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Assessing Default Risk of a Public Company:

An Empirical Analysis on the Basis of Volkswagen AG

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Abstract

The outbreak of the financial crisis brought credit default risk back to the minds of investors. It is the most important risk for debtholders and there is no ideal way given by legislation in how to assess it. Several different approaches evolved over time like ratio analysis, structural or reduced form models. They all have in common that they try to predict at least bankruptcy probability and some further attempt to give an indication about how to price it. Besides that non-quantitative measures such as market-, peer- or economic analysis are taken into consideration.

In order to evaluate performance of these models but credit default risk in general, Volkswagen AG, the German car manufacturer is chosen. It is on its way to become the world's largest carmaker and offers a long history for examinations.

By applying different models to VW's case, results have shown that single ratios are superior to all other models evaluated. Structural models have strengths and weaknesses over time due to their assumptions and multi-ratio models' performance is the worst. VW would have been bankrupt several times according to their predictions.

Nevertheless the other models pointed out that VW's credit worthiness recently improved and market expects it to continue. Therefore investing in VW's credit risk seems a reasonable decision for investors.

I would like to thank Martin Amann for his helpful advice regarding rating agencies and their methodology in assessing credit risk, my former colleagues Matthias Kreie and Konrad Kleinfeld for their support regarding VW's bond time series and credit reports, and my brother for his advice and the discussions about the dissertation. Moreover I am very grateful to my supervisor Mark Shackleton for all his support.

Alexander Thimm

Lancaster, July 2013

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List of Abbreviations

Abbreviation	Definition
ASW	Asset Swap
bn	Billion
BPS	Basispoints
CDS	Credit default swap
CL	Current liabilities
EBIT	Earnings before interest and taxes
EBITDA	Earnings before interest, taxes, depreciation and amortization
ECB	European Central Bank
e.g.	exempli gratia
EPS	Earnings per share
Eq.	Equation
Est.	Estimated
FFO	Funds from operation
Fig.	Figure
LBBW	Landesbank Baden-Wuerttemberg
LTL	Long-term liabilities
m	Million
MDA	Multiple Discriminant Analysis
MQB	Modularer Querbaukasten (engl. Modular Transversal Toolkit)
ODE	Ordinary differential equation
PD	Probability of default (=default prob)

PV	Present value
Q	Quarter
S&P	Standard and Poor's
TA	Total assets
UK	United Kingdom
US	United States
VW	Volkswagen
WACC	Weighted average cost of capital
Yr.	Year

List of Symbols

Symbol	**Definition**
$A(\cdot)$	Asset value
α	Bankruptcy cost in percent
A_B	Asset value at bankruptcy
$BC(\cdot)$	Bankruptcy cost
C	Coupon payment
c	Coupon
$D(\cdot)$	Debt value
$DD(\cdot)$	Distance to default
$Div(\cdot)$	Dividend
$\Delta(t_{n-1}, t_n)$	Year fraction
$E(\cdot)$	Equity value
F	Face value
g	Growth rate
$H(\cdot)$	Asset swap-spread
$I(\cdot)$	Interest
K	Hurdle
$\ln(\cdot)$	Natural logarithm
$\mu(\cdot)$	Drift rate
$m(\cdot)$	Cash pay-out
$P(\cdot)$	Present value of all cash payments
$PV01(0, T)$	Present value of one Euro Libor annuity

$\Phi(\cdot)$	Cumulative normal distribution
$Q(\cdot,\cdot)$	Survival probability
$R(\cdot)$	Recovery rate
$r(\cdot)$	Risk-free rate
$s(\cdot)$	Spread
$S(\cdot), S.; S(\cdot) = S.$	CDS-spread
$\sigma_A(\cdot)$	Asset volatility
$\sigma_E(\cdot)$	Equity volatility
τ	Tax rate
t	Today
t_n	nth cash flow date on the premium leg
T	Maturity
$TB(\cdot)$	Tax benefit
$v(\cdot)$	Value
$W(\cdot)$	Wiener process
$y(\cdot)$	Yield
$Z(\cdot,\cdot)$	Libor zero coupon bond price

1 Introduction

"It is widely accepted that one of the causes of the deep financial crisis witnessed since mid-2007 has been the deviation from well-established principles in the management of risk, in particular credit risk, by financial institutions" (González-Páramo 2010). These are the ECB's executive board member introductory words at Risk Europe 2010 in Frankfurt am Main which emphasize some of the main tasks of financial institutions: risk taking, risk management and the pricing of risk. Task one and two can be practiced by diversification according to portfolio theory (Markowitz 1952), for instance whereas the last one requires an in-depth understanding of the borrower and the risks associated with the loan. Especially the prediction of default, the risk that payable interest or principal payments cannot be made as scheduled (O'Kane 2008:32), and the losses which occur from such events are main concerns for banks.

In order to be prepared for such worst case scenarios and to comply to legal requirements (Basel Committee on Banking Supervision 2006) banks are required to establish appropriate credit risk assessment processes (Basel Committee on Banking Supervision 2000:3). Moreover banks should monitor the credits and *'consistently determine provisions for loan losses in accordance with the bank's stated policies and procedures, the applicable accounting framework and supervisory guidance'* (Basel Committee on Banking Supervision 2006:1). The stated goal is that banks have to be able to fulfil regulatory capital requirements which should prevent them from bankruptcy due to default losses (Basel Committee on Banking Supervision 2006:10).

Besides that the committee remains relatively silent in how banks have to achieve this goal. According to principle six, reasonable estimates and experienced credit judgement are mentioned but no information about the procedures or models is given (Basel Committee on Banking Supervision 2006). Therefore banks are responsible to establish the appropriate methods for the purpose of adequate credit risk assessment.

In the literature there are several different approaches which deal with the problem of estimating default probabilities and the pricing of credit risk. Nevertheless, all models can be allocated to three main classes: empirical, structural and reduced form (Chacko et al. 2007:65).

To begin with empirical or balance sheet based models which focus on accounting ratio analysis (Beaver 1966) or the more advanced ones that incorporate the most significant ratios to compute statistics like the Z-score by Altman (1968). They attempt to predict likelihood of bankruptcy in the future by using past accounting information.

Another approach is the structural or contingent claim model. It was first applied by Merton (1974) and is also built up on the balance sheet. Based upon the assumption that the firm value follows Geometric Brownian Motion, it tries to model the future process of the assets through time and compares it to the debt value at a specific point in time. That is why the model can be considered forward looking. Since the Merton model is the foundation of that approach, several other authors have developed extensions or their own models like, Black and Cox (1976), Geske (1977), Leland (1994) and Longstaff and Schwartz (1995) or Mella-Barral and Perraudin (1997).

In contrast to the previously mentioned models, reduced form models attempt to predict the probability of default by considering external signals (Chacko et al. 2007:65). That means that these models consider statistical or econometric data for the forecasting of default events. This implies that default is regarded as a random event. According to Chacko et al. (2007) models of Duffie and Singleton (1999) or Jarrow and Turnbull (1995) can be considered as reduced form or default intensity ones.

The structure of the dissertation is as follows. In the first part different credit default models are presented to the reader with their assumptions, methodology and their evolution through time. The second part is the application of the models to a public company. Therefore Volkswagen AG, the German carmaker is chosen since the firm does not only fulfil the requirement but also operated successfully in recent years.

