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# Limited Risk-Sharing and Capital Structure

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## Abstract

This paper explores consequences of different marginal risk premiums for low-beta and high-beta securities on firms' optimal capital structures. I assume that the *law of one price* fails because cross-sectional risk-sharing through short-selling is limited. Firms can create value through a capital structure with debt and equity that optimally exploits different marginal risk premiums. The empirical prediction of the model is that firms with high systematic risks have a lower debt ratio than firms with low systematic risks. Empirical evidence that completes this paper is consistent with this theoretical result.

**JEL Classification:** D52, G12, G32

**Keywords:** capital structure, security design, risk-sharing, incomplete markets

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# 1 Introduction

This paper addresses the following research question: What is the optimal capital structure of firms when investors require higher marginal risk premiums for low-beta securities than for high-beta securities? I assume that firms cannot issue state contingent securities but are limited to issue debt and equity. Thus, the role of capital structure in this paper is to maximize the value of the firm's debt and equity securities by exploiting different marginal risk premiums.

Under the assumption of perfect markets, the *law of one price* ensures the optimal allocation of risk without any arbitrage opportunities, and capital structure is irrelevant (Modigliani and Miller, 1958). However, many reasons for market frictions are known, such as segmented markets, transaction costs, limited information, short-selling constraints or borrowing constraints (see, e.g., Constantinides, 2002; Lamont and Thaler, 2003). These market frictions may imply that the *law of one price* fails. The role of security design for optimal risk-sharing when markets are incomplete has been the subject of a growing body of research (see, e.g., Allen and Gale, 1988; Acharya and Bisin, 2005; Rahi and Zigrand, 2009), and is considered an important area for future research (see, e.g., Allen, 2008).

In order to focus the analysis on risk-sharing, the presented model ignores other important factors that play a role for capital structure.<sup>1</sup> First, it is assumed that firms and investors have the same information and expectations about the future. Second, no transaction costs, taxes or bankruptcy costs are considered. Third, it is assumed that the capital structure has no effects on any real decisions of the firm such as investments or business risk. The firm, of course, needs to consider all benefits and costs that are related to capital structure, i.e., agency costs, taxes, bankruptcy costs, investment opportunity costs, *and*, as argued in this paper, risk-sharing costs. To my knowledge, there is no theory about optimal capital structure based on risk-sharing.<sup>2</sup>

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<sup>1</sup>For a literature review on capital structure, see, e.g., the classical review by Harris and Raviv (1991), or Myers (2003). Hart (2001) provides a review with a focus on contract theory. For more recent textbook treatments, see, e.g., Brealey, Myers, and Allen (2008), Berk and DeMarzo (2007) or Tirole (2006). Parsons and Titman (2009) provide a review on empirical capital structure research.

<sup>2</sup>The *trade-off theory* focusses on taxes and bankruptcy cost, the *pecking order theory* focusses on asymmetric information, *agency theories* focus on incentive problems, *contracting theories* focus on control rights, and the *market timing theory* focusses on market conditions. When risk plays a role in one of these theories, it is

The relation between securities' systemic risks and securities' risk premiums on which this paper is based is highly relevant in practice. A survey by Graham and Harvey (2001) documents that about 75% of CFOs estimate the firm's cost of equity capital "always or almost always" based on the equity's systemic risk (CAPM beta). Thus, despite the various critique about the fit of the CAPM with empirical data, systemic risk plays a role for risk premiums - at least in the mind of CFOs who finally decide about the company's capital structure.<sup>3</sup>

The crucial assumption of the presented model is that low-beta securities are priced at a lower marginal risk premium than high-beta securities. The justification for this assumption is that the *law of one price* fails because of short-sales restrictions. In practice, short-sales are expensive for investors because of required cash collaterals and margin requirements (see, e.g., Shleifer and Vishny, 1997). Then, the market portfolio is typically not efficient and investors require different risk-premiums (Ross, 1977; Sharpe, 1991). Suppose that two investor types exist: The more risk-averse investor type maximizes utility by purchasing low-beta securities, and in turn requires relatively low absolute but high marginal risk premiums. The less risk-averse investor type maximizes utility by purchasing high-beta securities, and in turn requires relatively high absolute but low marginal risk premiums. For example, consider two investors who are offered bonds and stocks of a low-beta utility firm and a high-beta travel firm. The more risk-averse investor purchases both bonds and requires a risk premium of 5% for the utility firm's investment grade bond and a significantly higher risk premium of 8% for the travel firm's high-yield bond. The less risk-averse investor purchases both stocks and requires a risk premium of 10% for the utility firm's stock and a marginally higher risk premium of

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not about *risk-sharing among investors* but other aspects that are related to risk. For example, if bankruptcy is costly because of extraordinary restructuring costs, as assumed in the *trade-off theory*, the firm's risk characteristics of future cash flows and capital structure determine expected bankruptcy costs. Another theory where risk plays a role is that of Leland and Pyle (1977). They develop a model with asymmetric information where risk-averse entrepreneurs can signal a high quality project to outside investors by keeping a large equity stake. In both examples, risk affects some costs that are relevant for the firm's optimal capital structure, but risk is not the source of the optimization problem.

<sup>3</sup>For a review on the CAPM critique, see, for example, Cochrane (1999). For example, Banz (1981) finds that the average return of small firms is above the average return of big firms which cannot be explained by the CAPM. Fama and French (1992) find that there is virtually no cross-sectional beta-mean return relation. However, in defence of the CAPM, it is argued that the CAPM that explains expected returns with *ex ante* betas should not be rejected based on studies that measure *ex post* betas, which is the case for many studies (e.g., Levy, 2010). Moreover, mean-varient efficient market proxies should reflect all assets, including real estate, etc., and proxies are difficult to calculate in practice. As shown in studies by Roll and Ross (1994) and Levy and Roll (2010), a small variation of the sample parameters can make a typical market proxy efficient. Thus, even after more than 40 years since the development of the CAPM, the debate if it is a useful model for estimating expected returns is still alive.

11% for the travel firm's stock.

The main result of this paper is that capital structure matters because it allows firms to optimally allocate the firm's risk to its debt securities and equity securities, and to thereby exploit different marginal valuations of investors. A firm's optimal capital structure depends on its risk characteristics, measured as the beta of its unlevered equity. I show that firms with high systemic risk have relatively more equity than firms with low systemic risk. This theoretical result of the model is consistent with new empirical evidence about the capital structure of US firms during the years 1999 to 2009.

The paper proceeds as follows. Section 2 discusses the related literature. Section 3 presents the model. Section 4 characterizes the optimal capital structure of firms. Section 5 test the empirical prediction of this paper with an empirical study. Finally, Section 6 contains concluding remarks. Detailed calculations and proofs appear in the appendix.

## 2 Relationship to the literature

This paper builds on important ideas of Allen and Gale (1988). They show that firms can increase the total value of securities by choosing an optimal *security design* when markets are incomplete and investors have different marginal valuations of different securities. Their model assumes the existence of different types of consumers, each of which values one of the optimal securities more highly than the other types do. Then, firms can price their securities according to the highest marginal valuation of investors. In contrast to their model, my model assumes that investors agree about the relative valuations of securities, namely less risk is better than more risk. This is crucial for my assumption about required risk premiums and implications for capital structures of firms.

This paper is also related to Acharya and Bisin (2005) and Rahi and Zigrand (2009) who study optimal security design in incomplete markets. Acharya and Bisin (2005) find that the introduction of new assets and the integration of segmented markets can generate welfare gains, and they derive the optimal financial market structure. Rahi and Zigrand (2009) study strategic intermediaries (arbitrageurs) who exploit mispricings across different mar-

ket segments. Different from these papers, limited risk-sharing in my model is not based on segmented markets. I assume that all investors can trade existing securities with each other, but they cannot make arbitrage profits through restructuring securities, short-selling or borrowing.

The role of short-sale restrictions for the capital asset pricing model has been considered since the early 70s (Blume and Friend, 1973; Ross, 1977; Sharpe, 1991). The main finding from this literature is that with short-sale restrictions, the market portfolio may not be efficient and the CAPM does not hold. It follows that “there may not be a linear relationship between expected return and beta” (Sharpe, 1991, p.505). As documented by D’Avolio (2002) for data from a large financial institution over the period 2000 to 2001, 84% of the stocks in the market could be borrowed (short-sold), and the average costs to borrow these securities were only 24 basis points per annum (value weighted) or 60 basis points per annum (equal weighted). However, arbitrage involves more than these costs (see, e.g., Shleifer and Vishny, 1997; Mitchell, Pulvino, and Stafford, 2002; Gabaix, Krishnamurthy, and Vigneron, 2007). For example, different from most textbook examples, the required cash collateral and additional margin requirements (up to 50% of the transaction volume) make short-selling expensive.

The largest part of the security design literature is based on asymmetric information, which is explicitly ignored in my model. However, both this paper and the security design literature that focusses on agency costs and monitoring have the common idea that securities should be structured such that they can be offered to the investor clientele who values them most. Gorton and Pennacchi (1990) are the first to suggest splitting cash flows to address asymmetric information. They develop a model in which banks issue bank debt (deposits) that is risk-free and liquid and therefore protects uninformed investors. Their model focusses on a financial intermediary, but they state that firms could also split risky cash flows as an alternative to bank intermediation. Boot and Thakor (1993) focus on investors’ incentives to perform monitoring. They show that a firm or a financial intermediary can create an *informationally sensitive* security by splitting cash flows and issuing debt (informationally insensitive) and equity (informationally sensitive). Security design makes informed trade more profitable for equity holders and thereby also benefits the issuer. Plantin (2004) combines the ideas of Gorton and Pennacchi (1990) and Boot and Thakor (1993) in a model and shows that

splitting cash flows into several securities is a value-maximizing arrangement for the issuer.<sup>4</sup>

Another related field of the literature analyzes the role of bankruptcy costs for a firm's capital structure. Ross (1985) argues that bankruptcy costs are higher during an economy-wide downturn. Thus, firms with high systemic risk have higher expected bankruptcy costs and therefore have lower optimal debt ratios than firms with low systemic risk. Similar to the idea by Ross (1985), this paper also links capital structure to systemic risk. The important difference is the transmission channel. In the theory of Ross (1985), systemic risk impacts capital structure *indirectly* as driver of bankruptcy costs. Bankruptcy costs have no role in my model. I assume that systemic risk impacts capital structure *directly* because of limited risk-sharing.

