs of being over- or underlevered. The x-axis is the deviation D of the chosen principal from the optimal leverage in the corresponding state. The cost of being over- or underlevered $c_i(D)$ are measured as difference between the optimal and the chosen levered firm value in percent. The solid lines are the cost in an expansion and the dashed line in a recession.

levered firm value is smaller than the optimum.

We measure the costs of being over- or underlevered c_i as the loss in the levered firm value as percentage of optimal value v_i^* and dependent on the present state $i = 1, 2$. In this context we regard the levered firm value v_i as a function of the (non-optimal) principal P and define the difference between chosen principal P and optimal principal P^* as $D = P - P^*$. Initial EBIT x_0 are treated as a constant parameter of the levered firm value. We can now write the costs of being over- or underlevered $c_i(D)$ as

$$c_i(D) = 1 - \frac{v_i(P^* + D)}{v_i(P^*)} \ . \tag{33}$$

Figure 2b plots the costs c_i against the difference in principals D for both states i. For $D = 0$ the firm incurs no additional costs. If the principal is too low, i.e. $D < 0$, the firm faces costs of being underlevered due to missing tax benefits because the tax deductible coupon payments are lower than they are in the optimal case. These costs are higher in recessions since expected future earnings decrease on average and other means of creating shareholder value become more important. The costs of being underlevered are limited to maximum benefits to leverage.

For $D > 0$ the firm faces costs of being overlevered. Beyond the optimal principal marginal default costs increase more rapidly than tax benefits due to the high default probability. The difference in growth rates across the business cycle leads to higher costs of being overlevered in recessions. The loss of shareholder value is in this case not limited to the tax benefits because a very high leverage can diminish the levered value to the liquidation value of the assets. Combining our results, our model shows that in recessions it is more important to operate at the optimal leverage because additional costs can reduce the shareholder value more heavily.

For a small deviation from the optimum the costs do not exceed a high percentage of the levered firm value. For example, adjustment costs for debt-equity swaps to return to the optimum might outweigh the benefits. If adjustment costs are smaller than 1% of the levered firm value, then a deviation of -40 or +30 units of debt would be still be less costly than adjusting to the optimum. Hence, firms do not tend to adjust their leverage often as long as a state switch does not occur and the optimum remains the same. In contrast, if a state switch occures then the optimal principal moves by about 24 units. Especially a switch from an expanison to a recession leads to costs of overlevering, because the optimal principal is reduced by those 24 units. Now, the costs of being overlevered can exceed some percentage points of the levered firm value and it would be optimal to adjust to the target leverage. Therefore, leverage adjustments should be more common around turning points than within a state of the business cycle. Since costs of being overlevered are higher in recessions, adjustments are more likely in this state of the economy than in expansions. Our theoretical results establish empirically testable implications on the timing of capital structure adjustments.

Table 3: Results on the parameter estimation for changing macroeconomic conditions. All parameters but μ_2, σ_2, and λ_2 are held constant to the values of the benchmark scenario. The bold number indicate the benchmark scenario.

μ_2	σ_2	λ_2	l_1^*	l_2^*	b_1^*	b_2^*	$v_1(x_0)$	$v_2(x_0)$
-0.18			0.48	0.44	0.044	0.040	174.9	138.8
-0.15			0.50	0.46	0.048	0.044	192.9	157.3
-0.12			0.52	0.48	0.052	0.048	216.2	181.6
-0.08			0.55	0.51	0.059	0.055	261.0	228.1
	0.275		0.50	0.45	0.047	0.042	192.7	157.1
	0.250		0.50	0.46	0.048	0.044	192.9	157.3
	0.200		0.50	0.47	0.050	0.047	193.2	157.8
	0.150		0.51	0.49	0.052	0.050	193.6	158.2
		0.35	0.44	0.39	0.037	0.032	145.3	108.0
		0.65	0.50	0.46	0.048	0.044	192.9	157.3
		0.95	0.54	0.51	0.057	0.053	235.5	201.6
		1.25	0.57	0.54	0.064	0.060	273.7	241.4

4.4 Changes in macroeconomic risk

As noted by Stock and Watson (2002) macroeconomic risk has changed over time. A shift in macroeconomic conditions influences the market value of corporate debt and equity because it strongly affects the default risk. In our model there are three ways to reflect macroeconomic risk: the size of the negative growth rate μ_2, the volatility of EBIT in recessions σ_2 and the rate of leaving a recession λ_2.