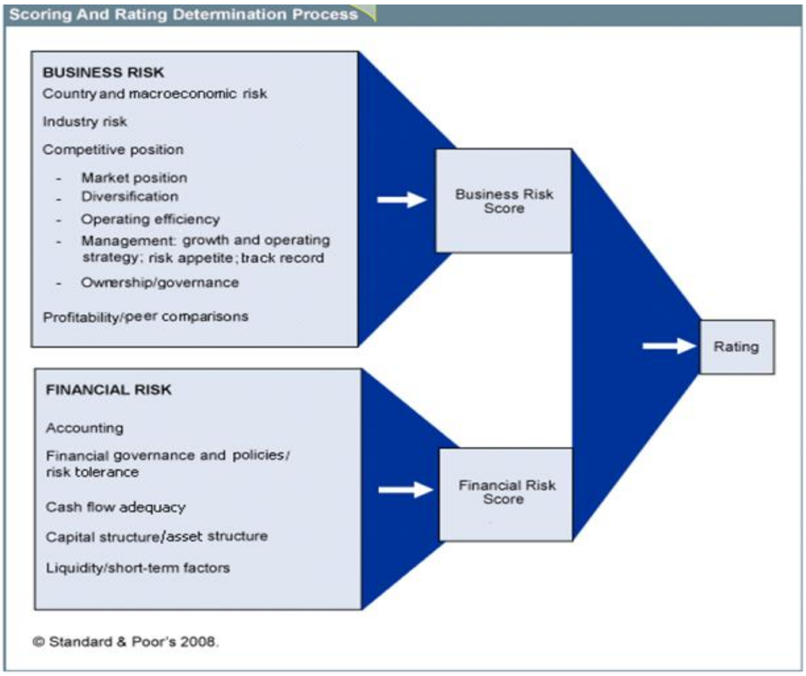
The goal of the dissertation can be regarded as assessing VW’s credit risk by applying different credit default risk models. The dissertation concludes with a short summary of the results.

2 Empirical Models

2.1 Single ratio Analysis

According to Beaver (1968:179) increases in the likelihood of failure are signalled up to five years before the default of the company by financial ratios. S&P and LBBW (Amann 2011) state that company ratings are composed of the financial risk profile and the business risk profile which can be considered as the sources of corporate credit risk.

Figure 1: Scoring and Rating Determination Process (Sources of Credit Risk)



Source: S&P and Amann (2011)

Additionally Revsine et al. (2005:233) emphasize that credit risk analysis is processed by assessing liquidity and solvency using financial ratios. In order to evaluate and quantify differences among companies, accounting ratios are considered amongst others in the rating process by rating agencies (Wen and Zhang 2013:2). They can be classified as activity, liquidity, solvency, coverage, performance and profitability ratios. Some ratios, which are also applied in part two of the dissertation, are shown in the following (Moeller 2012:335-336, Corey et al. 2013).

Liquidity Ratios:

Equation 1: Current Ratio

$$Current\ Ratio = \frac{Current\ Assets}{Current\ Liabilities}$$

Regarding the current ratio it can be seen that the higher the value the better the liquidity of the company[1].

Profitability Ratios

Equation 2: Gross Profit Margin

$$Gross\ Profit\ Margin = \frac{Gross\ Profit}{Sales}$$

Equation 3: Net Profit Margin

$$Net\ Profit\ Margin = \frac{Net\ Income}{Sales}$$

These ratios measure the portion of gain of one unit of revenue. Gross profit considers direct- and net profit also includes indirect cost. It can be regarded as an indicator of market power and efficiency[2] as well. Nevertheless all ratios have in common that they should be considered over time and in comparison to peer companies. In his first paper Beaver (1966:191) has pointed out that non-failed firm ratios have remained stable whereas failed firm ratios worsened over the five year period, in particular in the last year.

Solvency Ratios:

Equation 4: Financial Leverage

$$Financial\ Leverage = \frac{Average\ Total\ Assets}{Average\ Total\ Equity}$$

Equation 5: Debt-to-Assets

$$Debt - to - Assets = \frac{Total\ Debt}{Total\ Assets}$$

Low solvency risk is accompanied by low financial leverage and debt-to-assets.

[1] Even though current assets are liquid in general there still remain differences in liquidity between cash and accounts receivable, for instance.
[2] This means that it considers the overhead cost of the firm and if the firm is able to increase the market price (in order to maintain the level of profitability) after suppliers have increased their prices.

Coverage Ratios:

Equation 6: Debt Coverage

$$Debt\ Coverage = \frac{EBIT}{Total\ Debt}$$

Equation 7: Interest Coverage

$$Interest\ Coverage = \frac{EBIT}{Interest\ Payments}$$

Equation 8: Fixed Charge Coverage

$$Fixed\ Charge\ Coverage = \frac{EBIT + Lease\ Payments}{Interest\ Payments + Lease\ Payments}$$

All presented coverage ratios have in common that the higher the value the better the financial strength of the firm. Furthermore it has to be said that the debt coverage ratio has '*excellent discriminatory power throughout the five year period*' (Beaver 1968:101).

Besides financial ratios, stock price changes can be used to predict default (Beaver 1966:180). Having considered annual stock returns he concluded that if companies face financial difficulties worse than expected, prices are adjusted downwards.

Equation 9: Annual Stock Return

$$Return_{it} = \frac{Dividend_{it} + Price_{it} - Price_{it-1}}{Price_{it-1}}$$

Equation 10: Earnings per Share

$$Earnings\ per\ Share = \frac{Earnings}{Share\ Price}$$

Therefore the expected ex ante return would be less than the ex post return and vice versa. Nevertheless statements about the magnitude of the difference cannot be made in advance because it depends on the degree of unexpected deterioration. These results are further supported by Maricica and Georgeta (2012) who also conducted research about the power of financial ratios.

An additional point which has to be kept in mind is the industry in which the examined firm is operating. To further clarify, an interest coverage ratio of two for a beverage company is different to a technology firm which has the same ratio but is more dependent on the business cycle (Berman and Pfleeger 1997). Furthermore accounting statements are built upon conservatism, book values reflect past performance and subject to management opinion (Mensah 1984:381). In particular, default prediction is of limited use under the going concern assumption (Hillegeist et al. 2004:6). Besides that, high misclassification rates are distinctive of backward looking ratio models (Begley et al. 1996:281).

Beaver concludes that ratios are not the only source investors' use nor that they only take the most recent value into account. He further underlines that multi-ratio models which consider differences of the previous ratio values have greater power in forecasting than single ratios. This statement is partially contradicted by Deakin (1972). He infers from his studies that Beaver's approach (1966) is more accurate on longer term whereas Altman's model (1968) is better over one year. This view is shared by Holmen (1988) whose research findings are that the application of Altman's Z-score led to more prediction errors than Beaver's debt coverage ratio. Another disadvantage is that accounting ratio distributions change over time (Mensah 1984:393) which requires redevelopments.

2.2 Multi-ratio Models

2.2.1 Altman Z-Score

In 1968 Altman (1968) published his model which predicts bankruptcy by using linear combination of five different financial ratios. As shown below the model is the mixture of ratios selected from list of twenty-two ones that predicted future bankruptcy of the sample firms under consideration best. Each ratio has assigned its own weighting which are outcomes of MDA.

