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An extension of the Merton model - The effect of including the cost of operating leverage

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Abstract

We ask whether the Merton's structural model of credit risk is improved by including the cost of operating leverage. We test this by extending the Merton model and testing whether the estimated credit spread is closer to the observed credit spread before or after the extension. We present two different extensions where the difference is the assumption of seniority of the costs of operating leverage. In the first we assume that the costs have the highest seniority, while in the other, the costs rank pari passu with interests and dividends. We find that both models improve the model slightly. Therefore, we conclude that our findings are a small step in finding the complete model for estimating credit spreads.

Keywords: Merton model, Operating leverage, Credit spread puzzle, Default probabilities

Introduction

Structural models of credit risk have been the focus of a great amount of research and academic papers. A large share of these is trying to find unifying models which explain the credit spread of corporate bonds. Many different approaches have been tested and used to explain the Credit Spread Puzzle. The puzzle that credit risk only accounts for a small fraction of the observed corporate-Treasury yield spreads (Feldhütter & Schaefer, 2016).These approaches have often increased in complexity and model inputs, for example time-varying Sharpe ratios and stochastic volatility premiums.

In this thesis we will test whether the existing structural Merton model is an adequate model of credit risk, only lacking the correct input to close the Credit Spread Puzzle. Following previous research, fixed costs have the same attributes as debt servicing (Novy-Marx, 2011). Therefore, we test whether the inclusion of the cost of operating leverage improves the Merton model. Previous research has found that it should affect the credit risk, but no previous research has tried to include this cost in the Merton model. For this reason, it makes our thesis intriguing and gives us motivation for our work. In order to test the operating leverage effect on credit spreads, we will propose two different extensions to the model, with different assumptions of priority in the case of default.

Our findings indicate that the Merton model is improved when the cost of operating leverage is included. However, the improvement is not enough to close the Credit Spread Puzzle, only to reduce it. Thus, the complete and unifying Merton model should include the cost of operating leverage, and, additional factors that will affect a firm's credit risk.

In the following paragraphs we will describe our analysis and findings. Firstly, we will specify our research question and hypothesis. Then, give a summary of previous research of similar topics and important findings, and introduce the original Merton model which we have based our extensions on. After this, we will describe our data, before we describe our methodology of how we have extended the Merton model. Lastly, we will present our analysis and findings, before we discuss the limitations of our model and what could be a focus in future research.

Research question and hypothesis

Standard credit risk models, like the Merton model, struggle to match observed credit spreads and default probabilities. Previous research shows the Merton model tends to underestimate credit spreads. Our research question is therefore; if operating leverage is included in the Merton model will this close the unexplained gap between theoretical and observed prices?

Operating leverage is a highly relevant accounting measure which affects companies' cash flows. A higher operating leverage would lower companies cash flow, which would lower the potential payments to creditors. It makes sense that the creditors should incorporate the leverage effect of operating leverage when calculating the default probabilities and pricing a bond. This gives us a motivation to test whether the leverage effect of operating leverage would increase the degree of explanation of the Merton (1974) model. Following the operating leverage hypothesis (Novy-Marx, 2011), we expect that rational investors should consider the operating leverage, and thus, including this variable into the model should enhance its performance. This gives our hypothesis:

Hypothesis: Will the inclusion of operating leverage in the Merton model improve its performance?

H_0: Yes, since rational investors should consider all relevant information when valuing an asset and thus, according to the operating leverage hypothesis, investors should consider operating leverage. Therefore, the inclusion of operating leverage will improve the model and its explanatory power *(Additionally, the Merton model is correct).*

H_1: No, investors do not consider the operating leverage when valuing a bond, either because they already consider "enough" information or the cost/reward is not great enough. Thus, the model will not be improved when operating leverage is included *(Potentially, the model is wrong).*

Literature review

Articles and papers

In this section we will investigate some important studies concerning the credit risk puzzle and operating leverage hypothesis, and briefly describe their main findings. This is to create a broader understanding and knowledge of the purpose, and the need for our research. Most of the previous studies have not covered the link between the "Credit Spread Puzzle" and operating leverage. Hence, most of the studies we mention will mainly focus on those two subjects individually. Further, we will mention studies that cover the structural models and estimation of operating leverage techniques that we are planning to employ in our work. And lastly, we will introduce the Merton model.

Merton's research published in 1974 has been an essential part of the academic theme of valuating corporate debt. His research covers important themes regarding credit spreads and the design of the firm's capital structure. In this paper, Merton introduces his model, which is an extension of the Black & Scholes option-pricing model, which we will elaborate in a simple fashion later. The model uses some simplifying assumptions and thus, is able to price a bond through an option-pricing model framework. The Merton model has proven to be an effective model in pricing risky liabilities, but a large amount of previous research has not been able to explain the complete "Credit Spread Puzzle" using it (Feldhütter & Schaefer, 2016).

Huang and Huang, in their first draft in 2003, were able to provide a consistent answer to how much of the historically observed Corporate - Treasury yield spread is due to credit risk. Although the literature within this framework had earlier failed to reach a consensus in answering this question. In their research, they are using a large class of structural models to generate consistent credit yield spreads, given that each of the models is calibrated to match historical default loss. They conclude that credit risk accounts for only small fraction of the credit spread for investment grade bonds, while for high yield bonds, the credit risk accounts for a much larger fraction of the observed Corporate -Treasury yield spreads (Huang & Huang, 2003). This gives us further motivation to investigate if

operating leverage, additionally to the credit risk, could explain the Corporate-Treasury yield spread.

In Chen, Collin-Dufresne and Goldstein's paper published in 2009, they extend the results shown by Huang and Huang in 2003, by calibrating all models to Sharpe ratios, recovery rates and historical default rates. Their result shows that the Merton model underpredicts actual spreads, which is referred to as the credit spread puzzle, and investigates whether it can be resolved. Their standard explanation of the credit spread puzzle is that structural models as the Merton model, only capture credit risk and ignore other factors which could explain credit spreads (Chen, Collin-Dufresne, & Goldstein, 2009).

Further, Chen, Collin-Dufresne and Goldstein provide a simple equation, based on the Merton model to calculate the credit spread. The intuition behind their expression for credit spread is simply the sources of the credit spread puzzle. Chen, Collin-Dufresne and Goldstein's argue that, these sources are that: expected default rates π^P are low, recovery rates (1-L) are substantial, and the Sharpe ratio θ of individual firms are low due to a sizable level of idiosyncratic risk. By the importance of the Sharpe Ratio they state that as idiosyncratic risk increases (i.e., Sharpe ratio decreases), defaults become less systematic, and then the risk-premiums associated with corporate bonds (i.e., the second term in Equation 1) decrease. Their expression is as follows:

$$(y - r) = -\left(\frac{1}{T}\right) * Log\left(1 - L * N\big(N^{-1}(\pi^P) + \theta * \sqrt{T}\big)\right) \qquad (1)$$

where;

- $(y - r)$ = the credit yield spread of the corporate bond versus the "risk free" rate.
- $(1 - L)$ is the recovery rate, constant for each firm.
- π^P is the probability of default.
- $\theta = \frac{\mu - r}{\sigma}$ is the Sharp ratio of the firm's assets.

The assumptions made by Chen, Collin-Dufresne and Goldstein for Equation 1 are:

1. Liability of the firm is a zero-coupon bond with maturity T.

2. Default can occur only at maturity and only if firm value $V(T)$ falls below an exogenously specified default boundary B[1].

3. Bondholders receive a constant recovery rate $(1 - L)$ if default occurs. Thus, L can be interpreted as the loss rate given default.

Due to the compelling arguments done by Chen, Collin-Dufresne and Goldstein, we will later on apply Equation 1 in order to estimate the credit spreads for our chosen firms.

In Huang and Huang's continued research, published in 2012, they extend their research from their first draft in 2003. Here they show that besides the credit risk, other factors could explain the credit spread. They provide evidence that states that credit spread puzzle cannot alone be explained by jumps in the firm value process, time-varying asset risk premia, endogenous default boundaries, or recovery rate. Hence, there is more to the credit spread puzzle that has not yet been found, increasing our motivation to seek evidence that operating leverage can explain some of this puzzle.

In Feldhütter and Schaefer's working paper from 2016, they continue the research done by Huang and Huang (2012) and Chen, Collin-Dufresne and Goldstein (2009), aiming to solve the credit spread puzzle. As mentioned in earlier research, they define the credit spread puzzle as standard structural models that failed to explain the credit spread. In this study they used empirical default rates for a much longer time series than previous studies, in order to estimate expected default probabilities with a reasonable degree of reliability. Their research reveals that long history of default rates is necessary, and that they are able to match their model spread with actual investment spread well. Further, their research provides indications that the credit spread puzzle has less to do with deficiencies of the models than with the way in which they have been implemented (Feldhütter & Schaefer, 2016).

In Bloomfield and Yehuda's paper from 2012, they investigate the relationship between consumer sentiments and operating leverage and its effect on credit

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[1] Default boundary is defined as the face value of debt F in the original Merton (1974) framework

spreads. Their study provides evidence of correlation between consumer sentiments and operating leverage, but that bond markets fail to incorporate this information into the price of firm-specific credit risk (the credit spread). This research paper is relevant for our thesis for several reasons. Firstly, because they propose a way to estimate the cost of operating leverage and that they find evidence of operating leverage affecting the credit spread (Bloomfield & Yehuda, 2012). Although their focus is operating leases, their findings are in line with our hypothesis and hence, are of great interest to our continued research. In addition, Bloomfield and Yehuda define operating leverage in a way that suits our research. They derive and show how to estimate the cost of operating leverage. Other papers define operating leverage as a ratio of how levered the assets are. However, using Bloomfield and Yehuda's approach, we are able to estimate the costs of operating leverage and implement it into our model. This approach will be further explained later in the methodology part of our thesis.

Another reason for the importance of this paper for our thesis is due to their broad discussion on why markets might (or might not) treat fixed costs as debt-like items. For our thesis, this discussion is highly relevant since we are trying to find factors that investors or credit analyst are not incorporating when pricing debt. This also gives us further motivation to solve the credit spread puzzle. Bloomfield and Yehuda argue that fixed costs mainly consist of contractual obligation, which are executory in nature. These obligations would most likely not decrease in bad times, and might therefore increase the risk of short-term liquidity problems that could lead to bankruptcy. Consequently, the fixed costs reflect a firm's future liability and according to structural models of debt pricing (Merton, On the pricing of corporate debt: The risk structure of interest rates, 1974), should affect the market price of corporate debt.