Several empirical studies consider the relevance of a firms' systemic risk for capital structure. They predominantly support the relevance of systemic risk for capital structure, (e.g., Sugrue and Scherr, 1989; Kale, Noe, and Ramirez, 1991). However, some studies find no significant effects. Empirical results on the relevance of volatility in general are mixed (e.g., Castanias, 1983; Bradley, Jarrell, and Kim, 1984; Kim and Sorensen, 1986). For a recent review on empirical capital structure research, see Parsons and Titman (2009) or Frank and Goyal (2009) who also provide new empirical evidence.

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<sup>4</sup>Besides the security design literature that focusses on agency costs and *monitoring*, a second important strand of the literature focusses on agency costs and *signalling*. Leland and Pyle (1977) develop a model in which the entrepreneur has private information about a project and can signal a high quality of this project by keeping a large investment in the project. The entrepreneur is risk-averse and a large investment is costly because it prevents better diversification. DeMarzo (2005) examines the impact of pooling and tranching on signalling costs. The model assumes that signalling costs come from an above market discount rate of the issuer. The results are that pooling may increase or decrease the entrepreneur's signaling costs depending on the specifics of the information asymmetries, which DeMarzo interprets as *information destruction* effect and *risk diversification* effect. Tranching reduces signalling costs as it creates a low-risk and highly liquid security.

### 3 Model

#### 3.1 Outline

The model has one period. I consider one firm that decides about its capital structures in order to maximize the value of its securities. The firm may issue debt and equity. The firm is fully financed. The model assumes symmetric information between the firm and investors, and no transaction costs or taxes. The investment program of the firm is exogenous and does not depend on its capital structure. Figure 1 shows the timeline of the model.

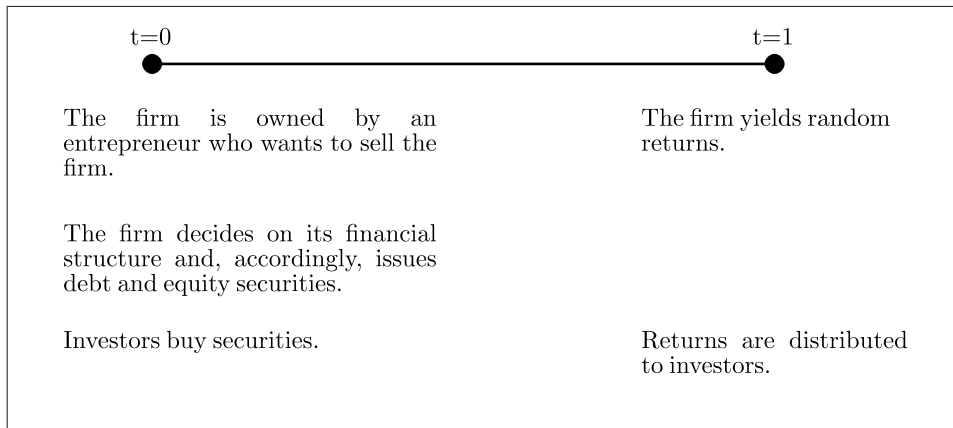


Figure 1: Timeline of the model

#### 3.2 The Firm

I consider one firm that is characterized by its normally distributed random return  $X^U \sim \mathcal{N}(\mu, \sigma^2)$  in  $t = 1$  and the sensitivity of its return to the return of the overall market, denoted as  $\beta^U$  (the superscript  $U$  stands for the *unlevered* firm). All returns are nonnegative. The firm is initially owned by an entrepreneur who only wants to consume in  $t = 0$ . This assumption ensures that the entrepreneur wants to maximize the firm's value at  $t = 0$ . The expressions *entrepreneur* and *firm* are used interchangeably.



The firm may issue debt and equity, or just unlevered equity.<sup>5,6</sup> A firm's security is denoted as  $X^\tau$ , where  $\tau \in \{D, E, U\}$  represents the security type. A capital structure with debt and equity is defined by a face value of debt  $F \in (0, \bar{X}^U)$ , where  $\bar{X}^U$  represents the highest possible value of  $X^U$ . A debt security is given by  $X^D = \min(F, X^U)$ . An equity security is given by  $X^E = X^U - X^D$ . The limited liability of investors is ensured through the earlier assumption that all returns of the firm are non-negative. All securities are divisible.

### 3.3 Risk premiums

Risk premiums required by investors are independent from the capital structure decision of a single firm because it is assumed that the securities offering of a single firm is a very small fraction of the overall market.

**Risk premiums for low-beta and high-beta securities.** I assume that low-beta securities are priced at a lower marginal risk premium than high-beta securities.<sup>7</sup> In absolute terms, low-beta securities have lower risk premiums than high-beta securities. Risk premiums are represented as a concave function of systemic risk, what I call the *security market curve*:

$$r(\beta^\tau) = \begin{cases} r_f + \beta^\tau r_1^P, & \forall X^\tau \text{ with } \beta^\tau \leq \bar{\beta} \\ r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^\tau r_2^P, & \forall X^\tau \text{ with } \beta^\tau > \bar{\beta} \end{cases}, \quad (1)$$

where  $r_f$  represents the risk-free rate,  $\beta^\tau$  represents the systemic risk of the security  $X^\tau$ ,  $r_1^P$  and  $r_2^P$  represent marginal risk premiums where  $r_1^P > r_2^P$ , and  $\bar{\beta}$  represents the threshold between the “low-beta” and “high-beta” securities. In the following, I motivate the non-uniform marginal risk premiums stated above with further assumptions about the market

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<sup>5</sup>This assumptions includes that firms cannot issue state-contingent securities. In particular the diversifiable risk portion and the systemic risk portion of a cash flow are not separately contractible. Contracts such as debt contracts and equity contracts must be written on the composite cash flow of a firm.

<sup>6</sup>The defining characteristic of a debt security is that the promised payment that is given by the face value of debt is the same in all states. In states where the return of the firm is below the face value of debt, debt investors receive the entire return. The defining characteristic of an equity security is that equity investors get the return above the face value of debt. A face value of zero or a face value equal to the maximum return of the firm implies that only unlevered equity is issued. A face value between zero and the maximum return of the firm implies a capital structure with debt and equity.

<sup>7</sup>For clarity, note that the terms “*marginal risk premium of a security*” and “*risk premium of systemic risk*” are equivalent.

structure.

**Limited risk-sharing.** Different from models with perfect markets, I assume that the *law of one price* fails for systemic risk because of short-sales restrictions.<sup>8</sup> Investors can make arbitrage profits from trading existing securities, but not from restructuring securities which requires the issuance of new securities.<sup>9</sup> Thus, the *law of one price* holds for the price of each security, but not for the price of the underlying of each security, i.e., a security’s systemic risk. This is a crucial difference from models with segmented markets where the same security trades for different prices in separate markets. Ross (1977) explores short-sale restrictions for the capital asset pricing model. He finds that the CAPM may not hold and that the efficient portfolios may lie on a concave curve that maps expected risk premiums to the standard deviations of portfolios (see, in particular, Figure 2 on page 182 in Ross’s paper).<sup>10</sup>

**Risk preferences of investors** All investors only care about systemic risk and not about diversifiable risk. It is assumed that one investor type ( $j = 1$ ) is more risk-averse and one investor type ( $j = 2$ ) is less risk-averse. Investors only want to consume in  $t = 1$ . This assumption allows to focus on the cross-sectional risk-sharing among investors, and to abstract from intertemporal dynamics.

**Systemic risks.** The concept of risk premiums that I use is best described as *macro* risk premiums rather than *market* risk premiums. As stated by Cochrane (2008, p.239), “risk

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<sup>8</sup>As a reference point for the analysis, consider the following brief review of the neoclassical assumptions and implications for risk premiums: Perfect markets prevent arbitrage opportunities, such that the *law of one price* holds for all assets. In particular, all investors with mean-variance risk preferences require a uniform risk premium for systemic risk. Investors optimize their utility by investing in a combination of a risk-free (government) security and the market portfolio, as reflected in the *two funds theorem*. All securities are priced on the *security market line* given by  $r = r_f + \beta_i r^P$ , where  $r_f$  represents the risk-free rate,  $\beta_i$  the systemic risk of security  $i$ , and  $r^P$  the systemic risk premium (also called *equity risk premium*). When a firm increases its leverage, i.e., replaces a fraction of its relatively expensive equity with relatively cheap debt, this apparent gain is offset by the higher risk premiums investors require for the debt and the equity of the higher leveraged firm. Consequently, capital structure is irrelevant.

<sup>9</sup>For example, Stiglitz (1974) allows arbitrageurs to restructure firms with a capital structure that is not optimal and thereby generalizes the result that capital structure is irrelevant. In particular, a financial intermediary “reconstitutes the firm, i.e., purchases all of its bonds and shares, then issues bonds and shares in exactly the same ratio as in the original [optimal] situation” (p.864). If such arbitrage profits can be made costlessly, it follows that capital structure is irrelevant.

<sup>10</sup>A correction of Ross’ result regarding possible “kinks” in the mean variance frontier is provided by Dybvig (1984).

premiums should reflect aggregate, macroeconomic risks; they should reflect the tendency of assets to do badly in bad economic times.” Accordingly, I assume that the sensitivity of a security’s return to the macro portfolio determines the security’s risk premium. This sensitivity is denoted as the *beta* or the *systemic risk* of a security. I assume that the macro portfolio includes non-traded assets such as real estate and the present value of labor income. Therefore, investors cannot optimize their portfolios by directly investing in the macro portfolio. This concept simplifies the analysis because I do not need an *efficient market portfolio*, which does not exist with short-sales constraints, for the pricing of securities.

**Macro portfolio.** The value of the macro portfolio in  $t = 0$  is denoted as  $M$ , and its random return in  $t = 1$  is denoted as  $X^M$ . It is assumed that  $X^M$  is a normal distributed variable, i.e.,  $X^M \sim \mathcal{N}(\mu_M, \sigma_M^2)$ .

**Illustration.** Consider Figure 2 where the basic idea of the *security market curve* is illustrated. The x-axis shows the systemic risk of a security and the y-axis shows the respective risk premiums required by investors. The dotted lines represent the indifference curves of the more risk-averse investor type (left) and the less risk-averse investor type (right). The more risk-averse investor type maximizes utility by purchasing a portfolio with the low-beta securities, and the less risk-averse investor type maximizes utility by purchasing a portfolio with the high-beta securities. It is assumed that all low-beta securities with  $\beta^T \leq \bar{\beta}$  constitute a portfolio  $M_1$ . The beta of  $M_1$  is the value weighted average of the betas of all low-beta securities. Correspondingly, all high-beta securities with  $\beta^T > \bar{\beta}$  constitute a portfolio  $M_2$ . All high-beta securities must have a higher risk premium than all low-beta securities. Otherwise, the less risk-averse investor type would prefer a low-beta security to a high-beta security. Accordingly, as pointed out in the example in the introduction, stocks typically have a higher risk premium than bonds. Securities that are offered to the more risk-averse investor type are priced over the line that crosses the risk-free rate,  $r_f$ , and the tangency portfolio  $M_1$ . Securities that are offered to the less risk-averse investor type are priced over the line that crosses the point of the highest beta and risk premium in  $M_1$ ,  $(\bar{\beta}, r(\bar{\beta}))$ , and the tangency portfolio  $M_2$ . As already noted, investors cannot short-sell securities or borrow securities on margin. Therefore, the more risk-averse investor type cannot short-sell the high-beta securities which

he considers overvalued because of the relatively low risk premium, and the less risk-averse investor type cannot leverage (buy many times) the low-beta securities which he considers undervalued because of the relatively high risk premium.