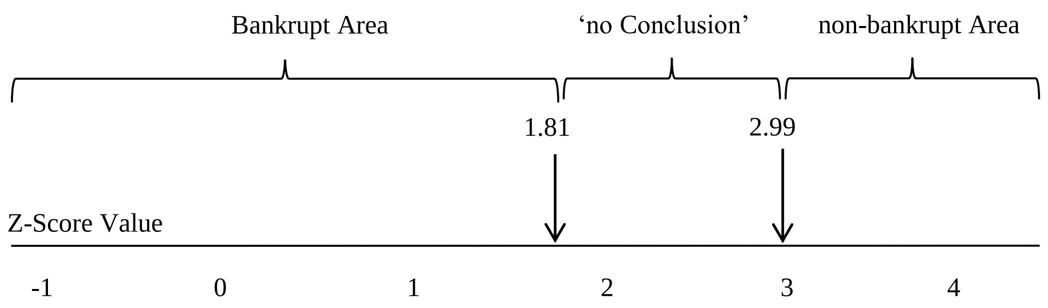
Equation 11: (Altman 1968:594) Z-Score

$$Z - Score = 0.012\frac{Working\ Capital}{Total\ Assets} + 0.014\frac{Retained\ Earnings}{Total\ Assets} + 0.033\frac{EBIT}{Total\ Assets} + 0.006\frac{Market\ Value\ Equity}{Book\ Value\ of\ Total\ Debt} + 0.999\frac{Sales}{Total\ Assets}$$

Following explanations are given by Altman with respect to chosen ratios. The definition of working capital is current assets deducted by current liabilities. In case the firm has continuous operating losses the first ratio is shrinking since current assets will be declining more than total assets (Altman 1968:594). Ratio number two measures cumulative retained earnings and implicitly contains information about firm's age (Altman 1968:595). Probability of failure is significantly higher in the early stage. Assets true productivity without any tax or leverage influence is presented by ratio three. Altman (1968:595) states that the survival of the firm depends on its earnings power of assets which is reflected by this one. Part four of the equation, the reciprocal of the leverage ratio, is the linkage to the market (Altman 1968:595). Defining insolvency as the point in time when debt exceeds equity, this ratio shows the distance to that boundary. Only referring to the statistical significance, the sales/total assets ratio would not be included in the model (Altman 1968:596). Nevertheless, it is ranked second in the overall discriminating ability of the model due to its relationship to other ratios in the equation. It reflects firm's activity (Chacko et al. 2007:123).

Having set the model, it is calibrated by examining sample firms. As it can be seen from the illustration below no conclusion can be made for scores between 1.81 and 2.99. For values lower than 1.81 or higher as 2.99 the result will be bankruptcy or no default within the next year, respectively.

Figure 2: Z-Score Classification



Source: Own representation based on Altman (1968:603)

Applications of the model have shown that it predicts bankruptcy up to two years accurately (Altman 1968:609). However prediction power is decreased significantly after the second year. One weakness of the model is that it only regards publicly traded US manufacturing companies. Therefore Altman (2000:25) published a revised model for private firms, Taffler (1982) developed his model for UK companies and Casey and Bartczak (1985) published their cash flow data model.

2.2.2 Zeta™ Analysis

A few years after the Publication of the Z-Score Altman, Haldeman and Narayanan (1977) made public another model called Zeta™ analysis. Linear as well as quadratic approach were examined by the authors. Based on the list of twenty eight different financial ratios, the seven most significant ones with regard to bankruptcy prediction of sample firms were chosen (Altman et al. 1977:34). These are EBIT/totals assets, standard error of estimate of EBIT/TA, interest coverage ratio, retained earnings/total assets, current ratio, common equity/total equity and total assets. Their range is from liquidity to company size.

Applying the model to sample firms has shown prediction accuracy of default of over 90% in the first and up to 70% over five years (Altman et al. 1977:31). That is significant improvement in comparison to the Z-Score, especially over the long run (Altman et al. 1977:40). In the short run up to two years and under direct comparison the Z-Score is slightly more exact in forecasting non-bankruptcy (ibidem). Moreover the model is valid for manufacturing and non-manufacturing companies and the linear model is superior to the quadratic one (Altman et al. 1977:31).

2.2.3 Ohlson Model

Ohlson (1980:111) implemented his model by using conditional logit regression analysis. His aim was to avoid problems which occur in MDA. In addition the model does not require any assumptions which have to be made regarding prior probabilities of default as well as the distribution of predictors (Ohlson 1980:112). Besides these advantages there are weaknesses of the model like data collection. In order to make realistic predictions of failure, predictors have to be available in advance of the default event (Ohlson 1980:113). This can be problematic since annual reports are not publicly available at fiscal year-end due to the compulsory auditing process. There are several other issues which are mentioned by Ohlson that have to be considered but to conclude a long story short it can be said that much depends on the data (Ohlson 1980:113).[3]

Ratios or predictors which were selected by him for his probabilistic model of bankruptcy are the following ones: the logarithm of total assets/GNP (X_1) price level

[3] The exact mathematical equations and derivations are not shown here since the author's intention is to put the emphasize on the evolution of empirical models and a brief comparison.

index reflected size of the firm. Some of the other ratios such as total liabilities/total assets (X_2), working capital/total assets (X_3), current liabilities/current assets (X_4), funds provided by operations/total assets (X_5) or net income/total assets (X_6) are already known from the previous models or appear in a slightly different way. Completely different are the scaled change in net income (X_7), the binary approach for total assets minus total liabilities (X_8) and net income for the last two years (X_9). In this case binary means that if both figures are negative input in the equation is one and zero for positive values (Ohlson 1980:118-119).

Equation 12: (Ohlson 1980:121) Model

$$O - Score = -0.407 * X_1 + 6.03 * X_2 - 1.43 * X_3 + 0.0757 * X_4 - 1.83 * X_5 - 2.37 * X_6 - 0.521 * X_7 - 1.72 * X_8 + 0.285 * X_9 - 1.32.$$

To convert the O-score into a probability following equation is applied:

Equation 13: (Ohlson 1980) Conversion Formula

$$(1 - Q(t,T)) = \frac{\exp(O - score)}{(1 + \exp(O - score))}.$$

The decision rule is that companies with $(1 - Q(t,T)) > 0.5$ are at risk and $(1 - Q(t,T)) < 0.5$ are safe. Having performed calculations, results have shown that there are four factors of statistically significance which influence the default probability within one year (Ohlson 1980:110). These are size, measures of financial structure, performance and current liquidity, whereas the evidence for the first three is larger than for the last one. Nevertheless, prediction error rate of the model is higher than the rates of both previously presented models by Altman. It can be seen that no market based data such as price for instance are incorporated in the model (Ohlson 1980:111). Including this kind of data can reduce disadvantages leading to more prediction power. Other models, which are not very different to the presented ones are Shumway (2001) and Zmijewski (1984) or the hybrid CHS (Campbell et al. 2011) model which is a combination of accounting and market data.[4]

[4] Some of these models are applied in the second part of the dissertation. For more information about the models, mechanics and assumptions, the author encourages the reader to view the academic papers referred to at the end.