First, we analyze the impact of the growth rate in contractions on optimal leverage and the benefit to leverage. Table 3 shows the results of a variation in μ_2 from -0.18 to -0.03. As macroeconomic risk decreases, the optimal leverage ratios increase by 7% and benefits rise by 1.5% in both states. The effect of a changing growth rate is reflected the strongest in the levered firm value which rises by 50% and is driven by an increase of the unlevered asset value that rises due to the change in μ_2. The firm responds to lower risk with an increase in leverage that comes with the trade-off of a higher default probability. In comparison to the levered firm value the change in benefits to leverage is only marginal.

As a second approach, we focus on the effect of a change in the EBIT volatility. σ_2 reflects the deviation from the downtrend of EBIT and is twofold. The chances of achieving high

EBIT levels increase at the cost of a higher default probability. The results of our parameter variation in table 3 yield that the downside risk is larger because the firm operates at a lower leverage ratio for high values of σ_2. The decline in the optimal leverage ratio in recessions is more sharply than in expansions because a present recession influences the valuation stronger than future recessions due to discounting of cash flows. The benefit to leverage decreases slightly from 5.2% (5%) to 4.7% (4.2%) as volatility increases because the firm is less likely to benefit from future tax shields. In contrast, the levered firm value is almost unaffected by an increase in σ_2 which indicates that the change in the tax shield and in the default costs are of equal magnitude. As shown in equation (8), the unlevered firm value is independent of σ_2 and constant in the parameter variation.

The third factor that characterizes a recession is the expected length of the state which equals the inverse of the rate of leaving state two λ_2. The length of a contraction determines the time during which the EBIT is exposed to the negative growth rate μ_2. Our results yield that a short recession (i.e. a high rate of leaving a recession) results in higher optimal leverage ratios (0.57 and 0.54). In case of a long recession the optimal ratios are much lower (0.44 and 0.39). The levered firm value is strongly affected by the length of a recession and so are the benefits to leverage that almost double.

Combining the results of the three parameter variations, we find that a reduction in macroeconomic risk increases optimal leverage. By acting optimally firms can achieve similar benefits by adjusting their financial policy to the new conditions. Shareholders profit primary through the increase in the unlevered firm value, but not through the benefits to debt financing which remain almost equal. Applying this finding to corporate financing policies, we conclude that after the observed change of macroeconomic risk in the 1980s, debt became more attractive to firms because the default risk was reduced. Speaking empirically, optimal leverage ratio should be higher after the change in the macroeconomic risk.

5 Concluding remarks

Our study shows that macroeconomic conditions are an important determinant of capital structure decisions. Optimal leverage and benefits to leverage depend on the present state of the economy and on the additional risk of a sudden switch to the other state. Optimal leverage ratios and benefits to leverage vary pro-cyclically, i.e. they are higher in expansions, because of varying growth rates of EBIT. Even though debt becomes more risky in recessions, tax benefits remain an important mean to maximize the levered firm value.

A change in macroeconomic risk, such as milder or less volatile recessions, leads to an increase of the levered firm value and the optimal leverage ratios. However, benefits to leverage increase only a little. Hence, after the change in macroeconomic risk in the 1980s, firm values and leverage ratios should have gone up, but firms should not have profited much from increasing tax benefits.

Our model shows that being over- or underlevered is more costly in recessions and that capital structure adjustments due to these costs are more common in recessions or around turning points. If a firm has problems to determine its optimal capital structure exactly, then the firm should act more conservatively and issue less debt. The costs of the lower tax shield are smaller than possible high default costs.