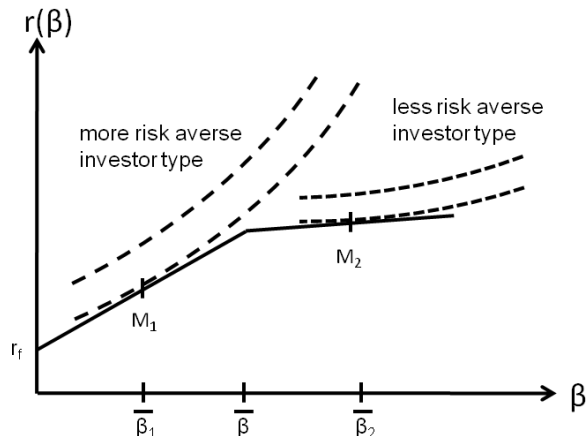


Figure 2: Risk premiums. The x-axis shows the systemic risk of a security and the y-axis shows the respective risk premiums required by investors.  $r_f$  represents the risk-free rate of return. The optimal portfolio for the more risk averse investor type is  $M_1$ . The optimal portfolio for the less risk averse investor type is  $M_2$ .

**Empirical evidence.** The assumption about different marginal risk premiums for low-beta and high-beta securities is crucial for the analysis in the present paper. As argued in the following section on the optimal capital structure of firms, low-beta securities typically represent corporate debt and high-beta securities typically represent equity. To my knowledge, there is no empirical work that makes the marginal risks premiums of debt and equity comparable, and thus could directly support or reject this assumption. It is generally assumed that the historical equity risk premium is around 6% (e.g., Mehra and Prescott, 1985). The historical debt risk premium is unclear. A study by Elton, Gruber, Agrawal, and Mann (2001) shows that “a large part of the risk on corporate bonds is systemic rather than diversifiable” (p. 247), but does not quantify what could be considered a historical debt risk premium.

Another view on risk premiums is that of firms. As stated by the so-called *under-leverage puzzle* (Miller, 1977), firms use debt less than one would expect based on the capital structure theories. In particular, expected bankruptcy costs do not seem to explain the relatively little use of debt.<sup>11</sup> From this perspective, it seems reasonable to explore effects of relatively

<sup>11</sup>In contrast to this finding, Almeida and Philippon (2007) argue that the traditional practice of using

expensive debt.

### 3.4 Characteristics of securities

As stated in the previous section, investors care only about expected returns and systemic risk. Correspondingly, the value of each security is fully characterized by its expected return,  $E(X^\tau)$ , and its systemic risk,  $\beta^\tau$ . Let  $D$  represent the firm's debt market value,

$$D = \frac{E(X^D)}{1 + r(\beta^D)}, \quad (2)$$

where  $E(X^D)$  and  $r(\beta^D)$  denote the expected value and the risk premium (in %) of the debt security, respectively. The sensitivity of a debt security's return to the return of the overall market is given by

$$\beta^D = \frac{\text{Cov}\left(\frac{X^D - D}{D}, \frac{X^M - M}{M}\right)}{\text{Var}\left(\frac{X^M - M}{M}\right)}. \quad (3)$$

Recall that  $M$  and  $X^M$  represent the market value in  $t = 0$  and the random return in  $t = 1$  of the overall market, respectively. Thus,  $\frac{X^M - M}{M}$  reflects a percent change in the return of the market relative to its market value.  $\frac{X^D - D}{D}$  reflects the percent change in the return of the debt security relative to its market value. Furthermore, let  $E$  represent the firm's equity market value,

$$E = \frac{E(X^E)}{1 + r(\beta^E)}, \quad (4)$$

where  $E(X^E)$  and  $r(\beta^E)$  denote the expected value and the risk premium (in %) of the equity security, respectively. The sensitivity of its return to the return of the overall market is given by

$$\beta^E = \frac{\text{Cov}\left(\frac{X^E - E}{E}, \frac{X^M - M}{M}\right)}{\text{Var}\left(\frac{X^M - M}{M}\right)}. \quad (5)$$

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historical default rates severely underestimates the average value of distress costs, and that *distress risk premia* should also be considered. Then, according to their calculations, a role of expected bankruptcy costs for capital structure decisions is much more plausible. The present study also argues that risk premiums are relevant, but does not interpret this as a component of bankruptcy costs.

Note that the beta of a security depends on the security's market value in  $t = 0$ , i.e.,  $D$  and  $E$  for debt and equity of firm  $i$ , respectively. Thus, if different investor types value a security differently, the beta of the security depends on how it is structured or sold. Finally, let  $\bar{V}$  represent the market value of the unlevered firm,

$$\bar{V} = \frac{E(X^U)}{1 + r(\beta^U)}. \quad (6)$$

where  $E(X^U)$  and  $r(\beta^U)$  denote the expected value and the risk premium (in %) of the unlevered equity, respectively. The sensitivity of its return to the return of the overall market is given by

$$\beta^U = \frac{\text{Cov}\left(\frac{X^U - \bar{V}}{\bar{V}}, \frac{X^M - M}{M}\right)}{\text{Var}\left(\frac{X^M - M}{M}\right)}. \quad (7)$$

## 4 Optimal Capital Structure

### 4.1 On the relevance of capital structure

A firm chooses a capital structure that maximize the value of the firm, i.e.,

$$\max_F V = \frac{E(X^D)}{1 + r(\beta^D)} + \frac{E(X^E)}{1 + r(\beta^E)}. \quad (8)$$

Recall that  $X^D = \min(X^U, F)$  is the debt security with a face value  $F$ ,  $X^E = X^U - \min(X^U, F)$  is the equity security,  $E(X^D)$  and  $E(X^E)$  are the respective expected values, and  $r(\beta^D)$  and  $r(\beta^E)$  are the respective risk premiums. Capital structure is irrelevant if investors require uniform risk premiums for systemic risk. Then, conversely, capital structure matters if investors require *non*-uniform risk premiums for systemic risk. Firms, of course, can only profit from it if securities are offered to different investor types with different valuations for systemic risk.

First, consider a firm with a relatively low beta of the unlevered firm, as illustrated in Figure 3(a). The firm's systemic risk is given by  $\beta^U$  and its risk premium is given by  $r(\beta^U)$ . The unlevered firm is priced at a relatively high marginal risk premium. Capital structure is

irrelevant if all securities are priced at this marginal risk premium (as shown by the steep solid/dotted line). Given the concave shape of the *security market curve*, the firm can increase the firm value when it offers securities to investors who require a risk premium below the steep solid/dotted line. By construction, the beta of the firm’s debt security  $\beta^D$  is below  $\beta^U$  and the beta of the firm’s equity security  $\beta^E$  is above  $\beta^U$ . Thus, the firm chooses a capital structure where its levered equity is a “high-beta” security and priced at the flat solid line.

Second, consider a firm with a relatively high beta of the unlevered firm, as illustrated in Figure 3(b). The unlevered firm is priced at a relatively low marginal risk premium but at a relatively high absolute risk premium. Again, capital structure is irrelevant if all securities are priced at this marginal risk premium (as shown by the flat dotted/solid line). The firm can increase the firm value when it offers “low-beta” debt to investors who require a risk premium below the flat dotted/solid line.

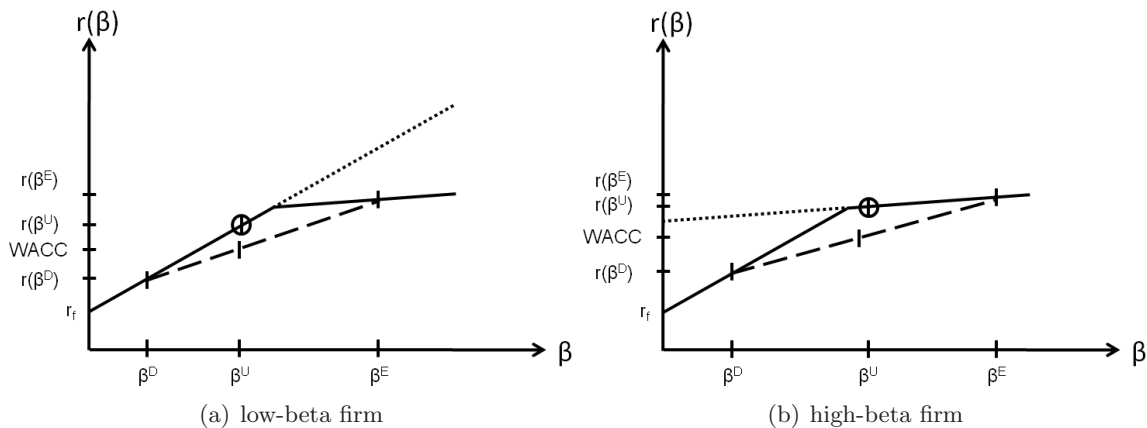


Figure 3: Relevance of capital structure. The x-axis shows the systemic risk of a security, i.e.,  $\beta^U$  for the unlevered firm,  $\beta^D$  for a debt security, and  $\beta^E$  for an equity security. The y-axis shows the respective risk premiums (WACC stands for the *weighted average costs of capital*). The solid line represents the risk premiums required by investors. The circle represents the unlevered firm. The dotted line represents the *hypothetical* risk premiums if all securities are priced at the same marginal risk premium as the unlevered firm. The dashed line represents the linear combination of a debt and equity security.