3 Structural Models

3.1 Merton-Model

3.1.1 Option Approach

The first structural model was published by Merton (1974). It is based on the assumption of perfect capital markets and that firm's asset value follows a lognormal process where $A(t)$, $D(t)$ and $E(t)$ represent asset, debt as one zero coupon bond and equity value, respectively.[5] Moreover volatility $\sigma_A(t)$ is assumed to be constant, bankruptcy is costless, debt consists of a zero coupon bond with face value F and maturity T, there are no dividend payments or other cash outflows and $dW(t)$ is a Wiener process. Under risk neutrality drift rate $\mu(t)$ equals risk-free rate $r(t)$ which is constant as well (Modigliani and Miller 1957)[6]. Relaxing assumptions by allowing for cash pay-outs per unit time $m(t)$ is shown by Cossin and Pirotte (2001), for instance.

Equation 14: (O'Kane 2008:38:) Asset Value

$$A(t) = D(t) + E(t)$$

Equation 15: (Merton 1974:450) Asset Value Process

$$\frac{dA(t)}{A(t)} = \mu(t)dt + \sigma_A(t)dW(t)$$

At maturity T there are two possible scenarios. Solvency occurs if $A(T) \geq F$. Owners sell the firm before repaying the debt leaving $A(T) - F$ for them. Insolvency is declared if $A(T) < F$ resulting in takeover of the firm by debtholders. Equityholders would be left with nothing. Therefore payoffs for debt and equityholders at maturity can be written and drawn as follows:

Equation 16: (Merton 1974:453) Payoff to Debtholders at Maturity

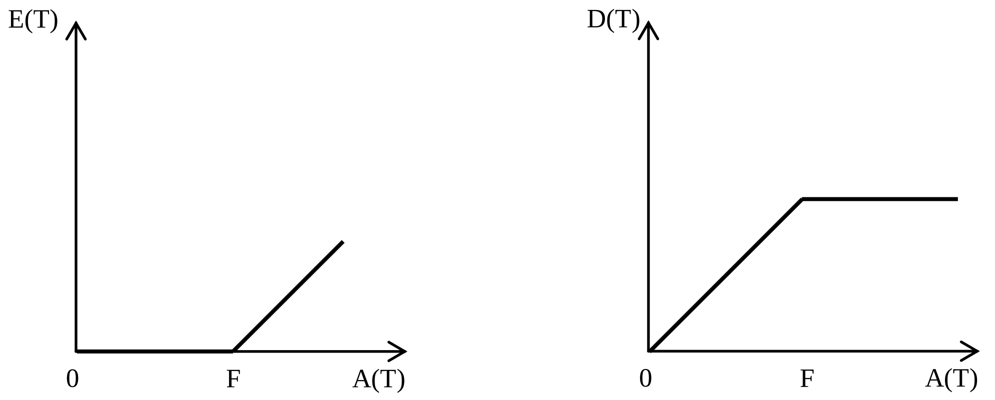
$$D(T) = F - \max[F - A(T), 0] = \min\,[F, A(T)]$$

Equation 17: (Merton 1974:454) Payoff to Equityholders at Maturity

$$E(T) = \max\,[A(T) - F, 0]$$

[5] The author follows the notation by Dominic O'Kane (O'Kane 2008).
[6] All models are applied under the assumption of risk-neutrality. Therefore drift rate is equal to risk-free rate. In general, the higher the drift rate the lower the PD. It does not affect the credit spread.

Figure 3: Payoff Diagram at Maturity



Source: Own representation based on O'Kane (2008:39)

As it can be seen payoffs at T are similar to call and put option payoffs at maturity. This means that option pricing theory (Black and Scholes 1973, Merton 1973) can be applied. Equity and debt value are given by:

Equation 18: (Merton 1974:454) Call Option on Firm's Assets

$$E(t) = A(t)\Phi(d_1) - F * \exp\left(-r(t)(T-t)\right)\Phi(d_2)$$

Equation 19: (Merton 1974:454) Put Option on Firm's Assets

$$D(t) = F * \exp\left(-r(t)(T-t)\right)\Phi(d_2) + A(t)\Phi(-d_1)$$

with

$$d_1 = \frac{\ln\left(\frac{A(t)}{F}\right) + \left(r(t) + 0.5 * \sigma_A^2(t)\right) * (T-t)}{\sigma_A(t) * \sqrt{T-t}}$$

and

$$d_2 = d_1 - \sigma_A(t) * \sqrt{T-t}$$

where $\Phi(\cdot)$ stands for the Gaussian cumulative function.

3.1.2 Credit Spread

3.1.2.1 Calculation

Credit spread s in the Merton framework can be defined as the risk premium above the risk-free rate (O'Kane 2008:40). It shows investor's compensation for bearing risk of investing in the instrument (O'Kane and Sen 2005:61).

Equation 20: (Merton 1974:454) Debt Pricing

$$D(t) = F * \exp\left(-(r(t) + s(t)) * (T - t)\right)$$

rearranged

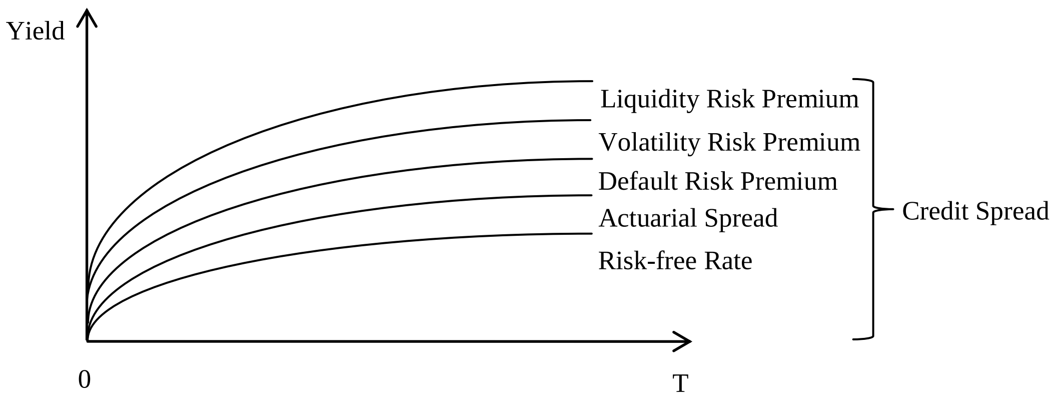
Equation 21: (Merton 1974:454) Credit Spread

$$s(t) = -\frac{1}{(T-t)} * \ln\left(\frac{D(t)}{F}\right) - r(t).$$

3.1.2.2 Components

Collin-Dufresne et al. (2001:2178) argue that credit spreads reflect the default probability and the change in the recovery rate. In the Merton model it is linked to structural variables as assets, equity and liabilities (Wang 2009:30). That is why the credit spread is an increasing function of leverage, defined by debt-to-asset ratio (Wang 2009:30). A more detailed approach is shown by O'Kane (2008:55) who divides the credit risk premium in the actuarial spread, default risk-, volatility risk- and liquidity risk premium. The actuarial spread is investor's compensation for the expected loss implied by historical default probabilities and recovery rates whereas default risk premium reflects the additional spread investors require for bearing the risk that true default risk is higher as stated by the actuarial spread. Changes in issuer rating are incorporated in the volatility risk premium.

Figure 4: Credit Spread Components



Source: Own representation based on O'Kane (2008:55)

It has to be said that the higher the credit spread the lower the credit rating. Moreover default probability increases with spread, in particular for non-investment grade issuers (O'Kane 2008:56). Credit spreads can be measured relative to treasury bonds or a swap curve which represents swap risk of AA-rated banks[7].