Bloomfield and Yehuda points out numerous possibilities as to why investors do not treat fixed costs as they do for operating lease obligation.[2] One reason is simply by the formal accounting definition, where operating leases are obligations that can be enforced by an outside party. Another possibility they mention is that firms have a legal right to avoid supposedly fixed costs.

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[2] In according to IAS 17, operating lease obligation is accounted for as fixed costs and enter in into the income statement.

In form of difficulties to incorporate fixed cost when pricing corporate debt, they point out two important reasons. Firstly, they argue that credit analysts have to conduct fairly complicated econometric estimation to do so, which they perhaps want to avoid. Secondly they point out the difficulties in extracting information about fixed costs. They refer to Financial Statement Presentation project (Financial Accounting Standards Board, 2010) where costs can differ by function, nature or measurement basis. One example of why this makes it difficult to incorporate fixed costs, is that financial statements make it very difficult to distinguish between expenses with a fixed nature and expenses with a variable nature.

Mandelker and Rhee (1984) provides empirical evidence on the trade-off hypothesis, where operating and financial leverage can be combined in different portions to obtain a desirable amount of risk of common stock. Their study shows that the degrees of operating and financial leverage explain a large portion of the variation of systematic risk (beta) (Mandelker & Rhee, The impact of the degrees of operating and financial leverage on systematic risk of common stock, 1984). Additionally, they found a significant correlation between the two types of leverage. This paper shows that operating leverage does affect the riskiness of an asset, and thus, investors should consider it when valuing a corporate bond, which is the main part of our hypothesis.

Novy-Marx (2011) provides direct empirical evidence for the "operating leverage hypothesis", which underlies most theoretical explanations of the value premium. This hypothesis explains value premium as firms with "levered" assets earn significantly higher average returns than firms with unlevered assets. Furthermore, the hypothesis states that production costs play much the same role as debt-servicing the exposure of a firm's underlying risk (Novy-Marx, 2011). Hence, even though this paper looks at the implication of operating leverage on equity returns their finding are in direct connection with our hypothesis and are a clear indication that operating leverage should be considered by investors.

By using the conclusions and themes of these papers, one can quickly see that there should be a connection between credit spreads and the degree of operating

leverage. The research on structural models concludes that there may be something other than credit risks that affects credit spreads. In the research on operating leverage, they find that this should be considered by investors, and that there are connections between operating leverage and returns. This further strengthens the motivation to test whether the credit spread puzzle can be solved or further minimized.

The Merton Model

The structural model we are extending in this thesis is the Merton model (Merton, On the pricing of corporate debt: The risk structure of interest rates, 1974), where Robert C. Merton is recognized as the first to apply option theory to the problem of valuing corporate debt. The model is referred to as a "structural approach" for estimating the credit spreads, because it relies on the firm's capital structure. Hence, it uses the firm equity value, debt face value, and the equity returns to evaluate the firm's assets and debt.

The Merton model makes two particularly critical assumptions[3].The first assumption is that the firm has issued one zero-coupon bond maturing at a future time T. Therefore, if the market value of its assets (*V*) is less than the promised debt repayment (*L*) at maturity *T*, the firm is said to be in default. As a simplification, the probability of default (*PD*) can be expressed as:

$$PD = \Pr(V_T < L_T) \tag{2}$$

where $\Pr(\cdot)$ is an unknown probability function. However, the complication of finding the market value of assets (i.e. the market value of assets is unobservable), makes the estimation of PD challenging.

On the other hand, if the firm is able to pay the promised debt repayment (L) at maturity, the residual asset value after the payment should go to the equity holders. The Merton model applies the Black & Scholes option-pricing model (Black & Scholes, 1973), and treats equity as a call option on the firm's assets with a strike price equal to the debt repayment amount:

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[3] We will in this thesis focus on the two crucial assumptions behind the Merton model. However, the model additionally assumes the following: no transaction cost, no bankruptcy cost, no taxes, unrestricted borrowing and lending at the risk-free interest rate, no short selling restrictions, log-normally distributed values.

$$E_T = \max(V_T - L_T, 0) \qquad (3)$$

where V_T is the value of the firm's assets, and L_T is the firm's total liabilities mapped into a zero-coupon bond at time T. The equity value is therefore written as the pay-off of a European call option written on underlying asset V_T , and with strike price L_T. When the market value of the firm's asset is greater than the zero-coupon debt, the firm's debt holders can be paid the full amount of L_T. Hence, the equity value will still be $V_T - L_T$. On the other hand, if the market value of the firm's assets falls below the debt level at time T, the critical value, the firm will default (Loffler & Posch, 2007). A graphical description of the pay-off structure is shown in Figure 1:
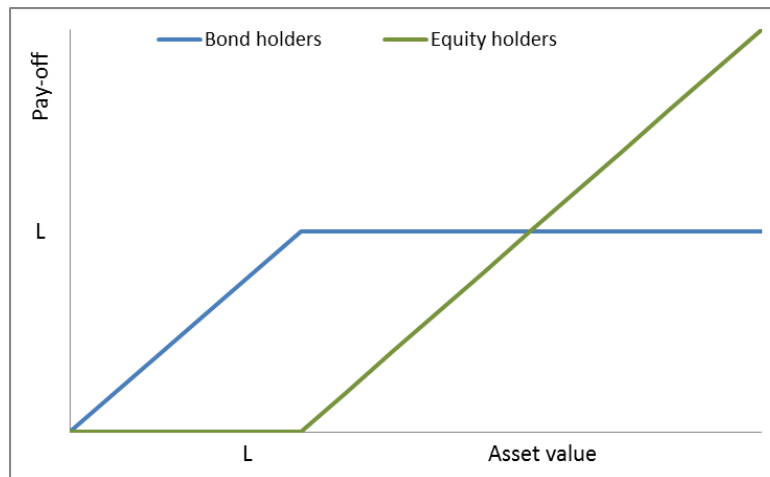
Figure 1: Payoff-structure for Bond and Equity holders

The second crucial assumption in the Merton model is that firm's asset value follows a geometric Brownian motion (GBM):

$$dV = \mu V dt + \sigma_V V dZ \qquad (4)$$

where μ is the expected continuously compounded return on V (i.e., the asset drift rate), σ_V is the asset volatility and dZ is a standard Weiner process. Additionally, a common assumption is that financial assets follow a log-normal distribution. The incremental changes in ln V follow a generalized Wiener process with drift $\mu - \frac{\sigma_V{}^2}{2}$. Thus, the logarithm of the asset values in time T follows the following

distribution:

$$\ln V_T - \ln V_t \sim N\left(\left(\mu - \frac{\sigma_V{}^2}{2}\right)(T-t), \sigma_V{}^2(T-t)\right) \tag{5}$$

where σ_V is the asset volatility, and μ is the drift parameter.[4]

The Probability of default

As mentioned before, using the Merton model we define the probability of default as the probability that the market value of the firm's assets falls below the debt level at time T. In general, the probability of default is the probability that a normally distributed variable x falls below z is given by:

$$\Phi\left[\frac{z - E[x]}{\sigma(x)}\right] \tag{6}$$

In previous research and literature, the probability of default is often expressed as distance to default (DD), as it measures the number of standard deviations the expected asset value V_T is away from the default. Hence, the distance to default and probability of default can be expressed as:

$$DD = \frac{\ln\left(\frac{V_t}{L_t}\right) + \left(\mu - \frac{\sigma_V{}^2}{2}\right)(T-t)}{\sigma_V\sqrt{T-t}} \tag{7}$$

$$Prob(default) = \Phi[-DD] \tag{8}$$

As the model uses equity and asset values to model probability of default, the model is indirectly pricing the default probability through the stock price (Ruttiens, 2013).The reason that this is the optimal approach is that the stock

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[4] Loffler & Posch (2007) states that a variable X whose logarithm is normal with mean E(ln X) and variance σ^2 has expectation E(X) = exp(E(ln X) + $\sigma^2/2$). Further, denoting the expected change of ln X by E(ln X) = $\mu - \sigma^2/2$ rather than by μ has the effect that change of X is E(X) = exp(μ) and thus depends only on the chosen drift parameter, and not on the variance σ^2

market is more liquid than the bond market for corporate bonds. Hence, the pricing is more likely to be efficient.

Figure 1[5] captures the intuition behind applying the Merton model, and what is required to determine the probability of default. Thus, it summarizes the equations stated until now. As shown above, the asset value follows a process of random walk with drift until time T. At maturity T, we see that the logarithm of the asset value is normally distributed. Graphically, we see that the default probability is determined by the probability that the logarithm of assets is lower than the logarithm of liabilities (i.e. call option on asset value with liabilities as strike price), assuming normal distribution.
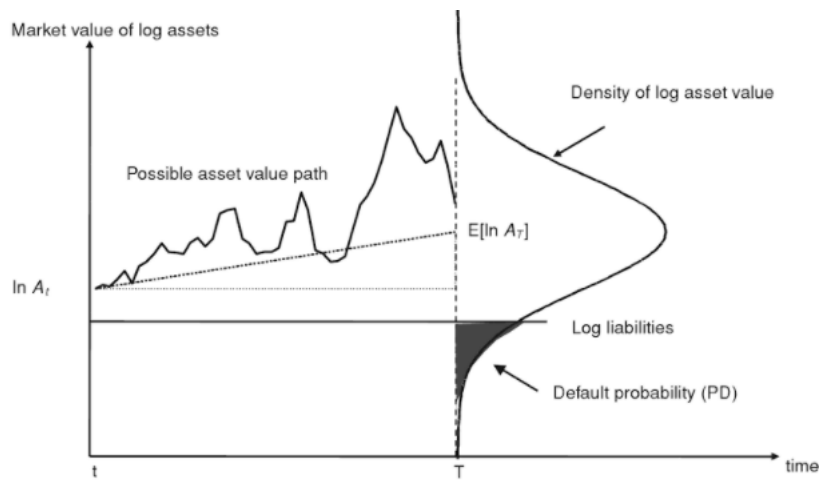
Figure 2: Default probability in the Merton model

Equity value and equity volatility

The Merton model utilizes market values, and this is the reason option pricing theory is implemented in the probability of default. One cannot observe the market value of asset, nor the volatility of assets. However, option pricing theory uses implied relationships between the unobservable $(V_T, \sigma_V{}^2)$, and the observable values. Hence, we can apply the standard Black-Scholes call option formula (Black & Scholes, 1973) on Equation 3, in order to express this relationship. Written as:

$$E_t = V_t \Phi(d_1) - Le^{-r(T-t)} \Phi(d_2) \tag{9}$$

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[5] The figure is obtained from Loffler & Posh (2007).