In summary, low-beta firms issue debt in order to benefit from the lower marginal risk-premiums of high-beta levered equity, and high-beta firms issue debt in order to benefit from the lower absolute risk-premiums of low-beta debt. Thus, the firm’s optimal capital structure implies that the debt security is a low-beta security and the equity security is a high-beta security. Using the definition of risk premiums in Equation 1, it follows that the respective

risk premiums for debt and equity are given by

$$r(\beta^D) = r_f + \beta^D r_1^P \quad (9)$$

and

$$r(\beta^E) = r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^E r_2^P. \quad (10)$$

Accordingly, the value of the firm is given by

$$V = \frac{E(X^D)}{1 + r_f + \beta^D r_1^P} + \frac{E(X^E)}{1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^E r_2^P}. \quad (11)$$

## 4.2 Characteristics of the optimal capital structure

This section further explores how the value of the firm's debt and the value of the firm's equity contribute to the firm's gain from leverage. I therefore compare the value of the levered firm with the value of the unlevered firm.

The value of the levered firm equals the value of the firm's debt plus the value of the firm's equity, i.e.,  $V = D + E$ . Correspondingly, under the assumption that capital structure is irrelevant, the value of the unlevered firm can be split into a *hypothetical* debt and equity component. Therefore, assume that all of the firm's securities are priced at the same marginal risk premium as the unlevered firm, i.e.,

$$\bar{r}(\beta^\tau) = \begin{cases} r_f + \beta^\tau r_1^P, & \forall X^\tau \text{ if } \beta^U \leq \bar{\beta} \\ r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^\tau r_2^P, & \forall X^\tau \text{ if } \beta^U > \bar{\beta} \end{cases}, \quad (12)$$

In the following, I refer to these risk premiums as *hypothetical* risk premiums or *security market line*. Moreover, I define

$$\bar{D} = \frac{E(X^D)}{1 + \bar{r}(\bar{\beta}^D)} \quad (13)$$



and

$$\bar{E} = \frac{E(X^E)}{1 + \bar{r}(\bar{\beta}^E)}. \quad (14)$$

Note that  $\bar{\beta}^D$  and  $\bar{\beta}^E$  are calculated based on  $\bar{D}$  and  $\bar{E}$ , respectively (as already noted, the beta of a security also depends on its value in  $t = 0$ ). Then, for any given capital structure, the value of the unlevered firm can be represented as

$$\bar{V} = \bar{D} + \bar{E}. \quad (15)$$

The relative gain from introducing a capital structure vs. the unlevered value of the firm is given by

$$\Delta V = V - \bar{V} \quad (16)$$

$$= D - \bar{D} + E - \bar{E} \quad (17)$$

$$= \bar{D} \frac{\bar{r}(\bar{\beta}^D) - r(\beta^D)}{1 + r(\beta^D)} + \bar{E} \frac{\bar{r}(\bar{\beta}^E) - r(\beta^E)}{1 + r(\beta^E)}. \quad (18)$$

See the appendix for detailed calculations.

Maximizing  $\Delta V$  is obviously equivalent to maximizing  $V$ . As already pointed out, capital structure only matters when debt and equity securities are priced at different marginal risk premiums. Therefore  $\beta^D \leq \bar{\beta}$  and  $\beta^E > \bar{\beta}$ . Then, if  $\beta^U \leq \bar{\beta}$ , it follows that  $\bar{r}(\bar{\beta}^D) = r(\beta^D)$ , and  $\Delta V$  becomes

$$\Delta V = \bar{E} \frac{\bar{r}(\bar{\beta}^E) - r(\beta^E)}{1 + r(\beta^E)}. \quad (19)$$

Correspondingly, if  $\beta^U > \bar{\beta}$ , it follows that  $\bar{r}(\bar{\beta}^E) = r(\beta^E)$ , and  $\Delta V$  becomes

$$\Delta V = \bar{D} \frac{\bar{r}(\bar{\beta}^D) - r(\beta^D)}{1 + r(\beta^D)}. \quad (20)$$

These results reinforce the intuition of the previous section: a low-beta firm uses its capital structure to maximize the relative value of its (high-beta) levered equity, while a high-beta firm uses its capital structure to maximize the relative value of its (low-beta) debt.

Equations 19 and 20 indicate that the firm must consider a trade-off for its optimal capital structure: spread vs. value. The terms  $\bar{r}(\bar{\beta}^E) - r(\beta^E)$  and  $\bar{r}(\bar{\beta}^D) - r(\beta^D)$  represent the spread between the *hypothetical* risk premiums and the (lower) *actual* risk premiums for equity and debt, respectively. This spread is highest for “extreme” securities. For a low-beta firm, this is extremely levered equity. For a high-beta firm, this is extremely safe debt. However, the spread between the risk premiums is not all that matters for the optimal capital structure. A second factor is the value of each security, represented by the terms  $\bar{E}$  and  $\bar{D}$  for equity and debt, respectively. “Extreme” securities only have a small value. Extremely levered equity implies a very high debt ratio of the firm which means a very small value of the equity security. Correspondingly, extremely safe debt implies a very small debt ratio of the firm which means a very small value of the debt security. Thus, maximizing  $\Delta V$  requires to consider both the “spread” factor and the “value” factor of the capital structure.

The optimal capital structure is illustrated with a numerical example. Figure 4(a) in the Appendix shows a risk-free rate of zero, a marginal risk premium for low-beta securities ( $\beta^T \leq 0.5$ ) of 8% and a marginal risk premium for high-beta securities ( $\beta^T > 0.5$ ) of 4%. Suppose the firm has an unlevered beta of  $\beta^U = 0.25$ . The dashed line represents the hypothetical risk premiums if all securities are priced at the marginal risk premium of the unlevered firm. Figure 4(b) illustrates how the beta of debt (the lower solid line) and the beta of equity (the upper solid line) depend on the debt ratio of the firm. Figure 4(c) illustrates how the required risk premiums for debt and equity depend on the debt ratio of the firm. The optimal capital structure of the firm is given for a debt ratio of 85%. This is where the value of the firm is maximized and, equivalently, the firm’s weighted average cost of capital (WACC) is minimized. The grey area shows the product of the spread between the *actual* and *hypothetical* risk premiums and the value of the equity security (scaled by the value of the unlevered firm and excluding discounting with  $1 + r(\beta^E)$ ), i.e.,  $\frac{\bar{E}}{V} (\bar{r}(\bar{\beta}^E) - r(\beta^E))$ . The same is illustrated in Figure 5 in the Appendix for a high-beta firm ( $\beta^U = 1$ ). The optimal capital structure of the firm is given for a debt ratio of 59%. The grey area shows the product of the spread and the value of the debt security (scaled by the value of the unlevered firm and excluding discounting with  $1 + r(\beta^D)$ ), i.e.,  $\frac{\bar{D}}{V} (\bar{r}(\bar{\beta}^D) - r(\beta^D))$ .

### 4.3 Empirical prediction

This section addresses the question how the firm's risk characteristics, as reflected in its unlevered beta,  $\beta^U$ , impact the firm's capital structure.<sup>12</sup> Let  $F^*$  denote the face value of debt that determines the firm's optimal capital structure. Then, the impact of  $\beta^U$  on a firm's capital structure is given by the partial derivative  $\frac{dF^*}{d\beta^U}$ .

**Proposition 1** (Firms' risk characteristics and capital structure). *A firm with high systemic risk tends to have less debt than a firm with little systemic risk.*

See the appendix for the proof.

The illustrations in Figure 4 and in Figure 5 which show a low-beta firm ( $\beta = 0.25$ ) with an optimal debt ratio of 85% and a high-beta firm ( $\beta = 1$ ) with an optimal debt ratio of 59%, respectively, are consistent with this result. Moreover, consider Figure 6 which shows another high-beta firm ( $\beta = 1.25$ ). This allows us to compare two firms that both benefit from issuing low-beta debt. The optimal capital structure of the firm is given for a debt ratio of 51%, which is also consistent with Proposition 1.

## 5 Empirical evidence

This section tests the empirical prediction of the model that a firm's systemic risk, as reflected in the firm's unlevered beta, impacts the firm's capital structure (see Proposition 1). To my knowledge, the role of unlevered beta for capital structure has not been tested in the more recent empirical studies.<sup>13</sup> I therefore explore if a firm's systemic risk adds explanatory power in a standard capital structure regression with recent data for the period 1999 to 2009.

Although the model highlights a potential new relation between a firm's systemic risk and optimal capital structure, the empirical prediction of the model is not unique. For example,

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<sup>12</sup>The analytical approach that I use is similar to the one of Green and Talmor (1986) or Campbell and Kracaw (1990) who model asymmetric information and asset substitution. In particular, Green and Talmor (1986) analyze the impact of the firm's risk level on capital structure, and Campbell and Kracaw (1990) analyze the impact of observable risk on capital structure.

<sup>13</sup>Studies by Sugrue and Scherr (1989) and Kale, Noe, and Ramirez (1991) support the relevance of systemic risk for capital structure.

a high unlevered beta may also be indicative for high bankruptcy costs. As argued by Ross (1985), bankruptcy costs are higher for firms that go bankrupt during an economy-wide downturn. Therefore, a significant role of systemic risk may also be based on alternative explanations.

## 5.1 Data and Methodology

The empirical study is based on Value Line data, as provided by Damodaran (2010). It represents yearly industry averages for the period 1999 to 2009. Each year includes data for about 90 industry sectors that represent about 6000 firms. Financial industries are excluded in the regressions. The total number of observations is 864.

I use simple OLS panel regression analysis to explain the debt ratio of firms. The regression setup is:

$$DR_{it} = \alpha_0 + \alpha_1 R_{it} + \sum_{n=2}^7 \alpha_n C_{nit} + T_t + \varepsilon_{it} \quad (21)$$

$DR_{it}$  is the debt ratio for the industry sector  $i$  in period  $t$ .  $R_{it}$  is a short hand for risk measures, namely *unlevered beta*, *STD (equity)* and *STD (firm value)*.  $C_{nit}$  includes  $n = 6$  control variables for each industry sector  $i$  in period  $t$ .  $T_t$  covers time effects for each period  $t$ . Finally,  $\varepsilon_{it}$  represents the error term.

The dependent variable *debt ratio* is calculated as the value of debt divided by the total value of debt and equity. I run all regressions both for market values and for book values of debt ratios.

The main explanatory variable is *unlevered beta* that represents the variable  $\beta^U$  from the capital structure model in Section 4. It is adjusted for cash holdings of firms. Other variables that are also linked to risk are *STD (equity)*, the standard deviation of stock prices measured over three years, and *STD (firm value)*, the estimated standard deviation of the firm value measured over three years. Different from *unlevered beta*, the variables *STD (equity)* and *STD (firm value)* obviously also reflect diversifiable (idiosyncratic) risk in addition to market

(systematic) risk. Thus, they may be indicative for bankruptcy costs. All three variables are highly correlated. The relations between these three main explanatory variables and the *debt ratio* (measured by market values) are illustrated in Figure 7.