3.1.2.3 Determinants

According to Collin-Dufresne et al. (2001) there is limited knowledge about the factors which determine credit spreads. Their findings have shown that one quarter of variation in credit spreads is explained by traditional models. After adding other variables was not successful they conclude that the remaining three quarters are driven by aggregate factors which are not associated with bond or stock markets but common to all outstanding bonds.

Another approach which relies on the Merton methodology is presented by Cooper and Davydenko (2007). In estimating the true cost of debt, they split the yield into two parts, expected default and expected return. Following the standard WACC approach the yield of high-rated bonds mainly consists of expected return whereas the return of non-investment grade bonds is dominated by expected default premium. Thus, they conclude that the standard methodology is appropriate for high-grade bonds but overestimate the cost of low-rated bonds which has to be adjusted downwards[8].

Similar results are shown by Huang and Huang (2003) who have also examined that investment-grade bonds' yield premium carries small fraction of default risk premium dependent on the maturity, whereas junk bonds' yield has greater relative portion of bankruptcy risk premium.

3.1.3 Default Probability

Default occurs if firm's asset value is below debt value at maturity.

Equation 22: (O'Kane 2008:41) Survival Probability

$$Q(t,T) = \Pr\left(A(T) \geq F\right) = \Phi(d_2).$$

Therefore the risk neutral default probability can be written as:

Equation 23: Default Probability

$$(1 - Q(t,T)) = \Phi(-d_2).$$

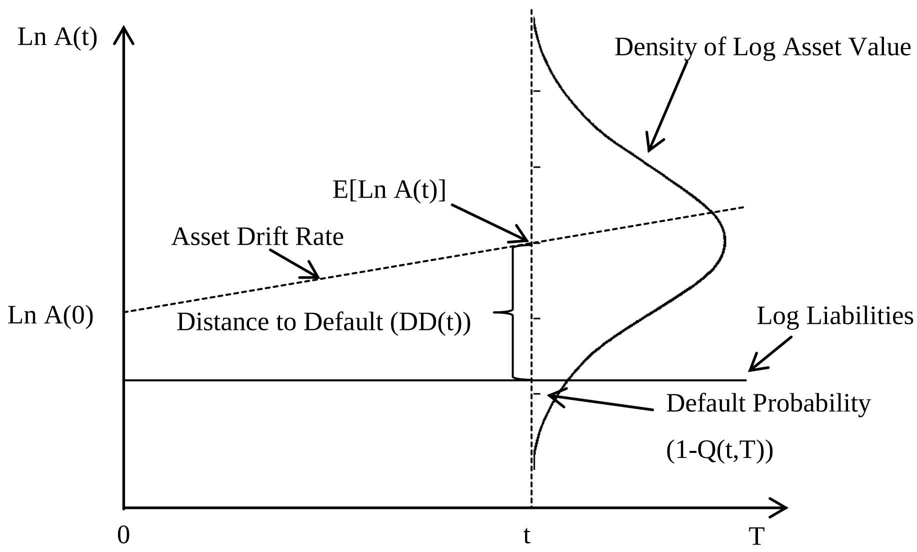
[7] Latter would lead to lower credit spreads in comparison to the risk-free rate.
[8] Merton model is used to determine the correct downward adjustment.

Another approach to assess the probability of default is to determine how far away the firm value is from being below F at maturity. This is known as the distance to default[9].

Equation 24: (Loeffler and Posch 2011:29) Distance to Default

$$DD(t) = \frac{\ln\left(\frac{A(t)}{F}\right) + \left(r(t) - \sigma_A^2(t)\right) * (T - t)}{\sigma_A(t) * \sqrt{(T - t)}}.$$

Figure 5: Distance to Default



Source: Own representation based on Loeffler and Posch (2011:28)

Defining $R(t)$ as the recovery rate at maturity the price of the zero coupon bond which pays F or $R(T)$ at time T is given by following equation:

Equation 25: (O'Kane 2008:41) Discounted expected Zero Coupon Bond Price

$$D(t) = F * \exp\left(-r(t)(T - t)\right) * \left(Q(t,T) + \left(1 - Q(t,T)\right) * R(T)\right)$$

$$= F * \exp\left(-\mathrm{r(t)(T - t)}\right) * \left(\Phi(d_2) + \Phi(-d_2) * R(T)\right).$$

Additionally the recovery rate $R(t)$ can be determined endogenously (O'Kane 2008:41). It is the value the investors receive at default divided by the bond's face value.

[9] Information about the accuracy of distance to default models are shown in the paper of Bharath and Shumway (2008).

Equation 26: (O’Kane 2008:41) Recovery Rate

$$R(t) = \frac{A(t) * \Phi(-d_1)}{F * \exp\left(-r(t)(T-t)\right)\Phi(-d_2)}$$

3.1.4 Asset Volatility

The asset volatility cannot be observed in the market. That is why it has to be computed by using its relation to equity volatility σ_E. Following equation is given by applying ito’s lemma:

Equation 27: (O’Kane 2008:41) Equity Volatility

$$\sigma_E(t) = \frac{\partial E(t)}{\partial A(t)} * \frac{A(t)}{E(t)} * \sigma_A(t)$$

$$= \sigma_A(t) * \Phi(d_1) * \frac{A(t)}{E(t)}.$$

3.2 Black and Cox Extension

Black and Cox (1976) extended the Merton model by adding a barrier function (Chacko et al. 2007:105). The result is that default can occur at any point in time, not only at maturity, whenever asset value falls below the specific constant threshold K known as safety covenant, for instance. The barrier function and the function to compute default probability can be stated as follows:

Equation 28: (Chacko et al. 2007:106) Barrier Function

$$A(t) = \begin{cases} K, for\ t < T \\ F, for\ t = T \end{cases}$$

and

Equation 29: (Chacko et al. 2007:107) Default Probability Barrier Function

$$(1 - Q(t,T)) = \Phi(h_1) + \exp\left\{2 * \left(r(t) - \frac{\sigma_A^2(t)}{2}\right) * \ln\left(\frac{K}{A(t)}\right) * \frac{1}{\sigma_A^2(t)}\right\} * \Phi(h_2)$$

with

$$h_1 = \frac{\ln\left(\frac{K}{\exp\left(r(t)(T-t)\right) * A(t)}\right) + \frac{\sigma_A^2(t)}{2} * (T-t)}{\sigma_A(t) * \sqrt{T-t}}$$

and

$$h_2 = h_1 - \sigma_A(t) * \sqrt{(T-t)}.$$

The zero coupon bond's price is:

Equation 30: (Chacko et al. 2007:109) Zero Coupon Bond Price

$$D(t) = \exp\big(-r(t)(T-t)\big) * \big(1 - Q(t,T)\big) * F.$$

To calculate the credit spread $s(t)$ following two equations are set equal, solved for the yield $y(t)$ and risk-free rate $r(t)$ has to be deducted in the end (Chacko et al. 2007:109):

Equation 31: (Chacko et al. 2007:109) Zero Coupon Bond Yield

$$\exp\big(-r(t)(T-t)\big) * \big(1 - Q(t,T)\big) * F = F * \exp\big(-y(t) * (T-t)\big).$$

In comparison to the Merton model, which has a default barrier of zero until maturity, the credit spread in the Black & Cox extension is higher for the same inputs (Chacko et al. 2007:109). This observation can be further explained by the possibility of early default which increases the credit spread. Therefore the spread in Black & Cox model will always be higher than the Merton one due to additional risk which better reflects reality.