With:

$$d_1 = \frac{\ln\left(\frac{V_t}{L}\right) + \left(r + \frac{\sigma_V{}^2}{2}\right)(T-t)}{\sigma_V\sqrt{T-t}} \quad and \ d_2 = d_1 - \sigma_V\sqrt{T-t} \qquad (10)$$

where E_t is the today's equity value, r denotes the risk free rate of return, and the $\Phi(\cdot)$ is the normal cumulative distribution function.

From Equation 9 we have one equation with two unobservable values (V_T, σ_V), and in order to solve the problem we can introduce another equation that also contains the same two unknowns. When applying Ito's Lemma (Itô, 1951) one can determine the instantaneous volatility of the equity[6] from the asset volatility:

$$\sigma_E = \frac{\sigma_V \Phi(d_1) V_t}{E_t} \qquad (11)$$

As σ_E can be estimated from historical data, we are left with the same two unknowns as in Equation 9. By solving for V_T and σ_V using Equation 9, 10 and 11, we have all parameters needed from the Merton model to determine the credit spread. The determination of credit spread will be described in the methodology part of our thesis.

Following this discussion of the Merton model, the rationale of the model is twofold (Ruttiens, 2013):

- The stock price reflects a firm's ability to pay its debt through its balance sheet.
- An option pricing model: "The current stock price embodies a forecast of default probability in the same way that an option embodies a forecast of being exercised".

This model has been further extended to include interest payments and dividends. These two cash flows are refinanced during the life time and repaid at the same time as the liabilities. Hence, the argument of a zero coupon bond is still valid; the face value is only increased during the lifetime of the bond. The above rationale and the extension with interest payments and dividends will enable us to test our

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[6] The equity price is assumed to follow a geometric Brownian motion

hypothesis, that operating leverage should be accounted for when pricing a corporate bond.

Data

In the following section we will present our dataset, how we have extracted it, and why. We have used data for listed US firms, as these are the most likely to have the most liquid bonds outstanding, and thus, the market is arguably more efficient.

Firm and bond selection

For our thesis, it has been important that the firms we have based our analysis on have outstanding bonds, and that the firms we have used represent all of the credit rating spectrum. Hence, we have used the firms that are part Bloomberg's bond indices for both high yield bonds (bonds with credit ratings lower than BBB- in S&P terms) and investment grade bonds (bonds with credit rating from and above BBB- in S&P terms). The indices we have used are: "Active investment grade US Corporate bond total return index" (Bloomberg L.P., 2017) and "Active high yield US corporate bond total return index" (Bloomberg L.P., 2017). Further, we have sorted the bonds and firms included in these indices so our dataset only includes non-callable bonds, rated bonds and senior unsecured bonds issued by US listed firms. We have used these criteria to ensure the quality of the data, that the bonds are liquid, and that special features of the bonds are not biasing our dataset and analysis.

Firms

From the selected firms, we are excluding financial institutions (SIC codes: 6000-6999) and utilities (SIC codes: 4800-4999) as we want to analyze corporate bonds, and the risks in these two sectors differs from the overall corporate sector.

Bonds

As mentioned above, we have only included rated, straight-, bullet corporate bonds. All the ratings are translated to an S&P equivalent, and where credit ratings differ, we have utilized the lowest. This is to ensure that the rating used is as conservative as possible so bonds that are rated too high do not bias the modelled spread. If only one of Moody's and S&P has a rating, we will utilize this.

Firm and bond summary

Below are some tables to summarize the dataset we have used in our analysis.

Table 1: Firm and bond summary

Industry	Number
Aircraft	3
Automobiles and Trucks	6
Beer & Liquor	6
Business Services	21
Business Supplies	1
Chemicals	6
Computers	11
Construction	2
Construction Materials	2
Consumer Goods	8
Defense	1
Electrical Equipment	2
Electronic Equipment	14
Entertainment	1
Food Products	12
Healthcare	5
Machinery	8
Measuring and Control Equipment	4
Medical Equipment	8
Non-Metallic and Industrial Metal Mining	3
Personal Services	3
Petroleum and Natural Gas	20
Pharmaceutical Products	13
Precious Metals	1
Recreation	1
Restaraunts, Hotels, Motels	6
Retail	22
Rubber and Plastic Products	1
Shipbuilding, Railroad Equipment	1
Shipping Containers	2
Steel Works Etc	4
Tobacco Products	3
Transportation	12
Wholesale	8
Total	**221**

Rating	Number
AAA	2
AA	9
A	40
BBB	103
BB	34
B	23
CCC or lower	10
Total	**221**

As seen in these tables, our dataset includes firms from a broad specter of industries and ratings. However, out of the total number of firms in our dataset, most of the bonds are rated in the BBB category. Therefore, in the analysis, we will present all our findings, but the main analysis will focus on the BBB segment.

Accounting data

As out analysis is based on year-end 2016, all our accounting data are based on the annual reports or 4th quarter reports issued by each firm. All of our accounting data are downloaded from CompuStat (CompuStat Industrial, 2017), however, if some of the data are missing, we have manually extracted it from the annual reports. The reason for missing data is mainly due to different accounting periods and unaudited data. We assume that this would have a minimal effect on our result.

Liabilities

For book value of liabilities, we extract current liabilities (CompuStat item LCT) and total liabilities (CompuStat item LT) for 4th quarter 2016. Long term liabilities are then calculated as total liabilities less current liabilities.

Equity value

For equity values we use the market value, which is calculated as the daily outstanding number of shares multiplied with the share price at year-end 2016 (CompuStat item MKVALTQ).

Interest rate

In order to find the implied interest rate for the total liabilities, we assume that interests paid are capturing all interest expenses for all liabilities stated in the balance sheet. However, this method does not capture the implied interest rate on net working liabilities, but to simplify the model, we have chosen to not consider these interest costs. The interest rate used in our model is calculated by dividing interest paid in 2016 (CompuStat item INPNY) by the average of total liabilities (CompuStat item LTQ):

$$Interest\ rate_{2016} = \frac{Interests\ paid_{2016}}{\frac{1}{2} * (Total\ liabilites_{2015} + Total\ liabilities_{2016})} \quad (12)$$

Dividends

In order to include dividend payments, we have used the total dividends paid in 2016 for each firm (Calculated as the sum of quarterly dividends per share, CompuStat item DVPSPQ, multiplied with the outstanding number of share at that date, CompuStat item CSHOQ). Additionally, to capture the total payments to shareholder, we have also included total share repurchases for 2016 (CompuStat item PRSTKCY).

For the dividend growth rate we have assumed 7.31%, in line with the implied dividend growth from the derivative market (Golez, 2014).

Additionally, we have assumed that only firms paying dividends and/or repurchased stocks will continue to do so. The reason for this assumption is that

paying dividends will increase the probability of default as the company reduces its asset base with dividends. Hence, we do not enforce dividend payments on firms not doing so.

Another reason is that dividends can be seen as signaling and that dividend payments are a way to convey information to the market (Brav, Graham, Harvey, & Michaely, 2005). Hence, the notion that dividend payments are the residual cash flow can be argued, which is an argument for not imposing dividend payments on firms not originally paying them.

Model input data

In this section we will elaborate on which data we have utilized in our model and if necessary, how we have calculated the different measurements.

Equity and asset volatility

The equity volatility is calculated based on daily return of the stock, and then annualized. We have utilized daily returns in 2016 in the following formula:

$$\sqrt{252} * \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} \tag{13}$$

where equity returns are calculated as:

$$r_t = \ln(\frac{P_t}{P_{t-1}}) \tag{14}$$

This is then used to estimate the first approximation of the asset volatility, before the minimization in the model, which is explained further in the thesis. For the approximation we assume[7] that $\Phi(d_1) = 1$ in Equation 11, so the approximation follows this formula:

$$\sigma_V = \sigma_E * \frac{E}{V} \tag{15}$$

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[7] Loffler & Posch (2007) describe why this approximation is reasonable. They argue that if $\Phi(d_1) = 1$ holds, it means that d_1 is large, which goes along with a high distance of default and a low probability of default. This follows by the similarity between d_1 (Equation 10) and DD (Equation 7) formula. Hence, since most firms have a smaller default probability than 5%, the approximation is reasonable.

Asset beta

In order to find the estimated asset beta (β_V), we estimate the equity beta following the Capital Asset Pricing Model ("CAPM") framework , using the same historical returns as in the volatility estimation. The equity beta (β_E) is calculated as:

$$\beta_E = \frac{\sigma_{i,M}}{\sigma_M^2} \tag{16}$$

where $\sigma_{i,M}$ is the covariance between the return of stock i and the market index (M) and σ_M^2 is the variance of the market index. In this thesis, we have applied the S&P500 index as a proxy for the market. For a further elaboration of the CAPM framework, we refer to Bodie, Kane and Marcus' "Investments".

From the equity beta, we find the asset beta by delevering it through the following approach, with the simplifying assumption that debt and tax shield carries no market risk (Koller, T., Goedhart, M., & Wessels, D., 2015)

$$\beta_V = \frac{\beta_E}{\left(1 + (1 - t_c) * \left(\frac{Debt}{Equity}\right)\right)} \tag{17}$$

In addition, we follow the argument of Bodie, Kane and Marcus that beta has the tendency to evolve toward 1, and that the estimated beta therefore has to be adjusted in that direction (Bodie, Kane, & Marcus, 2014).

$$\widehat{\beta_V} = \frac{2}{3} * \beta_V + \frac{1}{3} * 1 \tag{18}$$

Drift rate

In our model, we have applied the CAPM to estimate the asset drift rate, which is used in the calculation of the Distance to Default (Equation 7). We annualize each day's expected return and take the average for the total period to find the expected drift rate (Ruttiens, 2013).

$$\mu = \frac{1}{n}\sum_{i}^{n} 252 \left(\ln(1 + r_{f,i} + \widehat{\beta_V}(R_{m,i} - r_{f,i})) \right) \tag{19}$$

where $R_{m,i}$ is the daily return of S&P500, $r_{f,i}$ is the daily 5 year US Government Treasury yield.