Control variables included in the regressions are some standard variables for capital structure tests, e.g., as suggested by Damodaran (2010). These are: *price-to-book ratio*, *insider holdings*, *tax rate*, *expected growth*, *fixed-assets-to-book-value* and *EBITDA-to-market-value*.

Table 1 shows summary statistics and Table 2 shows correlations between the debt ratio and the main explanatory variables.

## 5.2 Main results

Table 3 shows OLS regression results with time fixed effects for average industry debt ratios that are based on market values. Robust standard errors are reported. Industry fixed effects are included in the robustness regressions that are discussed in the next section. The important result of this regression is that *unlevered beta* is highly significant for all specifications. The variable has a negative coefficient between -0.06 and -0.11. Thus, as predicted by Proposition 1, the debt ratio decreases in systemic risk. For the illustration of the economic impact of a negative coefficient of -0.1, suppose a firm has an *unlevered beta* of 1 and a *debt ratio* of 0.2. If the *unlevered beta* increases by 0.5 to 1.5, the *debt ratio* should decrease by 0.05 to 0.15. Looking at Figure 7(a), such an interpretation seems reasonable.

*STD (equity)* is significant if tested jointly with *unlevered beta* (Specifications 4), but not if tested as only explanatory variable for risk (Specification 2). Thus, the impact of *STD (equity)* on the capital structure is somehow vague. A particular problem with using *STD (equity)* as explanatory variable is endogeneity because, by construction, capital structure impacts the standard deviation of equity. This problem is not relevant for *unlevered beta* or *STD (firm value)*, at least not by construction.

*STD (firm value)* is highly significant for most specifications. Considering the coefficients, it has the strongest impact on the debt ratio among the three risk measures.

As expected, most of the control variables (*price-to-book ratio*, *tax rate*, *expected growth*, *fixed-assets-to-book-value* and *EBITDA-to-market-value*) are also significant in most of the regressions.

In summary, results of this empirical study confirm the relevance of systemic risk for a firm's capital structure. As predicted in Proposition 1 of the model, the unlevered beta has a significant and negative impact on the debt ratio of firms for all regressions.

### 5.3 Robustness regressions

Table 4 shows regression results with industry fixed effects. It could be expected that these results are less significant than the regressions without industry effects because the *debt ratio* and the *unlevered beta* are relatively stable for one industry over the 10 year time horizon used in this study. Thus, the industry dummies may have a strong effect on the regressions without explaining what really impacts the average capital structure of an industry. In spite of these considerations, the impact of the *unlevered beta* on the *debt ratio* of firms is highly significant or significant at the 5% level for all specification .

Table 5 and 6 show results where the dependent variable *debt ratio* is calculated from the book value of equity. These regressions have a lower explanatory power, measured as R-squared, than the regressions in Table 3 and Table 4 where the dependent variable *debt ratio* is calculated from the market value of equity. The adj. R-squared of the OLS regressions without industry fixed effects are 0.35-0.48 (market values) vs. 0.23-0.43 (book values). The R-squared (within) of the fixed effects regressions are 0.39-0.45 (market values) vs. 0.13-0.18 (book values).

## 6 Conclusion

The contribution of this paper is to complement existing theories on capital structure. To my knowledge, this is the first paper that explores consequences of a potential *non-linear* relation between securities' risks and securities' risk premiums on firms' capital structures. Based on

the assumption that low-beta securities are priced at a higher marginal but lower absolute risk premium than high-beta securities, I show that the firm's capital structure is relevant for the value of the firm. A firm's optimal capital structure reflects that the firm takes maximum advantage of the different marginal risk premiums required by investors. I show that firms with high systemic risks hold relatively more equity, and thus have a lower debt ratio than firms with low systemic risks. This theoretical result of the model is consistent with new empirical evidence about the capital structure of US firms during the years 1999 to 2009.

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## A Calculations and proofs

Calculations for Equation 16 (relative gain  $\Delta V$ ).

$$\Delta V = V - \bar{V} \quad (22)$$

$$= D - \bar{D} + E - \bar{E} \quad (23)$$

$$= \frac{E(X^D)}{1+r(\beta^D)} - \frac{E(X^D)}{1+\bar{r}(\beta^D)} + \frac{E(X^E)}{1+r(\beta^E)} - \frac{E(X^E)}{1+\bar{r}(\beta^E)} \quad (24)$$

$$= E(X^D) \left( \frac{1}{1+r(\beta^D)} - \frac{1}{1+\bar{r}(\beta^D)} \right) + E(X^E) \left( \frac{1}{1+r(\beta^E)} - \frac{1}{1+\bar{r}(\beta^E)} \right) \quad (25)$$

$$= E(X^D) \frac{(1+\bar{r}(\beta^D)) - (1+r(\beta^D))}{(1+r(\beta^D))(1+\bar{r}(\beta^D))} + E(X^E) \frac{(1+\bar{r}(\beta^E)) - (1+r(\beta^E))}{(1+r(\beta^E))(1+\bar{r}(\beta^E))} \quad (26)$$

$$= \frac{E(X^D)}{(1+\bar{r}(\beta^D))} \frac{(\bar{r}(\beta^D) - r(\beta^D))}{(1+r(\beta^D))} + \frac{E(X^E)}{(1+\bar{r}(\beta^E))} \frac{(\bar{r}(\beta^E) - r(\beta^E))}{(1+r(\beta^E))} \quad (27)$$

$$= \bar{D} \frac{(\bar{r}(\beta^D) - r(\beta^D))}{1+r(\beta^D)} + \bar{E} \frac{(\bar{r}(\beta^E) - r(\beta^E))}{1+r(\beta^E)} \quad (28)$$

**Proof of Proposition 1 (the firm's risk characteristics and capital structure).** I

need to show that

$$\text{sign} \left( \frac{dF^*}{d\beta^U} \right) < 0. \quad (29)$$

$F^*$  is only known implicitly. Using the implicit function theorem, the impact of  $\beta^U$  on  $F^*$  is given by

$$\frac{dF^*}{d\beta^U} = \frac{-\partial^2 V / \partial F \partial \beta^U}{\partial^2 V / \partial F \partial F}. \quad (30)$$

Assuming that the second-order condition for an interior optimum is satisfied, i.e.,  $\frac{\partial^2 V}{\partial F \partial F} < 0$ , it follows

$$\text{sign} \left( \frac{dF^*}{d\beta^U} \right) = \text{sign} \left( \frac{\partial^2 V}{\partial F \partial \beta^U} \right). \quad (31)$$

Recall that

$$V = \frac{E(X^D)}{1 + r_f + \beta^D r_1^P} + \frac{E(X^E)}{1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^E r_2^P}, \quad (32)$$

as specified in Equation 11. Next, I derive a representation of  $V$  in terms of  $\beta^U$ , and therefore establish a relation between  $\beta^D$  and  $\beta^U$ , as well as between  $\beta^E$  and  $\beta^U$ .

As stated in Equation 3, the beta of a debt security is defined as

$$\beta^D = \frac{\text{Cov}\left(\frac{X^D - D}{D}, \frac{X^M - M}{M}\right)}{\text{Var}\left(\frac{X^M - M}{M}\right)}, \quad (33)$$

which can be represented as

$$\beta^D = \frac{M \text{Cov}(X^D, X^M)}{D \text{Var}(X^M)} \quad (34)$$

$$= \frac{1 + r(\beta^D)}{E(X^D)} M \frac{\text{Cov}(X^D, X^M)}{\text{Var}(X^M)}, \quad (35)$$

$$= \frac{1 + r_f + \beta^D r_1^P}{E(X^D)} M \frac{\text{Cov}(X^D, X^M)}{\text{Var}(X^M)}. \quad (36)$$

Solving for  $\beta^D$ , we get

$$\beta^D = \frac{(1 + r_f) M \text{Cov}(X^D, X^M)}{E(X^D) \text{Var}(X^M) - r_1^P M \text{Cov}(X^D, X^M)}. \quad (37)$$

As stated in Equation 7, the beta of the unlevered firm is defined as

$$\beta^U = \frac{\text{Cov}\left(\frac{X^U - \bar{V}}{\bar{V}}, \frac{X^M - M}{M}\right)}{\text{Var}\left(\frac{X^M - M}{M}\right)}, \quad (38)$$

which can be represented as

$$\beta^U = \frac{M \text{Cov}(X^U, X^M)}{\bar{V} \text{Var}(X^M)} \quad (39)$$

$$= \frac{1 + r(\beta^U)}{E(X^U)} M \frac{\text{Cov}(X^U, X^M)}{\text{Var}(X^M)}. \quad (40)$$

Assume that  $\beta^U > \bar{\beta}$ , such that

$$r(\beta^U) = r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P \quad (41)$$

(the implications of this analysis are unchanged for  $\beta^U \leq \bar{\beta}$ ). It follows that

$$\beta^U = \frac{1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P}{E(X^U)} M \frac{\text{Cov}(X^U, X^M)}{\text{Var}(X^M)}. \quad (42)$$

The relation between  $\beta^D$  and  $\beta^U$  is based on the relation between  $\text{Cov}(X^D, X^M)$  and  $\text{Cov}(X^U, X^M)$ .