3.3 Leland Extension

3.3.1 Option Approach

Leland (1994) extended the Merton model by tax rate and cost of bankruptcy. It is also assumed that asset value follows Geometric Brownian Motion with constant fraction of firm value $\mathrm{m}(t)$ which can be distributed to debt and equityholders (Lando 2004:60). This model is built on the assumptions of perfect capital markets, perpetual coupon payments, constant capital structure and volatility.

Equation 32: (Leland 1994:1217) Asset Value Process

$$\frac{dA(t)}{A(t)} = (\mu(t) - m(t))dt + \sigma_A(t)dW(t)$$

Pay-outs have to be financed by equityholders or issuance of new debt. Therefore the value of the security G which receives coupon payment C instantaneously, can be written as (Pawlina 2011):

Equation 33: (Leland 1994:1218) ODE

$$rG = 0.5 * \sigma_A^2 * A^2 * G_{AA} + r * A * G_A + C$$

with

$$G_A = \frac{\partial G}{\partial A}$$

or

Equation 34: (Leland 1994:1218) General Solution

$$G(A) = \frac{C}{r} + U_1 * A + U_2 * A^{-X}$$

with

$$X = \frac{2 * r}{\sigma_A^2}.$$

In case that asset value is too low to justify coupon payments, equityholders can liquidate the firm (Lando 2004:61). The other default trigger is positive net worth covenant (Pawlina 2011). Liquidation means that owners get nothing whereas debt-holders receive the assets deducted by bankruptcy costs.

It can be shown that the firm value is equal to:

Equation 35: (Leland 1994:1221) Firm Value

$$v(A) = A - BC(A) + TB(A)$$

or

$$v(A) = D(A) + E(A)$$

where equity value can be rewritten as

Equation 36: (Leland 1994:1221) Equity Value

$$E(A) = A - (1-\tau) * \frac{c}{r} + \left[(1-\tau) * \frac{c}{r} - A_B\right] * \left[\frac{A}{A_B}\right]^{-X},$$

and debt value

Equation 37: (Leland 1994:1219) Debt Value

$$D(A) = \frac{c}{r} + \left[(1-\alpha) * A_B - \frac{c}{r}\right] * \left[\frac{A}{A_B}\right]^{-X}.$$

It can be observed that equityholders' claim is convex whereas debtholders' one is concave. In case asset value grows to infinity the amount of debt is calculated as $\frac{c}{r}$ and $(1-\alpha) * A_B$ is the debt value if the firm is liquidated. Under the assumption that debt is not protected, equityholders file for bankruptcy when:

Equation 38: (Leland 1994:1222) Bankruptcy Trigger for optimal Equity Management

$$\frac{\partial E}{\partial A}\bigg| A = A_B \quad = 0$$

resulting in the following firm value A_B at default:

Equation 39: (Leland 1994:1222) Firm Value at Default

$$A_B = (1-\tau) * \frac{c}{r} * \frac{X}{X+1} < (1-\tau) * \frac{c}{r}.$$

A_B will be reduced by higher asset volatility, risk-free interest rate and lower coupon (Leland 1994:1225). The perpetual coupon can be calculated by solving (Teixeira 2007:1147):

Equation 40: (Teixeira 2007:1147) Coupon Determination

$$F * \exp(-r * T) = \frac{C}{r_{Leland}}.$$

For protected debt, which has positive net-worth covenant, value is given by:

Equation 41: (Leland 1994:1234) Protected Debt

$$D(0)[A(0)] = \frac{c}{r} + \left[(1-\alpha) * D(0)[A(0)] - \frac{c}{r}\right] * \left[\frac{A}{D(0)[A(0)]}\right]^{-X}$$ [10]

This means that default occurs when A is equal to the debt's face value $D(0)$ at issuance (Pawlina 2011). $A(0)$ is the firm value when debt is issued. Protective debt leads to lower optimal leverage, interest costs $(\alpha > 0)$ and lower asset value

[10] Where $D(0)[A(0)]$ is the same as $D_0(A_0)$.

compared to unprotected debt. In an environment of high tax rates, interest rates and low bankruptcy costs, differences are the largest.

The tax advantage TB results from issuance of debt and is accompanied by the cost of bankruptcy BC (Lando 2004:60).

Equation 42: (Leland 1994:1220) Tax Benefit

$$TB(A) = \frac{\tau * c}{r} * \left(1 - \left[\frac{A}{A_B}\right]^{-X}\right)$$

Equation 43: (Leland 1994:1220) Bankruptcy Costs

$$BC(A) = \alpha * A_B * \left[\frac{A}{A_B}\right]^{-X}$$

If the firm value tends to infinity, TB equals $\frac{\tau * c}{r}$ and BC declines to 0. For a company in default, bankruptcy costs are $\alpha * A_B$. BC and the firm value have an inverse relationship whereas the higher the TB the higher the asset value (Leland 1994:1223). When $v(A)$ is close to $v(A_B)$ increasing the coupon can reduce debt value. Moreover debt value can be increased by higher firm risk and risk-free interest rate. That is the specific feature for the behaviour of non-investment grade bonds when taxes and bankruptcy costs are positive.

3.3.2 Credit Spread

In order to calculate the credit spread, yield spread has to be determined first before deducting the risk-free rate. It can be defined as:

Equation 44: (Leland 1994:1223) Yield Spread

$$R\left(\frac{C}{A}\right) - r(t) = \frac{c}{D(A)} - r = r * \frac{k * \left(\frac{c}{A}\right)^X}{1 - k * \left(\frac{c}{A}\right)^X},$$

where

$$k = \frac{1 + X - (1 - \alpha) * (1 - \tau) * X}{1 + X} * \left(\frac{(1 - \tau) * X}{r * (1 + X)}\right)^X.$$

Regarding investment grade firms, increasing the coupon as well as the bankruptcy costs lead to higher credit spreads (Leland 1994:1226). Higher tax rates or asset value lower the spread. For junk bonds, their yield declines when firm's risk is increased.

3.3.3 Default Probability

Default probability is computed as follows:

Equation 45: (Leland 1994:1219) Default Probability

$$(1 - Q(t,T)) = \left(\frac{A}{A_B}\right)^{-X}.$$

Since the default probability is known, it is possible to calculate the present value of bankruptcy costs:

Equation 46: (Leland 1994:1220) Present Value of Bankruptcy Costs

$$BC(A) = \alpha * A_B * \left(\frac{A}{A_B}\right)^{-X}.$$

3.3.4 Asset Volatility

Asset volatility has to be determined likewise to the Merton (1974) model by using ito's lemma (Teixeira 2007:1147).

Equation 47: (Teixeira 2007:1147) Asset Volatility

$$\sigma_E = \frac{\partial E(t)}{\partial A(t)} * \frac{A(t)}{E(t)} * \sigma_A$$

with

$$\frac{\partial E}{\partial A_U} = 1 + \left[\frac{C * (1 - \tau)}{r} - A_B\right] * X * \frac{A_U^{X-1}}{A_B^X}.$$

Higher asset volatility leads to lower credit spreads for investment grade bonds and to higher spreads for non-investment grade ones.