Sharpe-ratio

As mentioned earlier, a crucial input in the credit spread formula is the Sharpe-ratio. We have calculated the asset sharp ratio as:

$$\frac{\mu - r_f}{\sigma_V} \tag{20}$$

where μ is the drift rate, r_f is the risk free rate and σ_V is the asset volatility.

Recovery ratio

The recovery rate we have utilized is the average recovery rate for senior unsecured corporate bonds for each rating category. The recovery rate represents the ratio of the defaulted bond that is repaid to the bond holder. We have utilized Moody's Annual Default Study of corporate bonds. We have used the average senior unsecured bond recovery rates for 5 years prior to default, $1983 - 2016$ (Moody's Investor Service, 2017). The following table shows the different recovery rates for each rating segment.

Table 2: Recovery rates

Rating	Recovery rate
AAA	69,58 %
AA	43,18 %
A	44,17 %
BBB	43,52 %
BB	41,16 %
B	37,86 %
CCC	37,46 %

Time to maturity

In order to estimate each firm's time to maturity, we have followed (Loffler & Posch, 2007) approach. However, we have assumed that long-term liabilities have

a maturity of 7.5 years on average and that current liabilities have a maturity of 0.5 years. Thus, we have estimated the time to maturity as:

$$\frac{0.5 * Current\ liabilites + 7.5 * Long\ term\ liabilities}{Total\ liabilities} \tag{21}$$

In our sample, this gives us an average time to maturity of 5.2 years.

Tax

We have assumed that the corporate US tax rate is 35%, following OECD's tax overview for countries (OECD).

Risk free rate

In our model, we have assumed the risk free rate to be 1.94%, the 5 year US Government Treasury yield at year end 2016.

Methodology

As we want to test whether operating leverage has an effect on credit spreads, we are going to implement three models. The first model is following the standard Merton model, which is our starting point for the next two models. We will also use this model to compare it with our extended models in the analysis part. After going briefly through the first model, we will follow with our estimation of fixed costs, which will be used for our two extended versions to the standard Merton model. Finally, we will go through our two main models for this thesis, where we will include the operating leverage effect.

Unadjusted model

For the credit risk modelling we are following an approach done by Loffler and Posch (2007), where we implement the Merton model with a T-year horizon. We will in this section explain the unadjusted model, which we us as a starting point for our two extended versions to the model.

The unadjusted model uses the same set-up as the Merton model, but assumes only one debt maturity for each firm. Additionally, it considers interim payments,

interest and dividend, which the firm has to make before the debt maturity. The intuition behind this is that when we implement the Merton model with a horizon of several years, the interim payments (e.g. dividends and interest) that the firm makes before the maturity should be considered. In order to include these payments in a proper way into the Merton model, the following assumptions have been made:

1. Firms have issued only one coupon bond with maturity equal to the average maturity of liabilities (i.e. Equation 21).
2. We need to hypothetically shift the accrued interest and dividend payments into the future. Therefore, we assume the same maturity assumed for the coupon bond.
3. Hence, even though interest and dividends are actually paid before, we treat them as liabilities that have higher priority than the principle of the bond.

First of all, we start with the computation of accrued dividends and interest. As we are assuming a fixed maturity T (i.e. Equation 21), we can compute the value of accrued dividends and interest at time T. For the dividends we assume that they are paid annually with an annual growth rate g. The accrued dividends are obtained by the following equation:

$$D = \sum_{\tau=t+1}^{T} D_t (1+g)^\tau e^{r(T-\tau)} \qquad (22)$$

where D_t is the dividend value in time t, and r is the risk-free rate (i.e. yield of five year treasuries). Secondly, we need to obtain the accrued interest payments I. They are found with a similar procedure, where we assume that they are due annually, and with a coupon rate c (i.e. Equation 12):

$$I = \sum_{\tau=t+1}^{T} c * L * e^{r(T-\tau)} \qquad (23)$$

As we now have expressed how to obtain the accrued dividend and interest payments, we can begin to implement the pay-off structure.

Pay-off structure

As the interim payments are derived, we can examine the pay-off structure for the equity holders at maturity in order to end up with the equity value. Here we assume that accrued interest and dividends have equal priority. However, principal L has less priority than accrued dividends and equity. The pay-off structure is as follows:

$$
E(V_T, \sigma_V, T) = \begin{cases} \dfrac{D}{D+I} V_T, & \text{if } V_T < D + I \\ D, & \text{if } D + I < V_T < D + I + L \\ D + (V_T - I - D - L), & \text{if } V_T > D + I + L \end{cases}
$$

Each regime could be interpreted as follows:

- $V_T < D + I$: In this regime the asset value is not sufficient to cover the payments to equity and debt holders (i.e. the dividend and interest payments), and the firm is therefore in default.

- $D + I < V_T < D + I + L$: Asset value suffices to cover claims from dividends and interest, but since the principal L is not fully covered, the firm is in default. The equity holder will only receive the accrued dividends D.

- $V_T > D + I + L$: Asset value suffices to cover all claims, so the equity holders receives $D + (V_T - I - D - L)$, which is the same as the residual asset value after the payments to the debt holders (i.e. $V_T - L - I$)

Further, we can replicate the pay-off to equity holders with a portfolio of call options and direct investments in the underlying assets. Hence, the equity value is equal to:

- A share of $\dfrac{D}{D+I}$ in the assets, plus
- A share of $\dfrac{D}{D+I}$ in a short call on assets with strike $D + I$, plus a call on assets with strike $L + D + I$.

In Figure 3 the pay-off structure including the portfolio of call options and direct investments in the underlying assets is shown graphically.

Graphical depiction:
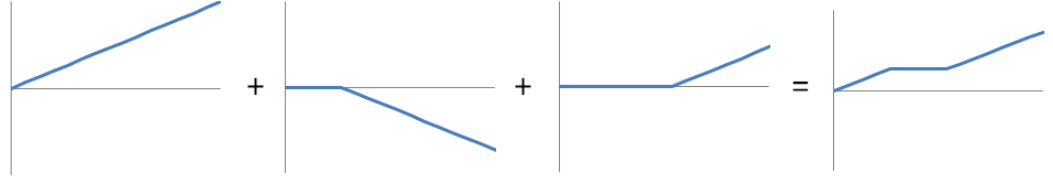
Figure 3: Pay-off structure for the unadjusted model

Equity value and equity volatility

By considering the pay-off structure from the last section, we can introduce the standard Black-Scholes option pricing formula to model today's value of equity.

$$E_t = V_t * \Phi(d_1) - (L + D + I)e^{-r(T-t)}\Phi(d_2) + \frac{D}{D+I} \ (V_t - V_t\Phi(k_1)$$
$$+ (D + I)e^{-r(T-t)}\Phi(k_2))$$

(24)

with:

$$d_1 = \frac{\ln\left(\frac{V_t}{L+D+I}\right) + \left(r + \frac{\sigma_V^2}{2}\right) * (T-t)}{\sigma_V\sqrt{T-t}} \ and \ d_2 = d_1 - \sigma_V\sqrt{T-t}$$

(25)

and:

$$k_1 = \frac{\ln\left(\frac{V_t}{D+I}\right) + \left(r + \frac{\sigma_V^2}{2}\right) * (T-t)}{\sigma_V\sqrt{T-t}} \ and \ k_2 = k_1 - \sigma_V\sqrt{T-t}$$

(26)

By using Equation 24 and Ito's Lemma we can derive an expression for the equity volatility. When we later on derive our two extended models, the derivation of the equity volatility will be explained in more detail. However, for the unadjusted model the equity volatility is written as:

$$\sigma_E = \sigma_V \frac{V_t}{E_t}\left[N(d_1) + \frac{D}{D + I}\left(1 - N(k_1)\right)\right] \qquad (27)$$

Since we now have two equations with two unknowns we can estimate the credit spreads. This procedure will be described later on, after going through our extended models. In the next section, we will describe the estimation of fixed cost, which we need to implement our two last models.

Estimating fixed costs

In order to test whether the operating leverage has an effect on credit spreads, we need to modify the standard Merton model and the Black and Scholes formula, which we introduced in the previous section. One crucial input for our modification is the fixed cost. However, fixed cost is very difficult to obtain directly from financial statements, and is treated differently among firms in the form of function, nature or measurement basis, as argued by Bloomfield & Yehuda (2012). Hence, we chose to follow their approach in order to get a transparant proxy for the fixed costs.

As fixed costs are costs we don't expect to change over shorter time periods, unlike sales and variable costs, we can distinguish between the fixed and variable component of total cash outflow by running a linear univariate regression. For each firm and quarter, we estimate the variable component of cash expense by regressing the change in cash expense on the change in sales for the previous 58 quarters. We run the following regression:

$$\Delta Cash\ expense_{t,t-4} = \beta_0 + \beta_1 \Delta Sales_{t,t-4} + \varepsilon_t \qquad (28)$$

where $\Delta Cash\ expense_{t,t-4}$ is the change in cash expense of the firm relative to four quarters previously, $\Delta Sales_{t,t-4}$ is change in total sale revenue relative to four quarters previously.

Cash expense is calculated by taking the difference between cash sales and cash flow from operations, excluding extraordinary items, interest and taxes, and including capital expenditure. We estimate cash sales as sales for the quarter

(CompuStat item SALEQ) plus the change in account receivable (CompuStat item ΔRECCHY)[8]. For the cash flow from operations, before extraordinary items, interest and taxes, we use the same definition as Bloomfield & Yehuda (2012). They define it as the change in the CompuStat item OANCFY, adjusted for interest and taxes. For the interest adjustments we use interest expense from the income statement (XINTQ) as a proxy for interest paid in cash. Further, we use total income taxes (TXTQ) and adjust them for deferred taxes (The change in TXDCY) and taxes payable (the change in TXACHY) that are reported on the statement of cash flows. Bloomfield & Yehuda (2012) argue that the variables for interest and taxes paid in cash for companies, which CompuStat collects, contain many missing values. Hence, the adjustments and proxies made for the interest and taxes, seem to be necessary in order to obtain accurate values. Lastly, we add the capital expenditures (CompuStat item CAPXY) to the cash flow from operations.