Our static setting can be extended to a dynamic setting, that would give the firm the option of restructuring its capital if EBIT have reached an upper threshold. However, the results of Hackbarth, Miao, and Morellec (2006) and Bhamra, Kuehn, and Strebulaev (2009) indicate that dynamics in structural models do not change the order of the results, only the level of leverage. Hackbarth, Miao, and Morellec (2006) find that optimal leverage is smaller when the firm has the option to issue debt in the future, but the cyclicality of debt issuances remains. In our model we omit the option of future debt issuance to keep the model parsimonious.

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A Appendix

A.1 Derivation of the differential equations in section

The derivation of the differential equations for the levered firm, the unlevered firm, and debt value follows Driffill, Raybaudi, and Sola (2003). First, we regard the unlevered firm value $u_t = u(x_t)$ of the firm which corresponds to the value of a firm that does not issue any debt. Let $\mathbb{E}$ denote the expectation operator on the σ-algebra that is generated by the Brownian motion and the Markov chain, and $\mathbb{E}_W$ denotes the expectation operator on the σ-algebra of just the Brownian motion. The infinitesimal change of its value can be described by the following equation:

$$r u_t \,\mathrm{d}t = (1-\tau) x_t \,\mathrm{d}t + \mathbb{E}[\mathrm{d}u_t] \,. \tag{34}$$

Since all investors are risk neutral, all cash flows are discounted at the risk free rate r. The required rate of return r equals the growth of after tax EBIT $(1-\tau)x_t$ plus the change in its value $\mathbb{E}[\mathrm{d}u]$ that arises because of a variation of x_t and a possible state switch. Let u_i denote the unlevered asset value conditioned on the state i. We assume that the present state is 1, so $i = 1$. With the transition probability λ_1 we have

$$\mathbb{E}[u_{t+\mathrm{d}t}] = (1 - \lambda_1 \mathrm{d}t)\ \mathbb{E}_W[u_1(x_{t+\mathrm{d}t})] + \lambda_1 \mathrm{d}t\ \mathbb{E}_W[u_2(x_{t+\mathrm{d}t})]. \tag{35}$$

The first summand denotes the event of remaining in state 1 times its probability, and the second part is the case of switching to state 2. The expected change of U on the interval $\mathrm{d}t$

is

$$\begin{aligned}
\mathbb{E}[\mathrm{d}u] &= \mathbb{E}[u(x_{t+\mathrm{d}t}) - u(x_t)] \\
&= (1 - \lambda_1 \mathrm{d}t)\ \mathbb{E}_W[u_1(x_{t+\mathrm{d}t})] + \lambda_1 \mathrm{d}t\ \mathbb{E}_W[u_2(x_{t+\mathrm{d}t})] - \mathbb{E}_W[u_1(x_t)] \\
&= \mathbb{E}_W[u_1(x_{t+\mathrm{d}t}) - u_1(x_t)] + \lambda_1 \mathrm{d}t\ \mathbb{E}_W[u_2(x_{t+\mathrm{d}t}) - u_1(x_{t+\mathrm{d}t})] \qquad (36)
\end{aligned}$$

The second summand describes a switch from state one to state two and is independent of the expectation operator $\mathbb{E}_W$. The first part equals the change of u given that the economy remains in the first state. Under the assumption of remaining in state one x_t is an Itô-process, so that we can apply Itô's lemma to $u_1(x_t)$ and receive

$$\mathrm{d}u_1 = \left(\mu_1 x u_1' + \frac{1}{2}\sigma^2 x^2 u_1''\right) \mathrm{d}t + \sigma_1 x u_1'\ \mathrm{d}W_t\ . \qquad (37)$$

It holds that $\mathbb{E}_W(\sigma_1 x\ \mathrm{d}W_t) = 0$ and we receive

$$\mathbb{E}[\mathrm{d}u] = \left(\mu_1 x u_1' + \frac{1}{2}\sigma_1^2 x^2 u_1''\right)\ \mathrm{d}t + \lambda_1(u_2 - u_1)\ \mathrm{d}t\ . \qquad (38)$$