I therefore use the following result on the covariance of normal distributed variables:

$$\begin{aligned} \text{Cov}(\min(X_1, X_2), X_3) &= \text{Cov}(X_1, X_3)\text{Prob}(X_1 = \min(X_1, X_2)) \\ &\quad + \text{Cov}(X_2, X_3)\text{Prob}(X_2 = \min(X_1, X_2)) \end{aligned} \quad (43)$$

where  $\text{Prob}(\cdot)$  represents a probability function. Note that

$$\text{Prob}(X_1 = \min(X_1, X_2)) = \text{Prob}(X_1 \leq X_2). \quad (44)$$

Thus,  $\text{Prob}(X^U = \min(X^U, F)) = \text{Prob}(X^U \leq F)$ , which represents the default probability of the firm, i.e., the probability that the firm's cash flow  $X^U$  is below or equal to the firm's face value of debt  $F$ . Moreover, note that  $\text{Cov}(F, X^M) = 0$  because  $F$  is a constant. Then, we get

$$\text{Cov}(X^D, X^M) = \text{Cov}(\min(X^U, F), X^M) \quad (45)$$

$$= \text{Cov}(X^U, X^M)\text{Prob}(X^U = \min(X^U, F)) \quad (46)$$

$$+ \text{Cov}(F, X^M)\text{Prob}(F = \min(X^U, F))$$

$$= \text{Cov}(X^U, X^M)\text{Prob}(X^U \leq F). \quad (47)$$

Using the result from Equation 42, which is equivalent to

$$\text{Cov}(X^U, X^M) = \frac{\beta^U \text{Var}(X^M) E(X^U)}{(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) M}, \quad (48)$$

it follows that

$$\text{Cov}(X^D, X^M) = \frac{\beta^U \text{Var}(X^M) E(X^U)}{(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) M} \text{Prob}(X^U \leq F). \quad (49)$$

Then, the systemic risk of debt  $\beta^D$  can be represented in terms of  $\beta^U$  as

$$\beta^D = \frac{(1 + r_f) M \text{Cov}(X^D, X^M)}{E(X^D) \text{Var}(X^M) - r_1^P M \text{Cov}(X^D, X^M)} \quad (50)$$

$$= \frac{(1 + r_f) M \frac{\beta^U \text{Var}(X^M) E(X^U)}{(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) M} \text{Prob}(X^U \leq F)}{E(X^D) \text{Var}(X^M) - r_1^P M \frac{\beta^U \text{Var}(X^M) E(X^U)}{(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) M} \text{Prob}(X^U \leq F)} \quad (51)$$

$$= \frac{E(X^U)(1 + r_f) \text{Prob}(X^U \leq F) \beta^U}{E(X^D)(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) - E(X^U) r_1^P \text{Prob}(X^U \leq F) \beta^U}. \quad (52)$$

Next, consider the relation between  $\beta^E$  and  $\beta^U$ . As stated in Equation 5, the beta of an equity security is defined as

$$\beta^E = \frac{\text{Cov}(\frac{X^E - E}{E}, \frac{X^M - M}{M})}{\text{Var}(\frac{X^M - M}{M})}, \quad (53)$$

which can be represented as

$$\beta^E = \frac{M \text{Cov}(X^E, X^M)}{E \text{Var}(X^M)} \quad (54)$$

$$= \frac{1 + r(\beta^E)}{E(X^E)} M \frac{\text{Cov}(X^E, X^M)}{\text{Var}(X^M)} \quad (55)$$

$$= \frac{1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^E r_2^P}{E(X^E)} M \frac{\text{Cov}(X^E, X^M)}{\text{Var}(X^M)}. \quad (56)$$

Solving for  $\beta^E$ , we get

$$\beta^E = \frac{(1 + r_f + \bar{\beta}(r_1^P - r_2^P)) M \text{Cov}(X^E, X^M)}{E(X^E) \text{Var}(X^M) - r_2^P M \text{Cov}(X^E, X^M)}. \quad (57)$$

Using the results from Equation 43 (Siegel, 1993) and from Equation 48, it follows that

$$\text{Cov}(X^E, X^M) = \text{Cov}(X^U - \min(X^U, F), X^M) \quad (58)$$

$$= \text{Cov}(X^U, X^M) - \text{Cov}(\min(X^U, F), X^M) \quad (59)$$

$$= \text{Cov}(X^U, X^M) - \text{Cov}(X^U, X^M)\text{Prob}(X^U = \min(X^U, F)) - \text{Cov}(F, X^M)\text{Prob}(F = \min(X^U, F)) \quad (60)$$

$$= \text{Cov}(X^U, X^M)(1 - \text{Prob}(X^U \leq F)) \quad (61)$$

$$= \frac{\beta^U \text{Var}(X^M) E(X^U)}{(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) M} (1 - \text{Prob}(X^U \leq F)). \quad (62)$$

Then, the systemic risk of equity  $\beta^E$  can be represented in terms of  $\beta^U$  as

$$\beta^E = \frac{(1 + r_f + \bar{\beta}(r_1^P - r_2^P)) M \text{Cov}(X^E, X^M)}{E(X^E) \text{Var}(X^M) - r_2^P M \text{Cov}(X^E, X^M)} \quad (63)$$

$$= \frac{(1 + r_f + \bar{\beta}(r_1^P - r_2^P)) M \frac{\beta^U \text{Var}(X^M) E(X^U)}{(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) M} (1 - \text{Prob}(X^U \leq F))}{E(X^E) \text{Var}(X^M) - r_2^P M \frac{\beta^U \text{Var}(X^M) E(X^U)}{(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) M} (1 - \text{Prob}(X^U \leq F))} \quad (64)$$

$$= \frac{E(X^U)(1 + r_f + (r_1^P - r_2^P)\bar{\beta})(1 - \text{Prob}(X^U \leq F))\beta^U}{E(X^E)(1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \beta^U r_2^P) - E(X^U)r_2^P(1 - \text{Prob}(X^U \leq F))\beta^U}. \quad (65)$$

Thus, we can use the new representations of  $\beta^D$  and  $\beta^E$  in Equation 32 (or, equivalently, 11) and get

$$V = \frac{E(X^D)}{1 + \frac{E(X^U)(1+r_f)\text{Prob}(X^U \leq F)\beta^U}{E(X^D)(1+r_f+\bar{\beta}(r_1^P-r_2^P)+\beta^U r_2^P)-E(X^U)r_1^P\text{Prob}(X^U \leq F)\beta^U} r^P} + \frac{E(X^E)}{1 + r_f + \bar{\beta}(r_1^P - r_2^P) + \frac{E(X^U)(1+r_f+(r_1^P-r_2^P)\bar{\beta})(1-\text{Prob}(X^U \leq F))\beta^U}{E(X^E)(1+r_f+\bar{\beta}(r_1^P-r_2^P)+\beta^U r_2^P)-E(X^U)r_2^P(1-\text{Prob}(X^U \leq F))\beta^U} r^P}. \quad (66)$$

It is now possible to analyze the impact of  $\beta^U$  on the optimal capital structure of the firm.

The first-order condition for the optimal value  $F^*$  is given by

$$\frac{\partial V}{\partial F} = \frac{\partial E(X^D)}{\partial F} \frac{(r_1^P - r_2^P)\bar{\beta}}{(1 + r_f)(1 + r_f + (r_1^P - r_2^P)\bar{\beta})} - \frac{\partial \text{Prob}(X^U \leq F)}{\partial F} \frac{E(X^U)(r_1^P - r_2^P)(1 + r_f + r_1^P \bar{\beta})\beta^U}{(1 + r_f)(1 + r_f + (r_1^P - r_2^P)\bar{\beta})(1 + r(\beta^U))} = 0 \quad (67)$$



Furthermore,

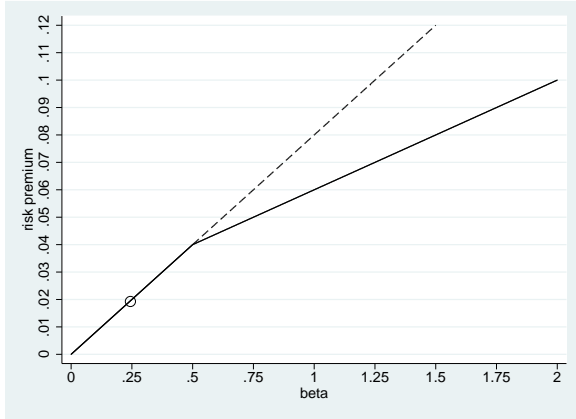
$$\frac{\partial^2 V}{\partial F \partial \beta^U} = - \frac{\partial \text{Prob}(X^U \leq F)}{\partial F} \frac{E(X^U)(r_1^P - r_2^P)(1 + r_f + r_1^P \bar{\beta})}{(1 + r_f)(1 + r(\beta^U))^2}. \quad (68)$$

We know that the default probability  $\text{Prob}(X^U \leq F)$  increases in  $F$ , i.e.,  $\frac{\partial \text{Prob}(X^U \leq F)}{\partial F} > 0$ , and that  $E(X^U)(r_1^P - r_2^P)(1 + r_f + r_1^P \bar{\beta})$  is positive. Thus,

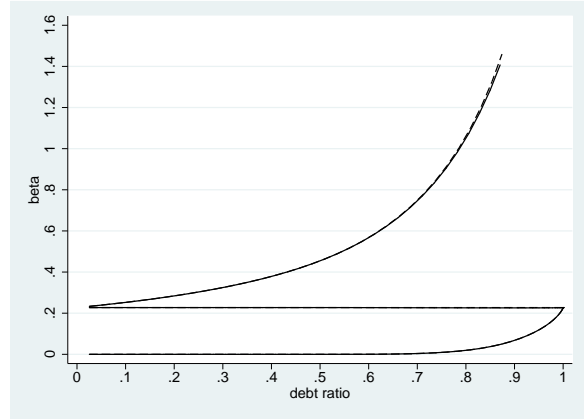
$$\text{sign} \left( \frac{\partial^2 V}{\partial F \partial \beta^U} \right) < 0. \quad (69)$$

*Q.E.D.*

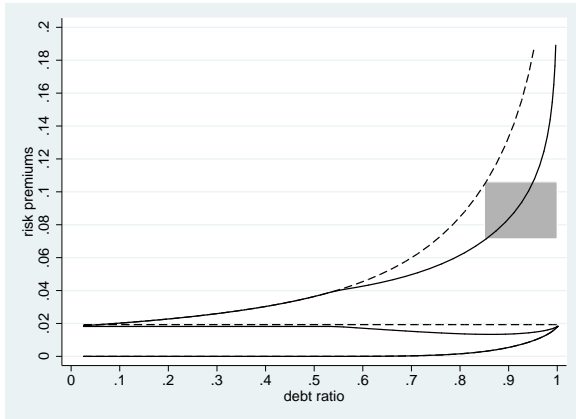
## B Figures: Illustrations of the model



(a) Risk premiums: The x-axis represents the beta of a security, and the y-axis represents the respective risk premiums. The solid line shows the *actual* risk premiums required by investors. The marginal risk premiums are 8% for low-beta securities ( $\beta \leq 0.5$ ) and 4% for high-beta securities ( $\beta > 0.5$ ). The circle marks the beta and required risk premium of the unlevered firm with  $\beta^U = 0.25$ . The dashed line represents the *hypothetical* risk premium if all securities are priced at the marginal risk premium of the unlevered firm.

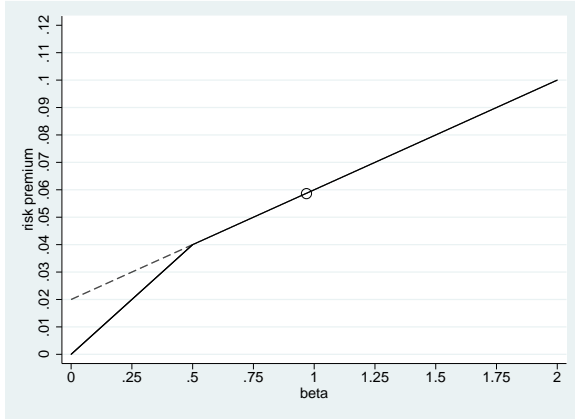


(b) Debt beta and equity beta: Calculations are based on a Monte Carlo simulation with random returns of the firm  $X^U \sim \mathcal{N}(4, 0.3025)$ . The x-axis represents the debt ratio of a firm, and the y-axis represents the respective betas of the firm's securities. The bottom line represents the debt security and the top line represents the equity security. Note that, in principle, different risk premiums (the actual or the hypothetical) also effect the beta of a security. Here, the effect is only minor and not visible in the figure.