From regression (Equation 28) we can extract the variable and the fixed components from total cash expense, whereas the variable component is estimated as the product of sales and β_1. Thus, the fixed component for each firm is the residual of the cash expense, $Cash\ expense_{t,t-4} - \beta_1 Sales_{t,t-4}$. Following Bloomfield, R., & Yehuda, N. (2012), we set up two critieria in order to estimate the fixed cost:

1. If $Cash\ expense_{t,t-4} - \beta_1 Sales_{t,t-4} < 0$, the variable component is set to equal the entire cash expense, while fixed component is set to zero.
2. If $\beta_1 < 0$, the variable component is set to zero, while the fixed component is set equal the entire cash expense.

Following these two criteria we finally have an estimation of the fixed costs for 2016. However, since this estimation is before tax, and costs are tax deductible and we therefore need to adjust the fixed costs to represent the cost after tax[9]. In the following section, we will describe how the estimated fixed cost is incorporated in our extended models.

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[8] We convert all year to date variables (ΔRECCHY, OANCFY, TXDCY, TXACHY and CAPXY) to quarterly date, by subtracting the previous values in quarters 2,3, and 4.

[9] We use a tax rate of 35%, as mentioned in the model input data section.

Adjusted Merton model

In this section we will go through our two extended versions to the standard Merton model. Considering the estimation of the fixed cost, we can include it into the unadjusted model. With this approach we want to investigate in which extent the two adjusted Merton models match observed credit spreads, and compare the results with the unadjusted model. We follow the same procedure as mentioned before, but now we introduce the operating leverage effect.

Firstly, we need to modify the standard call option formula (Equation 3) in the Merton model, so that it considers the operating leverage effect. Using the fixed cost estimated in the section above, we can introduce the modified asset value at t in the following equation:

$$V_t = E_t + L_t + PV(F) \qquad (29)$$

where $PV(F)$ is the present value of the fixed cost in time t.

Further, we can mathematically rewrite Equation 29, and end up with the pay-off to equity holders at time T. Written as:

$$E_T = Max(V_T - L_T - F_T, 0) \qquad (30)$$

Hence, the equity value is written as the pay-off of a European call option written on underlying asset V_T as before, but with a new strike price, $L_T + F_T$. When the market value of the firm's asset is greater than the zero-coupon bond and the fixed costs, the firm's debt holders can be paid the full amount of L_T, and F_T can be covered in whole. Hence, the equity value at time T will still be $V_T - L_T - F_T$. On the other hand, if the market value of the firm's assets falls below the debt level plus the fixed costs at time T, the critical value, the firm will default.

Fixed costs are payments the firm needs to pay every year, so it should enter our valuation of equity in a consistent way. Hence, we chose to treat the fixed cost as an interim payment in a similar way as the interest and dividend payments. However, firms normally pay the fixed cost before dividends and interest. One could therefore argue that fixed cost should have higher priority than dividends

and interest. Following this reasoning, we will test the operating leverage effect on credit spreads by implementing two extended models. The first case assumes that fixed cost has highest priority, and the second case we assume equal priority for the fixed costs, dividends and interest.

Further, we need to express the calculation of the accrued fixed costs. We assume annual payments and that they grow at the drift rate μ. The reasoning behind this assumption is that the fixed costs should grow in line with the firm. We obtain:

$$F = \sum_{\tau=t+1}^{T} F_t (1 + \mu)^\tau * e^{r(T-\tau)} \tag{31}$$

where F_t is the fixed cost just paid, and F is the end value of the fixed cost payments. In the following section we will show how the fixed cost comes in our models.

Pay-off structure

In order to implement the accrued fixed cost into the Black and Scholes formula for today's equity value (Equation 9), we need to implement a new pay-off structure for the equity holders. We consider two cases as mentioned above, where each case has different assumptions and pay-off structure. In Case 1 we assume that accrued fixed cost has priority over accrued dividends and interest in case of default. In Case 2 we assume that accrued dividends, interest and fixed cost have equal priority. By implementing two cases we can compare the final results with each other. The pay-off structure for both cases is as follows:

The adjusted model - Case 1:

$$E(V_T, \sigma_V, T) = \begin{cases} 0, & if \ V_T < F \\ \dfrac{D}{D+I}(V_T - F), & if \ F < V_T < D + I + F \\ D, & if \ D + I + F < V_T < D + I + F + L \\ D + (V_T - I - F - D - L), & if \ D + I + F + L < V_T \end{cases}$$

Interpret as follows:

- $V_T < F$: Asset value is not sufficient to cover the fixed cost (highest priority), and the firm is therefore in default. The equity holder receives nothing.

- $F < V_T < D + I + F$: Asset value cover the fixed cost, but not the payments to equity and debt holders (i.e. the dividend and interest payments). The equity holder will therefore receive their share $\frac{D}{D+I}$ of the residual asset value (Recall that fixed cost has highest priority, and it should therefore be paid before dividend and interest payments).

- $D + I + F < V_T < D + I + F + L$: Asset value is sufficient to cover all interim payments, but not the full principal L. Hence, the firm is therefore in default, and the equity holder only receives the accrued dividends, D.

- $D + I + F + L < V_T$: Asset value covers all claims, and the firm is therefore not in default. The equity holder receives the accrued dividend D, and the residual asset value after all other claimants are paid.

The adjusted model - Case 2:

$$E(V_T, \sigma_V, T) = \begin{cases} \dfrac{D}{D+I+F} V_T, & if \ \ V_T < D + I + F \\ D, & if \ D + I + F < V_T < D + I + L + F \\ D + (V_T - I - D - L - F), & if \ V_T > D + I + L + F \end{cases}$$

Interpret as follows:
- $V_T < D + I + F$: Asset value is not sufficient to cover the fixed costs, and the dividend and interest payments, and the firm is therefore in default.

- $D + I + F < V_T < D + I + F + L$: Asset value suffices to cover all claims, except for the full principal L, and the firm is therefore in default. The equity holders will only receive the accrued dividends, D.

- $V_T > D + I + L + F$: Asset value suffices to cover all claims, and the firm is therefore not in default. The equity holder receives the accrued dividend D, and the residual asset value after all other claimants are paid.

As we now have the pay-off structure for both our extended models, we can replicate these with portfolios of call options and direct investments in the underlying asset.

The adjusted model - Case 1:

A share of $\frac{D}{D+I}$ in a long call on asset with strike price F.

A share short call on assets with strike $D + I + F$.

A call on assets with strike $D + I + F$

$=$ Equity value

In Figure 4 the pay-off structure including the portfolio of two long calls and a short call is shown graphically.
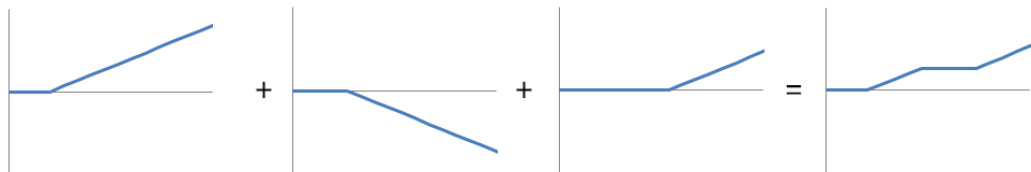
Figure 4: Pay-off structure for the adjusted model - Case 1

The adjusted model - Case 2:

A share of $\frac{D}{D+I+F}$ in the assets.
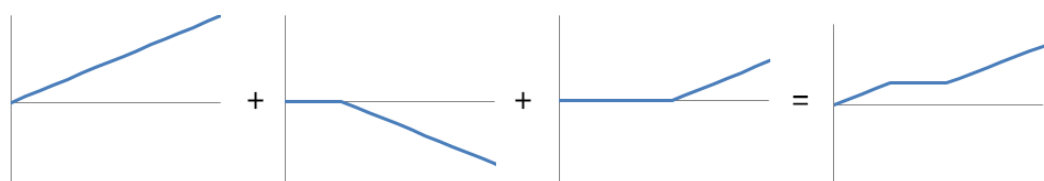
A share of $\frac{D}{D+I+F}$ in a short call on assets with strike $D + I + F$.

A call on assets with strike $D + I + F + L$.

$=$ Equity value

In Figure 5 the pay-off structure including the portfolio of direct investments in the underlying asset, short call and long call is shown graphically.

Figure 5: Pay-off structure for the adjusted model - Case 2

Equity value

Further, we use the new pay-off structures to modify the standard Black-Scholes option pricing formula in order to model today's equity value. For Case 1, whereas the fixed cost has highest priority, we can express the today's equity value as follows:

$$E_t = V_t * \Phi(d_1) - (L + D + I + F)e^{-r(T-t)}\Phi(d_2) + \frac{D}{D+I}\left(V_t\Phi(j_1)\right.$$
$$\left. - Fe^{-r(T-t)}\Phi(j_2) - V_t\Phi(k_1) + (D + I + F)e^{-r(T-t)}\Phi(k_2)\right) \quad (32)$$

with:

$$d_1 = \frac{ln\left(\frac{V_t}{L + D + I + F}\right) + \left(r + \frac{\sigma_V{}^2}{2}\right)(T - t)}{\sigma_V\sqrt{T - t}} \quad and \ d_2 = d_1 - \sigma_V\sqrt{T - t} \quad (33)$$

and:

$$k_1 = \frac{\ln\left(\frac{V_t}{D + I + F}\right) + \left(r + \frac{\sigma_V{}^2}{2}\right)(T - t)}{\sigma_V\sqrt{T - t}} \quad and \ k_2 = k_1 - \sigma_V\sqrt{T - t} \quad (34)$$

and:

$$j_1 = \frac{\ln\left(\frac{V_t}{F}\right) + \left(r + \frac{\sigma_V{}^2}{2}\right)(T - t)}{\sigma_V\sqrt{T - t}} \quad and \ j_2 = j_1 - \sigma_V\sqrt{T - t} \quad (35)$$

where j_1 and j_2 are new parameters related to the additional call option written on the assets, V_t, with strike price F.