Using (38), equation (34) equals

$$ru\ \mathrm{d}t = (1-\tau)x\ \mathrm{d}t + \left(\mu_1 x u_1' + \frac{1}{2}\sigma_1^2 x^2 u_1''\right)\ \mathrm{d}t + \lambda_1(u_2 - u_1)\ \mathrm{d}t\ . \qquad (39)$$

Hence, the differential equation to determine u_1 is

$$\frac{1}{2}x^2\sigma_1^2 u_1'' + \mu_1 x u_1' - r u_1 + \lambda_1(u_2 - u_1) + (1-\tau)x = 0\ . \qquad (5)$$

If we assume that the present state is 2, the same application of Itô's lemma yields

$$\frac{1}{2}x^2\sigma_2^2 u_2'' + \mu_2 x u_2' - r u_2 + \lambda_1(u_1 - u_2) + (1-\tau)x = 0\ . \qquad (6)$$

(5) and (6) form a system of ordinary differential equations that describe the liquidation value of the firm.

In order to derive differential equations for the value of corporate debt and the levered firm, one needs to substitute the continuous payment $(1-\tau)x$ in (34) by $C+mP$ or $(1-\tau)x+\tau C$, respectively.

In the case of corporate debt value $d_i(x)$ the firm defaults in state 2 but remains active in state 1 if $K_1 < x_t < K_2$. (35) reads in this case:

$$\mathbb{E}[d_{t+\mathrm{d}t}] = (1-\lambda_1\mathrm{d}t)\ \mathbb{E}_W[d_1(x_{t+\mathrm{d}t})] + \lambda_1\mathrm{d}t\ \mathbb{E}_W[\alpha_2 u_2(x_{t+\mathrm{d}t})], \tag{40}$$

where α_2 is the recovery rate in state 2. With this modification one can derive differential equations for the transient region by applying the same exercise as above.

A.2 Solving the differential equations

We will consider the case of corporate debt only. In the transient region we have to solve equation (11):

$$\frac{1}{2}x^2\sigma_1^2 d_1'' + \mu_1 x d_1' - (r+m)d_1 + \lambda_1(\alpha_2 w_2 x - d_1) + C + mP = 0 \tag{11}$$

which is a linear ordinary differential equation of second order. The homogeneous part of the solution reads

$$d_1^{\mathrm{hom}}(x) = A_1 x^{\gamma^1} + A_2 x^{\gamma^2}\ , \tag{41}$$

where γ_i are the roots of the characteristic equation of the equivalent differential equation with constant coefficients. γ_i satisfies

$$\gamma_{1,2} = 0.5 - \frac{\mu_1}{\sigma_1^2} \pm \sqrt{\left(0.5 - \frac{\mu_1}{\sigma_1^2}\right)^2 + 2\frac{r+m+\lambda_1}{\sigma_1^2}} \ . \tag{42}$$

The particular solution of (11) reads

$$d_1^{\text{part}}(x) = \frac{C+mP}{r+m+\lambda_1} + \frac{\alpha_2\lambda_1 w_2 x}{r+m+\lambda_1-\mu_1} \ . \tag{43}$$

w_2 is the constant coefficient for the function for the value of unlevered assets $u_i(x) = w_i x$. Combined, we have a function with two unknown coefficients A_1 and A_2:

$$d_1(x) = A_1 x^{\gamma_1} + A_2 x^{\gamma_2} + \frac{C+mP}{r+m+\lambda_1} + \frac{\alpha_2\lambda_1 w_2 x}{r+m+\lambda_1-\mu_1} \tag{44}$$