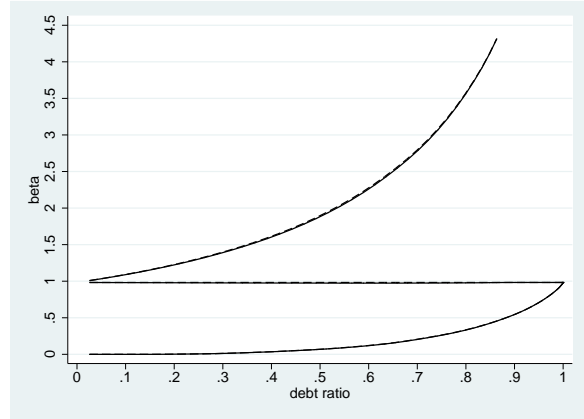


(c) Optimal capital structure: Using the input from the two figures above, this figure shows how the firm's debt ratio impacts risk premiums of the firm's debt and equity security. The solid lines show the risk premiums of the debt security (bottom), the equity security (top), and the firm's WACC (middle) if priced with the *actual* risk premiums. The dashed lines show the risk premiums of the debt security (bottom), the equity security (top), and the firm's WACC (middle) if priced with the *hypothetical* risk premiums. The firm's optimal debt ratio is 85%. This is where the spread between the equity risk premiums and its "size effect" matter most, as illustrated by the grey area.

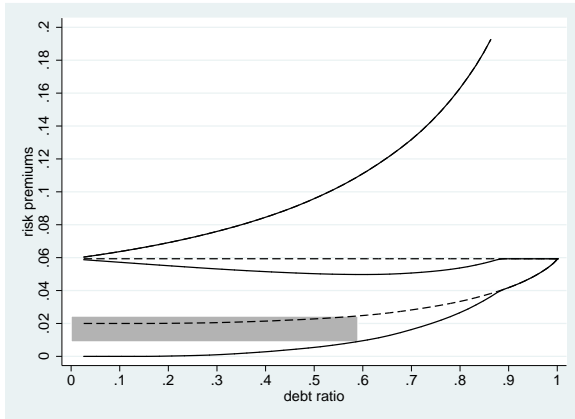
Figure 4: Optimal capital structure for a low-beta firm with  $\beta^U = 0.25$ .



(a) Risk premiums: The x-axis represents the beta of a security, and the y-axis represents the respective risk premiums. The solid line shows the *actual* risk premiums required by investors. The marginal risk premiums are 8% for low-beta securities ( $\beta \leq 0.5$ ) and 4% for high-beta securities ( $\beta > 0.5$ ). The circle marks the beta and required risk premium of the unlevered firm with  $\beta^U = 1$ . The dashed line represents the *hypothetical* risk premium if all securities are priced at the marginal risk premium of the unlevered firm.

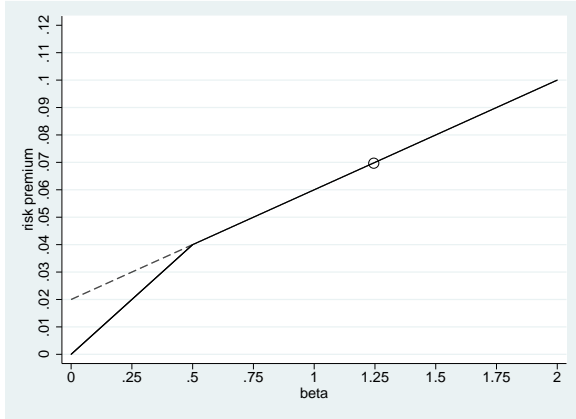


(b) Debt beta and equity beta: Calculations are based on a Monte Carlo simulation with random returns of the firm  $X^U \sim \mathcal{N}(4, 1.25)$ . The x-axis represents the debt ratio of a firm, and the y-axis represents the respective betas of the firm's securities. The bottom line represents the debt security and the top line represents the equity security. Note that, in principle, different risk premiums (the actual or the hypothetical) also effect the beta of a security. Here, the effect is only minor and not visible in the figure.

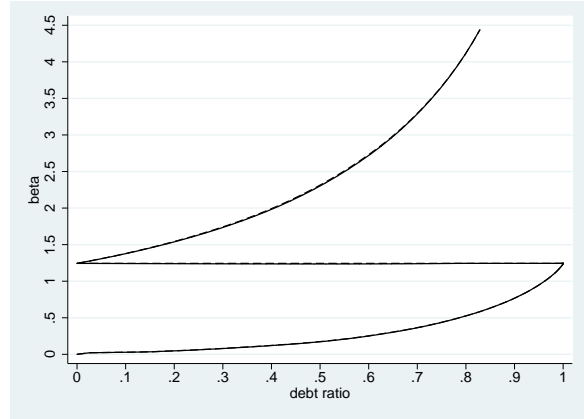


(c) Optimal capital structure: Using the input from the two figures above, this figure shows how the firm's debt ratio impacts risk premiums of the firm's debt and equity security. The solid lines show the risk premiums of the debt security (bottom), the equity security (top), and the firm's WACC (middle) if priced with the *actual* risk premiums. The dashed lines show the risk premiums of the debt security (bottom), the equity security (top), and the firm's WACC (middle) if priced with the *hypothetical* risk premiums. The firm's optimal debt ratio is 59%. This is where the spread between the debt risk premiums and its "size effect" matter most, as illustrated by the grey area.

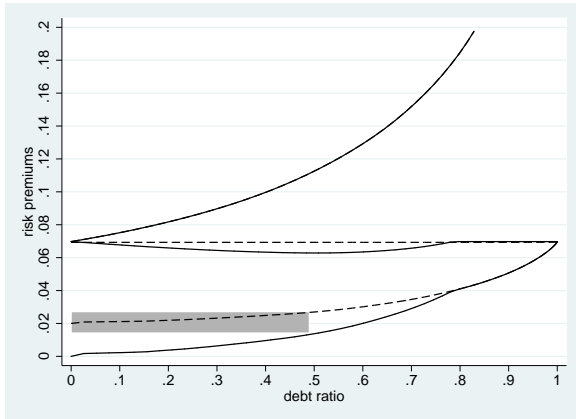
Figure 5: Optimal capital structure for a high-beta firm with  $\beta^U = 1$ .



(a) Risk premiums: The x-axis represents the beta of a security, and the y-axis represents the respective risk premiums. The solid line shows the *actual* risk premiums required by investors. The marginal risk premiums are 8% for low-beta securities ( $\beta \leq 0.5$ ) and 4% for high-beta securities ( $\beta > 0.5$ ). The circle marks the beta and required risk premium of the unlevered firm with  $\beta^U = 1.25$ . The dashed line represents the *hypothetical* risk premium if all securities are priced at the marginal risk premium of the unlevered firm.



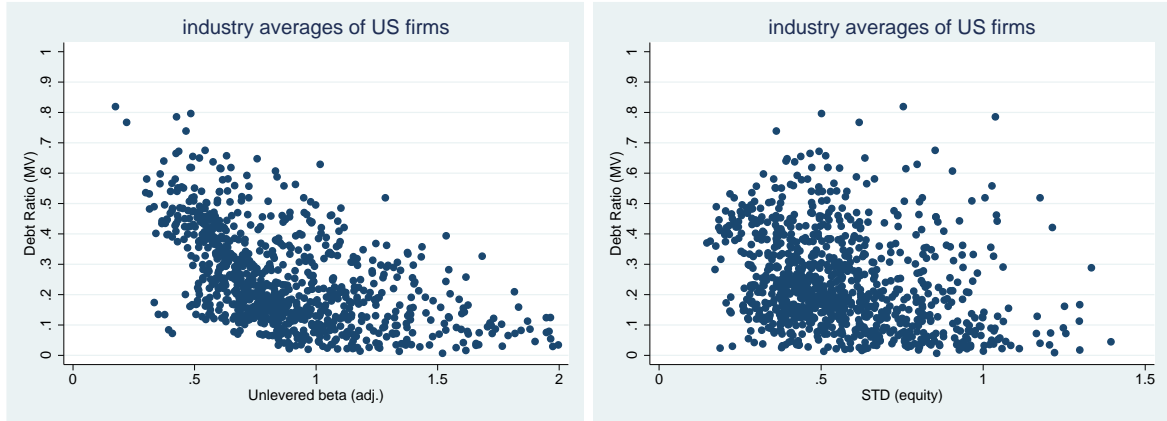
(b) Debt beta and equity beta: Calculations are based on a Monte Carlo simulation with random returns of the firm  $X^U \sim \mathcal{N}(4, 1.8125)$ . The x-axis represents the debt ratio of a firm, and the y-axis represents the respective betas of the firm's securities. The bottom line represents the debt security and the top line represents the equity security. Note that, in principle, different risk premiums (the actual or the hypothetical) also effect the beta of a security. Here, the effect is only minor and not visible in the figure.



(c) Optimal capital structure: Using the input from the two figures above, this figure shows how the firm's debt ratio impacts risk premiums of the firm's debt and equity security. The solid lines show the risk premiums of the debt security (bottom), the equity security (top), and the firm's WACC (middle) if priced with the *actual* risk premiums. The dashed lines show the risk premiums of the debt security (bottom), the equity security (top), and the firm's WACC (middle) if priced with the *hypothetical* risk premiums. The firm's optimal debt ratio is 51%. This is where the spread between the debt risk premiums and its "size effect" matter most, as illustrated by the grey area.

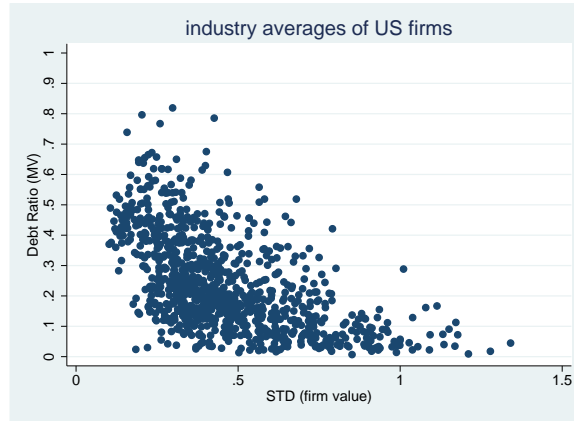
Figure 6: Optimal capital structure for a high-beta firm with  $\beta^U = 1.25$ .