3.4 Further Extensions and Performance of Structural Models

Further extension which contributed to the evolution of structural models but are not covered in the analysis in part two are summarized in brief. Geske (1977, 1979) and Geske and Johnson (1984) extended the Merton model by pointing out that sinking funds, safety convenants, multiple default options for coupons or other payment obligations can be dealt with as compound options. Influence of taxes and bankruptcy costs were examined by Turnbull (1979) whereas Kim, Ramaswamy and Sundaresan (1989) as well as Longstaff and Schwartz (1995) analysed the effects of different stochastic interest rate models within the structural framework (Charitou et al. 2008:156). Leland and Toft (1996) developed the Leland (1994) approach further by allowing for the study of the optimal maturity of debt and richer class of debt structures. Mella-Barral and Perraudin (1997) investigated strategic debt service within the Merton framework. Their research has shown that the credit spread can be determined too a large extent by this strategic behaviour of owners resulting in interest payments to debt-holders which are below the initially agreed ones.

There are some studies in which authors conducted research about the performance of structural models. Teixeira (2007) found that Merton (1974) and Leland (1994) overestimated bond prices while underestimating credit spreads. Spreads can be predicted for either very low or high levels depending on estimated asset volatility. Furthermore performance of both models was better for bonds with longer maturity or higher rating which can be specific for business sectors. Fabozzi et al. (2010) performed tests on six different structural models. Their results show the Black and Cox model (1976) is the best one and Geske's approach (1977) the second best one. They conclude that the worst performance of Merton's model is due to its unrealistic assumptions. Moreover they examined the determinants of bankruptcy prediction. According to their findings, continuous default, endogenous recovery and exponential barrier matter whereas random interest rates and flat default barrier are unimportant. Eom et al.'s (2004) outcomes are similar to the already presented ones. According to their examinations Merton's and Geske's model tend to underestimate credit spreads on average. This problem is less important for the second model because of the endogenous default boundary. The model by Longstaff and Schwartz (1995) shows high spreads on average influenced by stochastic interest rates. Nevertheless there are some bonds with very low spreads.

Agarwal and Taffler (2008) compared market-based and accounting-based default prediction models. From their findings it can be seen that structural models are not superior to accounting ones in predicting bankruptcy. It means the Z-Score model is slightly more precise leading to higher risk-adjusted revenues in a competitive loan market. Nevertheless differences between the two approaches are statistically not significant.

4 Reduced Form Models

4.1 Evolution

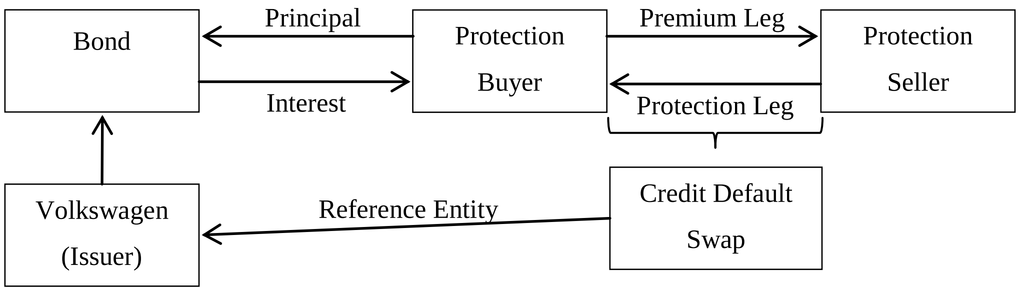
Reduced form models are mathematically advanced models which were introduced first by Jarrow and Turnbull (1992, 1995). Contrary to structural models which are limited due to delayed availability of information, problems in fitting the term structure of spreads and hard to apply to credit derivatives, reduced-form models model the probability of default itself (O'Kane and Turnbull 2003:5, Jarrow 2011:3). They can be used to extract default probabilities from market prices as well as deal with different maturities and more complex credit instruments. That is why they are chosen by market participants.

Lando (1998), Duffie and Singleton (1999) and Jarrow et al. (1997) further extended the initial approach in 1992. Nevertheless the Jarrow and Turnbull model (1995) is the widely used one (O'Kane and Turnbull 2003:5). It models the credit default as the first event of a Poisson process (ibidem).

4.2 CDS Market Model

The credit default swap is an OTC contract in which the protection buyer receives insurance against default of the reference entity by paying a fee to the protection seller (O'Kane 2008:82). To enter into the CDS contract which consists of two legs, the premium and protection one, is costless (ibidem).

Figure 6: Credit Default Swap



Source: Own representation based on O'Kane (2008:82).

Following formulas for the premium and protection leg are needed to calculate the CDS-spread (O'Kane 2008):

Equation 48: (O'Kane 2008:105) Present Value Premium Leg

$$\begin{aligned} Premium\ PV = {} & S_0 \Delta(t_{n^*-1}, t) Z(t, t_{n^*}) \big(1 - Q(t, t_{n^*})\big) \\ & + \frac{S_0}{2} \Delta(t, t_{n^*}) Z(t, t_{n^*}) \big(1 - Q(t, t_{n^*})\big) \\ & + S_0 \Delta(t_{n^*-1}, t_{n^*}) Z(t, t_{n^*}) Q(t, t_{n^*}) \\ & + \frac{S_0}{2} \sum_{n=n^*+1}^{N} \Delta(t_{n-1}, t_n) Z(t, t_n) \big(Q(t, t_{n-1}) + Q(t, t_n)\big). \end{aligned}$$

and

Equation 49: (O'Kane 2008:106) Present Value Protection Leg

$$Protection\ PV = \frac{(1-R)}{2} \sum_{k=1}^{K} \big(Z(t, t_k) + Z(t, t_k)\big)\big(Q(t, t_k) - Q(t, t_k)\big).$$

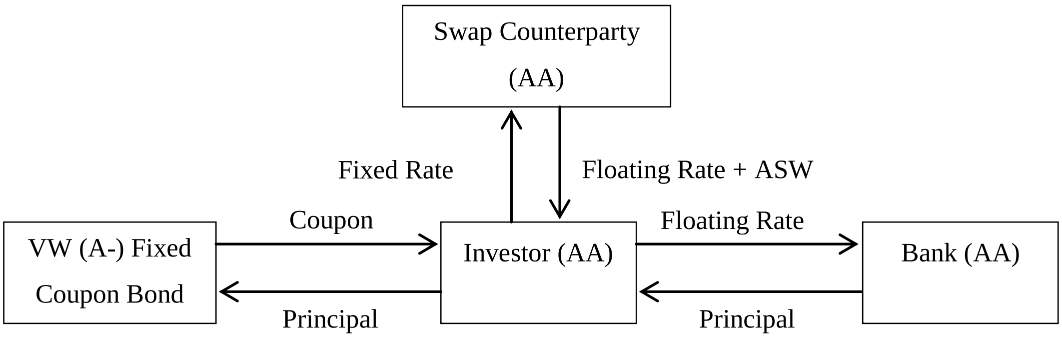
There are unknowns in both equations (Eq. 48 and Eq. 49). It is known that at initiation, the present value of the CDS is zero. Moreover the term structure of interest rate $Z(\cdot,\cdot)$ and the survival probability of the reference entity $Q(\cdot,\cdot)$ can be determined. Recovery Rate R is assumed to be constant and its value depends on the debt's seniority (ISDA 2003). All variables besides the credit spread S_0 are defined. Setting the two equations equal it is possible to solve for S_0. That is the insurance fee in BPS the protection buyer has to pay to the seller for bearing the risk of default of the reference entity.