For Case 2. whereas the accrued dividends, interest and fixed cost have equal priority; the today's equity value is similar to the unadjusted model. However, when we additionally include fixed cost into the Black-Scholes option pricing formula, we get:

$$E_t = V_t * \Phi(d_1) - (L + D + I + F)e^{-r(T-t)}\Phi(d_2) + \frac{D}{D + I + F}\,(V_t \\ - V_t\Phi(k_1) + (D + I + F)e^{-r(T-t)}\Phi(k_2)) \tag{36}$$

with:

$$d_1 = \frac{\ln\left(\frac{V_t}{L + D + I + F}\right) + \left(r + \frac{\sigma_V{}^2}{2}\right)(T - t)}{\sigma_V\sqrt{T - t}} \ and \ d_2 = d_1 - \sigma_V\sqrt{T - t} \tag{37}$$

and:

$$k_1 = \frac{\ln\left(\frac{V_t}{D + I + F}\right) + \left(r + \frac{\sigma_V{}^2}{2}\right)*(T - t)}{\sigma_V\sqrt{T - t}} \ and \ k_2 = k_1 - \sigma_V\sqrt{T - t} \tag{38}$$

As we now have an expression for the today's equity value for both cases, we need to express the equity volatility for the same cases in order to solve the problem with the two unobservable values (V_T, σ_V). The derivation of the equity volatility is described in the following section.

Equity volatility

Equation 32 and 36 are expressions for the equity value with two unknowns, asset value and the asset volatility. As mentioned before, we cannot observe the market value of assets and the asset volatility. We therefore need an alternative solution in order to find the today's asset value V_t. Thus, we follow a common way to extract the V_t and σ_V, whereas it is assumed a geometric Brownian motion model for equity price E_t. Consequently, we can apply the Ito's Lemma to determine the instantaneous volatility of the equity from the asset volatility:

$$\sigma_E E_t = \sigma_V \frac{\partial E_t}{\partial V_t} V_t \tag{39}$$

where σ_E is the instantaneous volatility of the company's equity at time t. We then take the partial derivative of Equation 32 and 36 with respect to asset value, V_t, and reallocate Equation 39.[10] Consequently, we end up with equations relating the equity volatility to the asset volatility for both cases:

---

[10] Same procedure is done in order to find an expression for equity volatility for the unadjusted model

The adjusted model - Case 1:

$$\sigma_E = \sigma_V \frac{V_t}{E_t}\left[N(d_1) + \frac{D}{D+I}\left(N(j_1) - N(k_1)\right)\right] \tag{40}$$

The adjusted model - Case 2:

$$\sigma_E = \sigma_V \frac{V_t}{E_t}\left[N(d_1) + \frac{D}{D+I+F}\left(1 - N(k_1)\right)\right] \tag{41}$$

As we are only including public traded firm, we can observe E_t from the market in both cases. In addition, we have estimated the equity volatility σ_E from historical data. Lastly, we can determine the unknowns V_t and σ_V by solving Equation 32 and 40 for Case 1 and Equation 36 and 41 for Case 2 simultaneously.

Minimize deviation data – model

When calibrating our multi-period model to equity value and equity volatility, we use solver to simulate the asset value and asset volatility for both cases. To do so, we are minimizing the squared percentage error between the observed values for equity and volatility and the imputed counterparts. The squared percentage errors are given by:

$$SE = \left(\frac{E_t^0}{E(V_t, \sigma_V)} - 1\right)^2 + \left(\frac{\sigma_E^0}{\sigma_E} - 1\right)^2 \tag{42}$$

Where E_t^0 and σ_E^0 are the observed equity value and equity volatility, and $E(V_t, \sigma_V)$ and σ_E is the modelled equity value and equity volatility. Finally, by minimizing the squared percentage error (Equation 42) and performing iterations with the Solver routine in Excel for each firm, we generate the final values for the asset value, V_t, and asset volatility, σ_V. Thus, the next step is to estimate the probability of default.

The probability of default is estimated by using the distance to default (DD) and the cumulative standard normal distribution. Written as:

$$DD = \frac{\ln\left(\frac{V_t}{L + D + I + F}\right) + \left(\mu - \frac{\sigma_V{}^2}{2}\right)(T - t)}{\sigma_V \sqrt{T - t}} \qquad (43)$$

$$Prob(default) = \Phi[-DD] \qquad (44)$$

where V_t and σ_V is the current values for asset value and asset volatility, and μ is the drift rate.

Credit spreads

As we are implementing three models with different pay-off structure and assumptions, we need a consistent way to estimate the credit spread in order to be able to compare them. As mentioned earlier, we use an expression derived by Chen, Collin-Dufresne, and Goldstein (2009) in order to estimate credit spreads. The expression[11] is as follows:

$$S = -\left(\frac{1}{T - t}\right)\log(1 - (1 - R)N\left[N^{-1}(\pi^p) + \theta\sqrt{T - t}\right] \qquad (45)$$

where S[12] is the credit spread, R is the recovery rate, π^p is the probability of default, and $\theta = \frac{\mu - r}{\sigma}$ is the Sharpe ratio on the assets of the firm.

There are several advantages of using this expression to estimate the credit spreads. One advantage is that the only values that differs across our three models, and are required to implement Equation 45, are the final values of the asset value and asset volatility. This makes our estimation more reliable and simplifies our comparison analysis. Another reason is that it depends only on three parameters (recovery rate, the Sharpe ratio and the probability of default), which are all crucial for the calibration of structural models (Chen, Collin-Dufresne, & Goldstein, 2009).

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[11] See Appendix A in the Chen, Collin-Dufresne, and Goldstein (2009) paper for the derivation of this expression.

[12] S is defined as (y-r), where y is the yield on the corporate bond and r is the risk free rate

Analysis (Results)

In this section, we will present our findings, based on the methodology described above. Firstly, we will compare our estimated average credit spread per rating with the average of actual credit spreads per rating. Secondly, we will test the rank correlation, Spearman's ρ. Lastly, we will present a graphical analysis. Together, these three analyzes will be combined into one overall conclusion of our work. As most of the firms in our dataset are in the BBB segment, we will base our main analysis on this group, as mentioned earlier in the thesis.

Average credit spreads per rating

The first analysis we have performed is to compare our estimated credit spread per credit rating for each of our models with the actual average credit spread per rating. In order to find a representative yield of the actual bonds, we have taken the average yield[13] in January and February 2017, before subtracted the risk free rate used throughout our model. The reason for this is that this is the two months closest to our time of estimation. Hence, we think that this average will be the closest to an actual yield at the time of our analysis for the bonds in our dataset. In the following table the findings are summarized:

Table 3: Average credit spreads in basis points (bps)

Rating	Actual	Unadjusted model	Adjusted model - Case 1	Adjusted model - Case 2
A or better	67	27	29	31
BBB	122	96	97	100
BB	215	178	181	188
B	307	305	356	358
CCC or worse	526	433	460	462

In Table 3, one can see that both adjusted models are closer to the actual spread for all ratings, expect B. When comparing our two models, Case 1 and Case 2, one can see that Case 2 is the model which predicts spreads closest to the actuals for all cases, except for B rated bonds. This is better shown by the squared percentage error for each rating category, which is shown in Table 4:

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[13] Mid yield extracted from Bloomberg

Table 4: The Squared Percentage error

Rating	Unadjusted model	Adjusted model - Case 1	Adjusted model - Case 2
A or better	34.65%	31.62%	28.27%
BBB	4.58%	4.28%	3.48%
BB	2.95%	2.55%	1.62%
B	0.00%	2.55%	2.84%
CCC or worse	3.14%	1.56%	1.46%

In the table above, we show the squared percentage error between the modelled spread and the actual spread for each rating category. For all rating categories except for A or better, all three models perform at a level that has to be classified as very satisfactory. When we look at the errors for the BBB rated firms, both the adjusted models perform slightly better than the unadjusted model (i.e. the unadjusted model differs with 0.30% from adjusted model - Case 1, and 1.10 % from adjusted model - Case 2). Additionally, the model in Case 2 performs better than the model in Case 1. The reason for this is that the probability of the asset value being smaller than the fixed cost (F) is so small, that the cost of sharing the values created up to $D + I + F$ between all three claims is marginally greater than paying the fixed cost first and then sharing interest (I) and dividends (D).

Lastly, in the unadjusted model we also find evidence of the credit spread puzzle, which is mentioned in the literature review. In the BBB segment, the unexplained spread is 26 basis points (bps), which is in line with previous research (Feldhütter and Stephen found it to be ~10bps). This unexplained spread is reduced to 25bps in Case 2 and 22bps in Case 1. The 1bps and 4bps reduction is not a great difference; however, it is a reduction of 0.30% for Case 1 and more than 1% point in the squared error for Case 2. This cannot be said to be revolutionary, but all efforts that are a part of closing the unexplained gap have to be taken into account. Based on this analysis, we conclude this paragraph by claiming that both our two models have improved the Merton model, if only, a marginal share.

Rank correlation: Spearman's ρ_s

In this analysis, we will analyze whether our models perform better than the unadjusted model in ranking the credit spreads. That being, which model has the highest correlation with the actuals when it comes to ranking the credit spreads

from highest to lowest. In order to perform this analysis, we have ranked the credit spreads for all models, and then calculated the correlation with the actual ranking for all three models. This analysis we have done following the approach of Spearman's ρ_s (Xu, Hou, Huang, & Zou, 2015). This analysis follows the following approach:

$$\rho_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)} \tag{46}$$

where:

$$d_i = Rank(x_i) - Rank(y_i) \tag{47}$$

where Rank(y_i) is the rank of the actual spreads and Rank(x_i) is the rank of the corresponding spread in the model.

Performing this analysis gives us the following results:

Table 5: Spearman's ρs

	Unadjusted model	Adjusted model - Case 1	Adjusted model - Case 2
ρ_s	0.5208	0.5282	0.5243

From Table 5, we can see that all models have a moderate rank correlation. For the unadjusted model, the adjusted model in Case 1 and 2, the rank correlations are 0.5208, 0.5282 and 0.5243 respectively. It is worth mentioning that both adjusted models perform slightly better than the unadjusted model. Contrary to the previous paragraph, in this analysis, Case 1 is the best performer. This means that the model in Case 1 is the best model of these three to rank the firm's spread.