## C Figures: Empirical study main explanatory variables



(a) unlevered beta and debt ratio

(b) STD (equity) and debt ratio



(c) STD (firm value) and debt ratio

Figure 7: Debt ratios and alternative explanatory variables. All data shows industry averages of US firms over the years 1999 to 2009. Financials are excluded. For clarity, Figure (a) shows values only up to an unlevered beta of 2, Figure (b) shows values up to a standard deviation of equity of 1.5, and Figure (c) shows values up to a standard deviation of firm value of 1.5.

## D Tables: Empirical study descriptives

Table 1: Summary descriptives

I use industry averages for the years 1999 to 2009. Each year includes data for about 90 industry sectors that represent about 6000 firms. Financial sectors are excluded.

	mean	sd	p1	p99
Debt Ratio (MV)	0.24	0.15	0.02	0.66
Debt Ratio (BV)	0.42	0.16	0.10	0.80
Unlevered beta (adj.)	0.99	0.55	0.35	3.19
STD (equity)	0.56	0.22	0.20	1.22
STD (firm value)	0.46	0.22	0.13	1.13
Price/BV	3.48	3.18	0.72	12.82
Insider holdings	0.10	0.08	0.00	0.34
Tax Rate (effective)	0.23	0.10	0.03	0.50
Expected Growth (EPS)	0.15	0.06	0.03	0.34
Fixed Assets/BV	0.50	0.31	0.08	1.33
EBITDA/Value	0.13	0.06	0.02	0.28
Observations	948			

Table 2: Correlations

I use industry averages for the years 1999 to 2009. Each year includes data for about 90 industry sectors that represent about 6000 firms. Financial sectors are excluded.

	1	2	3	4	5
1 Debt Ratio (MV)	1				
2 Debt Ratio (BV)	0.782***	1			
3 Unlevered beta (adj.)	-0.506***	-0.578***	1		
4 STD (equity)	-0.260***	-0.319***	0.563***	1	
5 STD (firm value)	-0.550***	-0.542***	0.670***	0.939***	1
Observations	948				

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

## E Tables: Main regression results

Table 3: OLS regression results for debt ratio (market values)

This table shows regression results for average industry debt ratios that are based on market values. The regression is estimated with time fixed effects. All variables represent industry averages for the years 1999 to 2009. Each year includes data for about 90 industry sectors that represent about 6000 firms. Financial sectors are excluded. Robust standard errors are reported. Data source: Damodaran (2010).

	(1)	(2)	(3)	(4)	(5)
Unlevered beta (adj.)	-0.1022*** (0.0000)			-0.1100*** (0.0000)	-0.0647*** (0.0000)
STD (equity)		-0.0317 (0.2171)		0.0641** (0.0150)	
STD (firm value)			-0.3227*** (0.0000)		-0.2348*** (0.0000)
Insider holdings	-0.0143 (0.8020)	0.0118 (0.8453)	0.0266 (0.6499)	-0.0257 (0.6505)	0.0077 (0.8921)
Price/BV	-0.0090** (0.0314)	-0.0083* (0.0664)	-0.0081** (0.0279)	-0.0087** (0.0375)	-0.0087** (0.0193)
Tax Rate (effective)	-0.1608*** (0.0018)	-0.0814 (0.1239)	-0.2869*** (0.0000)	-0.1090** (0.0412)	-0.2920*** (0.0000)
Expected Growth (EPS)	-0.0844 (0.3920)	-0.3194*** (0.0022)	-0.0314 (0.7387)	-0.1255 (0.2072)	0.0500 (0.5960)
Fixed Assets/BV	0.0389** (0.0279)	0.0841*** (0.0000)	0.0321* (0.0695)	0.0459** (0.0119)	0.0157 (0.3744)
EBITDA/Value	0.7894*** (0.0000)	0.8660*** (0.0000)	0.7183*** (0.0000)	0.7841*** (0.0000)	0.7099*** (0.0000)
Constant	0.2970*** (0.0000)	0.1948*** (0.0001)	0.3710*** (0.0000)	0.2607*** (0.0000)	0.3959*** (0.0000)
adj. R-squared	0.4357	0.3487	0.4508	0.4395	0.4780
N	948	948	948	948	948

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$



## F Tables: Robustness regressions

Table 4: Regression results for debt ratio (market values) with industry FE

This table shows regression results for average industry debt ratios that are based on market values. The regression is estimated with time and industry fixed effects. All variables represent industry averages for the years 1999 to 2009. Each year includes data for about 90 industry sectors that represent about 6000 firms. Financial sectors are excluded. Robust standard errors are reported (xtreg, fe robust). Data source: Damodaran (2010).

	(1)	(2)	(3)	(4)	(5)
Unlevered beta (adj.)	-0.0614*** (0.0046)			-0.0704*** (0.0010)	-0.0423** (0.0326)
STD (equity)		0.0434 (0.1856)		0.0833** (0.0128)	
STD (firm value)			-0.1851*** (0.0002)		-0.1473*** (0.0008)
Insider holdings	0.1299* (0.0952)	0.0987 (0.2226)	0.1245 (0.1750)	0.1203* (0.0870)	0.1374 (0.1116)
Price/BV	-0.0042 (0.1244)	-0.0039 (0.2272)	-0.0040 (0.1338)	-0.0040 (0.1469)	-0.0041* (0.0959)
Tax Rate (effective)	-0.0718 (0.1203)	-0.0634 (0.1734)	-0.1076** (0.0261)	-0.0486 (0.2730)	-0.0986** (0.0371)
Expected Growth (EPS)	-0.0816 (0.2801)	-0.0997 (0.1792)	-0.0722 (0.3089)	-0.0887 (0.2495)	-0.0677 (0.3497)
Fixed Assets/BV	-0.0763 (0.2136)	-0.0576 (0.3630)	-0.0651 (0.2877)	-0.0749 (0.2154)	-0.0755 (0.2080)
EBITDA/Value	0.6149*** (0.0045)	0.6442*** (0.0044)	0.5407*** (0.0090)	0.6365*** (0.0033)	0.5477*** (0.0078)
Constant	0.2966*** (0.0000)	0.1909*** (0.0014)	0.3449*** (0.0000)	0.2405*** (0.0002)	0.3695*** (0.0000)
R-sq (within)	0.4245	0.3920	0.4359	0.4364	0.4511
N	948	948	948	948	948

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 5: OLS regression results for debt ratio (book values)

This table shows regression results for average industry debt ratios that are based on market values. The regression is estimated with time fixed effects. All variables represent industry averages for the years 1999 to 2009. Each year includes data for about 90 industry sectors that represent about 6000 firms. Financial sectors are excluded. Robust standard errors are reported. Data source: Damodaran (2010).

	(1)	(2)	(3)	(4)	(5)
Unlevered beta (adj.)	-0.1463*** (0.0000)			-0.1500*** (0.0000)	-0.1060*** (0.0000)
STD (equity)		-0.1005*** (0.0003)		0.0302 (0.2836)	
STD (firm value)			-0.3964*** (0.0000)		-0.2524*** (0.0000)
Insider holdings	0.0353 (0.6043)	0.0812 (0.3067)	0.0900 (0.2371)	0.0299 (0.6607)	0.0590 (0.3974)
Price/BV	0.0076** (0.0261)	0.0083*** (0.0033)	0.0088** (0.0130)	0.0077** (0.0232)	0.0079** (0.0348)
Tax Rate (effective)	-0.1300*** (0.0073)	-0.0680 (0.1989)	-0.2627*** (0.0000)	-0.1056** (0.0419)	-0.2710*** (0.0000)
Expected Growth (EPS)	-0.2081** (0.0208)	-0.4917*** (0.0000)	-0.1969** (0.0373)	-0.2274** (0.0139)	-0.0636 (0.4853)
Fixed Assets/BV	0.0767*** (0.0000)	0.1320*** (0.0000)	0.0785*** (0.0000)	0.0799*** (0.0000)	0.0517*** (0.0048)
EBITDA/Value	0.3229*** (0.0062)	0.4320*** (0.0015)	0.2511** (0.0384)	0.3204*** (0.0067)	0.2374** (0.0361)
Constant	0.5200*** (0.0000)	0.4130*** (0.0000)	0.5854*** (0.0000)	0.5029*** (0.0000)	0.6263*** (0.0000)
adj. R-squared	0.3829	0.2313	0.3607	0.3832	0.4268
N	948	948	948	948	948

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 6: Regression results for debt ratio (book values) with industry FE

This table shows regression results for average industry debt ratios that are based on market values. The regression is estimated with time and industry fixed effects. All variables represent industry averages for the years 1999 to 2009. Each year includes data for about 90 industry sectors that represent about 6000 firms. Financial sectors are excluded. Robust standard errors are reported (xtreg, fe robust). Data source: Damodaran (2010).

	(1)	(2)	(3)	(4)	(5)
Unlevered beta (adj.)	-0.0451** (0.0212)			-0.0481** (0.0143)	-0.0278* (0.0945)
STD (equity)		0.0005 (0.9874)		0.0278 (0.3374)	
STD (firm value)			-0.1589*** (0.0069)		-0.1341** (0.0122)
Insider holdings	0.0255 (0.8183)	0.0076 (0.9488)	0.0239 (0.8448)	0.0223 (0.8381)	0.0323 (0.7826)
Price/BV	0.0052** (0.0444)	0.0054** (0.0225)	0.0054** (0.0364)	0.0053** (0.0418)	0.0053** (0.0491)
Tax Rate (effective)	-0.0176 (0.6403)	-0.0200 (0.6114)	-0.0480 (0.2190)	-0.0099 (0.7971)	-0.0421 (0.2732)
Expected Growth (EPS)	-0.0355 (0.6509)	-0.0454 (0.5644)	-0.0258 (0.7319)	-0.0379 (0.6336)	-0.0228 (0.7634)
Fixed Assets/BV	0.0806 (0.2449)	0.0929 (0.1750)	0.0882 (0.1825)	0.0811 (0.2429)	0.0814 (0.2261)
EBITDA/Value	0.0480 (0.7061)	0.0605 (0.6452)	-0.0178 (0.8730)	0.0552 (0.6663)	-0.0132 (0.9063)
Constant	0.4316*** (0.0000)	0.3790*** (0.0000)	0.4818*** (0.0000)	0.4129*** (0.0000)	0.4980*** (0.0000)
R-sq (within)	0.1544	0.1298	0.1740	0.1561	0.1822
N	948	948	948	948	948

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$