In the action region the system of differential equations (12) and (13)

$$\frac{1}{2}x^2\sigma_1^2 d_1'' + \mu_1 x d_1' - (r+m)d_1 + \lambda_1(d_2-d_1) + C + mP = 0 \tag{12}$$

$$\frac{1}{2}x^2\sigma_2^2 d_2'' + \mu_2 x d_2' - (r+m)d_2 + \lambda_2(d_1-d_2) + C + mP = 0 \tag{13}$$

is linear and of second order as well. By transforming the equations to a system with constant coefficients, one obtains the homogeneous solution functions

$$d_1^{\text{hom}}(x) = A_3 x^{\beta_1} + A_4 x^{\beta_2} + A_7 x^{\beta_3} + A_8 x^{\beta_4} \ , \tag{45}$$

$$d_2^{\text{hom}}(x) = A_5 x^{\beta_1} + A_6 x^{\beta_2} + A_9 x^{\beta_3} + A_{10} x^{\beta_4} \ . \tag{46}$$

β_i are the four distinct roots of the fourth order polynomial

$$\det\begin{pmatrix} -\beta & 1 & 0 & 0 \\ -a_1 & 1-a_4-\beta & -a_3 & 0 \\ 0 & 0 & -\beta & 1 \\ -a_6 & 0 & -a_2 & 1-a_5-\beta \end{pmatrix} = 0 \tag{47}$$

where

$$\begin{array}{lll} a_1 = \frac{-2(r+m)-2\lambda_1}{\sigma_1^2} & a_2 = \frac{-2(r+m)-2\lambda_2}{\sigma_2^2} & a_3 = \frac{2\lambda_1}{\sigma_1^2} \\ a_4 = \frac{2\mu_1}{\sigma_1^2} & a_5 = \frac{2\mu_2}{\sigma_2^2} & a_6 = \frac{2\lambda_2}{\sigma_2^2} \end{array} \tag{48}$$

that have to be calculated numerically. The particular solutions to (12) and (13) read

$$d_i^{\text{part}}(x) = \frac{C+mP}{r+m} \qquad i = 1, 2. \tag{49}$$

Combining (45), (45), and (49), the general solution functions have eight unknown coefficients:

$$d_1(x) = A_3 x^{\beta_1} + A_4 x^{\beta_2} + A_7 x^{\beta_3} + A_8 x^{\beta_4} + \frac{C+mP}{r+m} \tag{50}$$

$$d_2(x) = A_5 x^{\beta_1} + A_6 x^{\beta_2} + A_9 x^{\beta_3} + A_{10} x^{\beta_4} + \frac{C+mP}{r+m} \tag{51}$$

In line with Driffill, Raybaudi, and Sola (2003) we find that $\beta 1, \beta 2 < 0$ and $\beta 3, \beta 4 > 0$. Since the solution functions are bounded by the value of risk-free debt $\frac{C+mP}{r+m}$, it follows that $A_7 = A_8 = A_9 = A_{10} = 0$. Combining (44), (50), and (51) there are six coefficients left $A_1, A_2, A_3, A_4, A_5, A_6$ to be determined.

For every pair of real numbers A_j, A_i there is another number b_j that satisfies $b_j A_j = A_i$. In our case we can determine b_j independent of x and hence constant for a given set of parameters. Assuming $b_5 A_5 = A_3$ and $b_6 A_6 = b_4$ and plugging (50) and (51) into the differential equation (12) leads to

$$b_5 = -\frac{1}{\lambda_1}\left(\frac{1}{2}\sigma_1^2\beta_1(\beta_1 - 1) + \mu_1\beta_1 - (r+m) - \lambda_1\right) \tag{52}$$

$$b_6 = -\frac{1}{\lambda_1}\left(\frac{1}{2}\sigma_1^2\beta_2(\beta_2 - 1) + \mu_1\beta_2 - (r+m) - \lambda_1\right) \tag{53}$$

Now, there are four unknown coefficients left that can be determined uniquely with the boundary conditions (14) - (17).

When deriving the solutions for the value of the levered firm $v_i(x)$, one needs to set $m = 0$ and use the boundary conditions (23) - (26). The coefficients of the terms with positive exponents equal to zero because the levered firm value is bounded by $w_i x + \tau C$. $\hat{\beta}_i$ and $\hat{\gamma}_i$ correspond to β_i and γ_i with $m = 0$, $i = 1, 2$.

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