This property is not to be taken lightly. Relative valuations of securities are a common practice, and thus, improving the ability to correctly rank a security can improve the efficiency of pricing.

Additionally, our modelled spreads are sensitive to our assumptions and inputs. However, a model that is able to correctly rank the firm's spread will be valuable, as the inputs can be adjusted to match the correct spreads, while the ranking would still be correct.

Therefore, we conclude this paragraph by claiming that the small improvement in Spearman's ρ_s is evidence of an improved model. Further, in this analysis we find that the model in Case 1 is better than the model in Case 2.

Graphical analysis

The last analysis we perform is a graphical analysis where we plot the spread for each model in a scatterplot with the actual spread on the x-axis to see which of the models have the highest R^2.
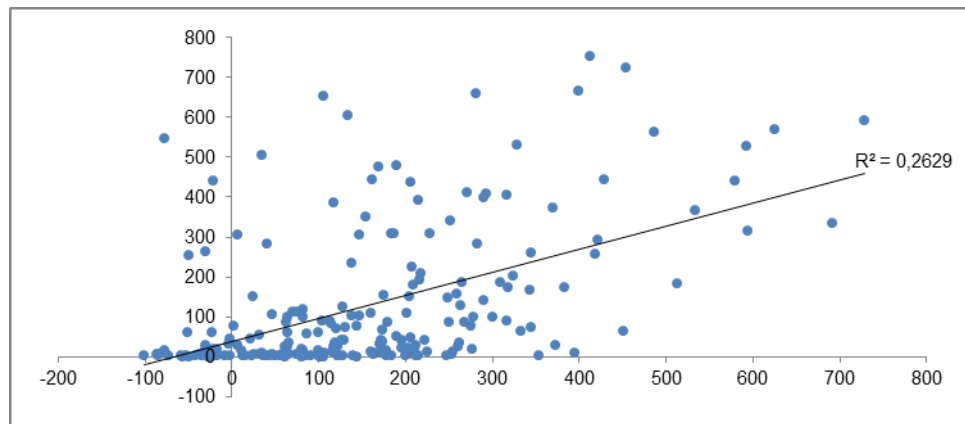
Figure 6: The unadjusted model
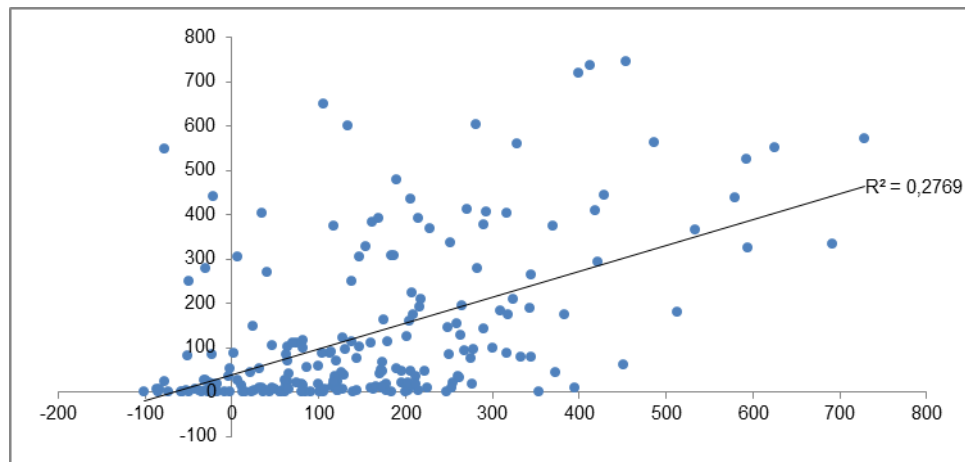
Figure 7: The adjusted model – Case 1

Figure 8: The adjusted model – Case 2

Analysis

All models perform approximately equally, but the adjusted models have a slightly better R^2 than the unadjusted model (i.e. 0.2629 for the unadj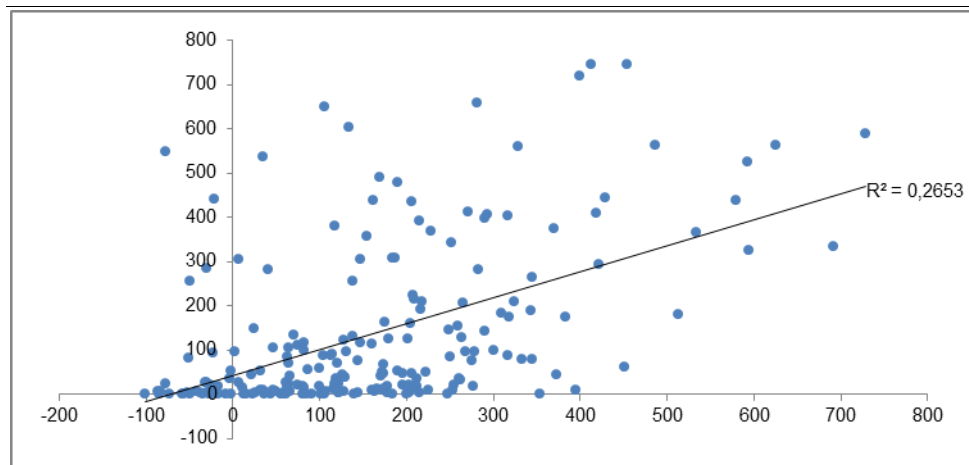usted model, 0.2769 for the adjusted model in Case 1, and 0.2653 for the adjusted model in Case 2). This analysis captures both the analysis of average credit spreads and Spearman's ρ_s. When comparing the two adjusted models, we find that the model in Case 1 is the better model in this analysis, marginally better than Case 2.

As this analysis captures the two previous ones, we will only conclude with that both adjusted models are better than the unadjusted model, and that the model in Case 1 is marginally better than the model in Case 2.

Overall conclusion

In order to conclude our analysis, we will summarize our findings and answer the question of whether the inclusion of operating leverage in the Merton model improves it.

We present evidence that both adjusted models are closer to the actual spreads than the unadjusted model. The difference is, however, small, but the adjusted models estimates a spread closer to adjusted model, which has to be said to be an improvement. Further, the study finds that the adjusted models are marginally better to rank the spreads than the unadjusted model. This implies that the relative valuation by the adjusted models are more correct than the unadjusted model.

Lastly, the adjusted models have a slightly higher explanatory power than the unadjusted model.

Based on our findings, we conclude that our adjusted models are slightly better than the unadjusted model. In order to rank our two adjusted models, we conclude that the model in Case 1 is a better model than the model in Case 2. The reason is that the differences in error of the estimated spreads are minimal. Additionally, the model in Case 1 is slightly better at ranking the spreads and has a slightly higher explanatory power.

Even though the adjusted model is not revolutionary better than the unadjusted model, we conclude that the Merton model is improved by including operating leverage. The reason is that every step that helps closing the Credit Spread Puzzle has to be included in the work of finding the complete and unifying model for prizing corporate bond debt. Our conclusion is also supported by our initial hypothesis and the operating leverage hypothesis. As investors should consider all aspects of a firm when the debt is valued and with a slightly improved model, we conclude that our models are slightly improving the Merton model.

Conclusion, criticism and future research

Our research indicates that the Merton model is improved by including operating leverage. However, this improvement is not revolutionary. The estimated credit spreads are slightly closer to the actual spreads than the unadjusted model. In addition, the adjusted models are better at ranking and have a slightly higher explanatory power. This improvement is, however, not enough to close the entire Credit Spread Puzzle, but can be seen as a step to finding a complete and unifying model for prizing corporate debt.

Criticism

The main drawback with our adjusted model is that the improvements are small compared with the extra work of including operating leverage in the model. Hence, for practical purposes and for a practical use, one has to consider the costs of the improvement with the benefits. We do not think the improvements are enough to include operating leverage in the model in practical use. However, for

academic purposes in order to find the complete model, our findings suggest that operating leverage should be included. This disadvantage comes in addition to the difficulty of implementing a structural model for credit risk (Wang, 2009).

Another limitation of our models is that the cost of operating leverage has to be estimated as it is not easily extracted from any financial report. This implies that the model for estimating the cost of operating leverage has to be the correct one in order for the answers to reflect the reality. Hence, in order to be certain of our findings, one has to be certain of the estimation.

The previous paragraph is also true for the Merton model as a whole. The model is based on the Black & Scholes model, which implies that if one is to find the true model, one has to assume that the Black & Scholes model is the correct model of the reality. This applies to all inputs in the model and all of its assumptions. Previous research has pointed out several weaknesses in the Merton model, and two of them are the estimation of drift rate and volatility. For instance, Trueck and Reachev (2009) argue that the fact that both volatility and drift rate of the firm's assets may also be dependent on the future situation of the whole economy is not considered.

Our estimation of equity volatility is extracted from historical data with a horizon of one year. Since the historical volatility is backwards-looking, one could argue that it is not a perfect estimate for the future volatility. In addition, the length of the horizon is debatable because the equity volatility is highly sensitive to jumps in the stock market. The second crucial input, drift rate, follows the same arguments as the equity volatility. The estimation of beta is dependent on historical data, and follows simplified assumptions. Hence, since drift rate and volatility are two crucial inputs in order to estimate credit spreads, it is important to keep in mind the criticism behind them.

Future research

As discussed in the previous paragraph, there are limitations to our model, and therefore, possibilities to improve it further. Additionally, in order to ensure that our findings are general and applicable to all firms, further research is needed.

The first point we would like to suggest is that a further extension that could improve the model is to make it capture the actual maturity of liabilities. In our model the time to maturity is a simplification and thus may not capture the true risk of the time to maturity. For example, if the true time to maturity is much shorter than our estimate, the risk of refinancing is greater due to less time to accumulate asset values greater than the liabilities. We believe that this would improve the model as it would better capture the reality of the firm.

Secondly, the model can be extended to include the tax shield and its value. Its value should already be included implicitly through the asset values but, if one were to capture its actual effect and implement it into the model, it could improve the model.

Another important factor our model does not consider is the liquidity premium of bonds. Less liquid bonds should be punished, compared to more liquid bonds, with a premium. Therefore, we think that if the model could be extended to include the firm's, or bond's, specific liquidity premium, it would better capture the pricing mechanisms of reality.

Lastly, since our model is only tested in one specific market at a specific point in time, we would propose that the model is tested at another point in time and/or on a different market. Through this one can test whether our findings are equal for all firms, or just for our dataset.

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Appendix

Preliminary Master Thesis

- Working title: Operating leverage's effect on credit spreads -

Supervisor: **Johann Reindl**

Examination code and name:

GRA19502 Master Thesis

Programme:

Master of Science in Business

Content

Content

Introduction

Corporate bonds tend to trade at a positive spread towards Treasuries. This is a natural result considering the spread being a risk premium, and that corporate bonds are perceived, and usually are, riskier than Treasuries. An increasing amount of research tries to explain this spread and how it is affected by credit risk, using leverage, credit rating scores and other variables deemed relevant.

Structural models of credit risk tend to not being capable of explaining the corporate-Treasury yield spread. This has been coined the "Credit Spread Puzzle". This puzzle has captured researchers' attention and has been tried resolved using different models, i.e. the Merton model and the Black & Cox model, and varying variables, i.e. sharp ratios and default probabilities. Feldhütter and Schaefer (2016), however, by extending the history of data, was able to close the credit puzzle within both the Merton model and the Black & Cox model.

The operating leverage hypothesis states that production costs play much the same role as debt-servicing, levering the exposure of a firm's assets to underlying risk (Marx, 2011). Hence, operating leverage should have a statistical significant effect on the corporate-Treasury yield spread. By introducing, and including, operating leverage into the Merton model, this paper will seek to find evidence of whether operating leverage can improve the explanatory power of models, and help close the "Credit spread puzzle". Closing this gap is important for understanding what investors are considering when bonds are priced in the secondary market.

In order to answer this question, we will modify the Merton model to include operating leverage, and test whether its performance is increased or not. In order to have comparable results, we will use data from the same period as Feldhütter and Schaefer.

Research question

Standard credit risk models, like the Merton model, struggle to match observed credit spreads and default probabilities. Our research question is; if operating leverage is included in the Merton model; will this close the unexplained gap between theoretical and observed prices?

Operating leverage is a highly relevant accounting measure which affects companies cash flows. A higher operating leverage would lower companies cash flow, which would lower the potential payments to creditors. It make sense that the creditors should incorporate the leverage effect of operating leverage when calculating the default probabilities and pricing a bond. This gives us a motivation to test whether the leverage effect of operating leverage would increase the degree of explanation of the Merton (1974) model. Following the operating leverage hypothesis (Marx, 2011), we expect that rational investors should consider the operating leverage, and thus, including this variable into the model should enhance its performance. This has lead to our hypothesis:

Hypothesis: Will the inclusion of operating leverage in the Merton model improve its performance?

H0: Yes, rational investors will consider all relevant information when valuing an asset and thus, according to the operating leverage hypothesis, investors should consider operating leverage.

H1: No, investors do not consider the operating leverage when valuing a bond, either because they already consider "enough" information, or the cost/reward is not great enough.

Literature review

In this section we will investigate some important studies concerning the credit risk puzzle and operating leverage hypothesis, and briefly describe their main findings. This would give us a broader understanding and knowledge for our research topic. However, most of previous studies have not covered the linkage between the "Credit Spread Puzzle" and operating leverage. Hence, most of the studies we are mentioning will mainly focus on those two subjects individually. Further, we will mention studies that covers the structural models that we are planning to employ in our work.

Merton's research published in 1974 have been an essential part of the valuation of corporate debt. His research covers important themes regarding credit spreads and the design of the firm's capital structure. In this paper, Merton introduces his model, which is an extension of the Black & Scholes option-pricing model. The model uses some simplifying assumptions and thus, is able to price a bond through an option-pricing model framework. The Merton model has proven to be an effective model in pricing risky liabilities, but a large amount of previous research has not been able to explain the complete "Credit Spread Puzzle" using it (Feldhütter & Schaefer, 2016).

Huang and Huang, in their first draft in 2003, were able to provide a consistent answer to how much of the historically observed corporate - Treasury yield spread is due to credit risk. Although the literature within this framework had earlier failed to reach a consensus in answering this question. In their research, they are using a large class of structural models to generate consistent credit yield spreads, given that each of the models is calibrated to match historical default loss. They conclude that credit risk accounts for only small fraction of the credit spread for investment grade bonds, while for high yield bonds, the credit risk accounts for a much larger fraction of the observed corporate -Treasury yield spreads (Huang & Huang, 2003). This gives us further motivation to investigate if operating leverage, additionally to the credit risk, could explain the corporate-treasury yield spread.

In Chen, Collin-Dufresne and Goldstein's paper published in 2009, they extend the results shown by Huang and Huang in 2003, by calibrate all models to Sharpe

ratios, recovery rates and historical default rates. Their result shows that the Merton model underpredicts actual spreads, which is referred to as the credit spread puzzle, and investigates whether it can be resolved. Their standard explanation of the credit spread puzzle is that structural models as Merton model only capture credit risk and ignore other factors which could explain credit spreads (Chen, Collin-Dufresne, & Goldstein, 2009).

In Huang and Huang's continued research, published in 2012, they extend their research from their first draft in 2003. Here they show that besides the credit risk, other factors could explain the credit spread. They provide evidence that states that credit spread puzzle cannot alone be explained by jumps in the firm value process, time-varying asset risk premia, endogenous default boundaries, or recovery rate. Hence, there are more to the credit spread puzzle that has not yet been found, increasing our motivation to seek evidence that operating leverage can explain some of this puzzle.

In Feldhütter and Schaefer's working paper from 2016, they continued the research done by Huang and Huang (2012) and Chen, Collin-Dufresne and Goldstein (2009), aiming to solve the credit spread puzzle. As mentioned in earlier research, they define the credit spread puzzle as standard structural models that failed to explain the credit spread. In this study they used empirical default rates for a much longer time series than previous studies, in order to estimate expected default probabilities with a reasonable degree of reliability. Their research reveals that long history of default rates is necessary, and that they are able to match their model spread with actual investment spread well. Further, their research provides indications that the credit spread puzzle has less to do with deficiencies of the models than with the way in which they have been implemented (Feldhütter & Schaefer, 2016).

In Bloomfield and Yehuda's paper from 2012, they investigate the relationship between consumer sentiments and operating leverage and their effect on credit spreads. Their study provides evidence of correlation between consumer sentiments and operating leverage, but that bond markets fail to incorporate this information into the price of firm-specific credit risk (the credit spread). This research paper is relevant for our research paper since they propose a way to

capitalize operating leverage and that they find evidence of operating leverage affecting the credit spread (Bloomfield & Yehuda, 2012). Although their focus is operating leases, their findings are in line with our hypothesis and hence, is of great interest in our continued research.

Mandelker and Rhee (1984) provides empirical evidence on the trade-off hypothesis, where operating and financial leverage can be combined in different portions to obtain a desirable amount of risk of common stock. Their study shows that the degrees of operating and financial leverage explain a large portion of the variation of systematic risk (beta) (Mandelker & Rhee, The impact of the degrees of operating and financial leverage on systematic risk of common stock, 1984). Additionally, they found a significant correlation between the two types of leverage. This paper shows that operating leverage does affect the riskiness of an asset, and thus, investors should consider it when valuing a corporate bond, which is the main part of our hypothesis.

Novy Marx (2011) provides direct empirical evidence for the "operating leverage hypothesis", which underlies most theoretical explanations of the value premium. This hypothesis explains value premium as firms with "levered" assets earn significantly higher average returns than firms with unlevered assets. Furthermore, the hypothesis states that production costs play much the same role as debt-servicing the exposure of a firm's underlying risk (Marx, 2011). Hence, even though this paper looks at the implication of operating leverage on equity returns, its findings are in direct connection with our hypothesis and is a clear indication that operating leverage should be considered by investors.

Data

So far, we have not started the work of extracting and working with our dataset. However, we have started the planning for what data we want to utilize to test our hypothesis, and how we will extract it. The following paragraphs are a brief explanation of the dataset we intend to use and why. The reason is that we have not been able to fully grasp the extent of the model and thus, not able to know the complete extent of what data we need. We will continue to work with the model, and continuously extract data as we progress.

In order to be able to comparing our results and test whether the implementation of operating leverage improves the Merton model, we will use the same dataset as Feldhütter and Stephen Schaefer (2016), to the extent where it is possible. Therefore, in our research, we will apply data from the US corporate bond market and listed US companies.

Since we are are trying to replicate the dataset used by Feldhütter and Schaefer, we will use the corporate bonds included in the Merrill Lynch investment grade and high-yield indices. However, for us to be able to implement operating leverage into the equations, we must utilize an additional condition. All companies used in our dataset must publish financial statements, or equivalent, with sufficient information regarding operating leverage. This dataset has also been used in other research, making it ideal for us when we need to compare our result with previous research. Following the same argument, we will not use TRACE transactions. Previous literature has not utilized this data, and using Feldhütter and Schaefer argument "we wish to use standard data sources used in earlier
literature, such that our results are most easily comparable with previous research", we come to the same conclusion.

Following Feldhütter and Stephen's data source for bond ratings, we will use the lower of S&P's rating and Moody's rating. This is to ensure that the rating used is as conservative as possible so bonds that is rated too high do not bias the modelled spread. If only one of Moody's and S&P has a rating, we will utilize this. Additionally, we will track rating changes to ensure that each bond is correctly categorized throughout the dataset.

The leverage ratio is calculated as in Feldhütter and Schaefer (2009), $\frac{Debt}{Equity+Debt}$. The equity value is calculated as the daily outstanding number of shares multiplied with the share price. The debt value is calculated as the latest quarterly information of long-term debt plus debt in current liabilities. This data will be extracted from DataStream.

In our continued work, when we are needed to extract or use additional data, we will continue using data as previous research has utilized. We want our results to be as comparable with previous research results as possible, and thus, the data used needs to be in line with previous research.

Progression plan

1st March 2017	Finish theoretical work and literature review (Chapter 2-3)
1st April 2017	Finish the remodeling of the Merton model and data collection (Chapter 4-5)
1st May 2017	Write the analysis and describe the results (Chapter 6)
1st June 2017	Conclude and write the introduction (Chapter 1 & 7)
15st August 2017	Finalize the master thesis
1st September 2017	Hand in the master thesis

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