4.3 Asset Swap-Spread

Another measure of credit risk which does not belong to the group of reduced form models is the asset swap spread (ASW-spread)[11]. It can be considered as a synthetic credit investment by purchasing a fixed coupon bond, entering into a payer swap and refinancing the whole position on a variable interest rate loan. The goal is to get a pure credit risk measure which is not affected by any refinancing issues.

[11] ASW-Spread is added to the reduced form models group because most of the market participants compare it to the CDS-Spread when default risk is analysed.

Figure 7: Asset Swap Mechanics



Source: Own representation

Following equation is used to determine the ASW-spread at time zero:

Equation 50: (O'Kane 2008:75) ASW at Initiation

$$H(0) = \frac{\frac{C}{F}\sum_{n=1}^{N} Z(0, \dot{t_n}) + 1 - P - \sum_{m=1}^{M} Z(0, t_m)\Delta(t_{m-1}, t_m)L(t_{m-1}, t_m)}{\sum_{m=1}^{M} Z(0, t_m)\Delta(t_{m-1}, t_m)}.$$

Rearranging and simplifying the ASW-spread can be written as:

Equation 51: (O'Kane 2008:75) ASW-Spread

$$H(0) = \frac{P_{Libor} - P}{PV01(0,T)}.$$

At initiation of the trade the ASW-spread is locked in. It is the credit risk premium over the trade's maturity at that specific point in time. Nevertheless the risk premium can be affected by liquidity issues when the amount of bonds outstanding is small, for instance. Therefore there can be differences between the ASW-spread and the CDS-spread. These can be illustrated by the credit default swap basis (Ali and Choudhry 2003):

Equation 52: (Ali and Choudhry 2003:20) Credit Default Swap Basis

$$Basis = Credit\ Default\ Swap\ Spread - Asset\ Swap\ Spread$$

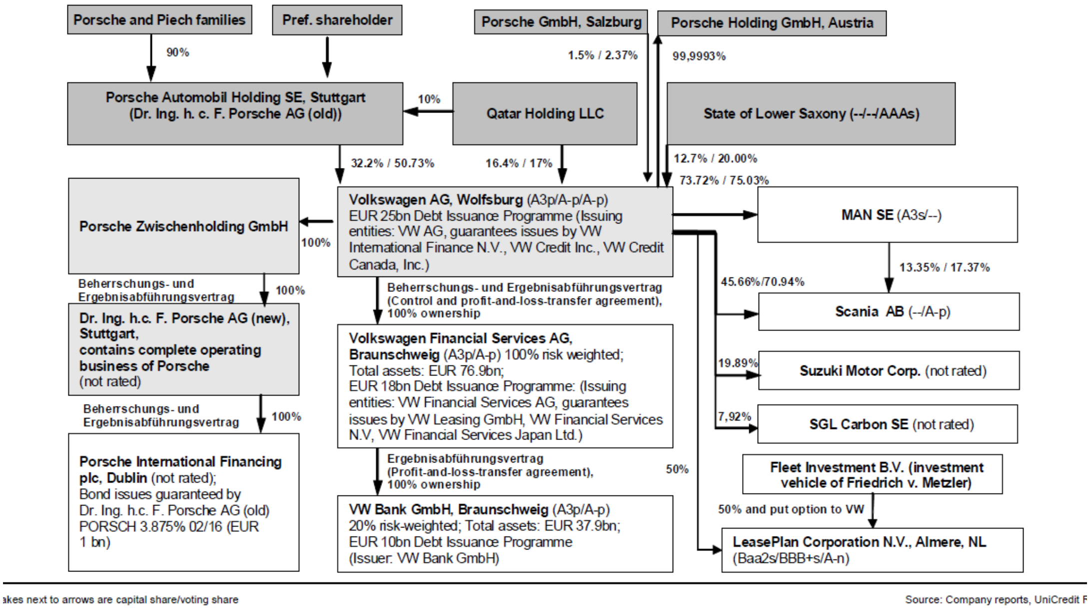
However, in theory and under perfect capital markets, the difference should be equal to zero (Choudhry 2004). That means that there is no possibility for arbitrage by trading the basis. Given this relationship ASW-spread can be regarded as a good indicator for credit risk.

5 Company Analysis of Volkswagen AG

5.1 Profile

German based carmaker Volkswagen, headquartered in Wolfsburg, manufactures luxury, economy, sports cars, motorbikes as well as trucks and commercial vehicles for sale worldwide (Volkswagen 2013). Moreover it provides financial services as insurance, rental and leasing.

Figure 8: Volkswagen Group



Source: Unicredit Research and Company Reports, Kreitmair (2013:2)

Twelve brands from seven different European countries belong to VW. These are Volkswagen, Audi, SKODA, SEAT, Bentley, Bugatti, Lamborghini, Porsche, Ducati, Volkswagen commercial vehicles, Scania and MAN (Volkswagen 2013). Around 550,000 employees are working in a hundred factories for VW, Europe's largest carmaker and the third largest worldwide by car sales in Q1 2013 (Volkswagen 2013, Fuss 2013:15). VW's global market share with respect to passenger cars is 12.6 percent (Volkswagen 2013a).

Main shareholders of VW can be seen from the table above. Nevertheless the special rights of Lower-Saxony have to be mentioned explicitly. The state has the right to send two delegates to the board of directors and voting rights of any shareholder are capped at twenty percent. Since important decisions on the annual meeting require an eighty percent majority, Lower-Saxony can veto major business decisions (Gesetz über die Überführung der Anteilsrechte an der Volkswagenwerk Gesellschaft mit beschränkter Haftung in private Hand 1960).

VW's equity capital consists of common and preferred stock. The latter are considered in the calculation of the DAX 30, the German main-market index, due to the low free-float of common stock (Volkswagen 2009). This change took place at the end of 2009. Given the market capitalization of around € 71.3 bn, VW is the most valuable German company as of 5th July 2013 (Deutsche Boerse 2013)[12].

5.2 Business Risk

As stated in chapter 2.1, assessment of default risk is performed by analysing not only financial but also business risk. Therefore, the author follows the approach shown in figure 1.

Country and Macroeconomic Risk

VW's major markets are western, eastern and central Europe, China, North and South America with market shares of more than 24%, 15.7%, 20.3%, 4.8% and 18.1%, respectively (Volkswagen 2013a). In Europe, Germany and UK are the most important countries for VW (Streda and Hon 2012:2). That is why the car manufacturer is exposed to changing economic conditions in these countries (ibidem). In the UK the market has grown slightly whereas the German car market decreased by around 1% in 2012 (ibidem). Moreover growth could be negatively influenced by the scrappage allowance which were provided in 2009 (Hoevelmann 2013:2). With regard to China where VW is the market leader, market is expected to grow further. Nevertheless a global crisis like the one in 2008 can negatively affect the firm as well as changing automotive business and legislation conditions (Streda and Hon 2013:3).

Market Position and Diversification

Leading or being among the leading car manufacturing firms measured by output is beneficial with respect to economies of scale (Streda and Hon 2012:3). Furthermore VW's cars are manufactured all around the world reducing currency risk (Streda and Hon 2012:2). Another advantage is that the multi-brand carmaker is not only offering

[12] Considering common and preferred stocks together.

mass-market and premium cars but also trucks, motorbikes and financial services (Kreitmair 2013:3). This further reduces business risk.

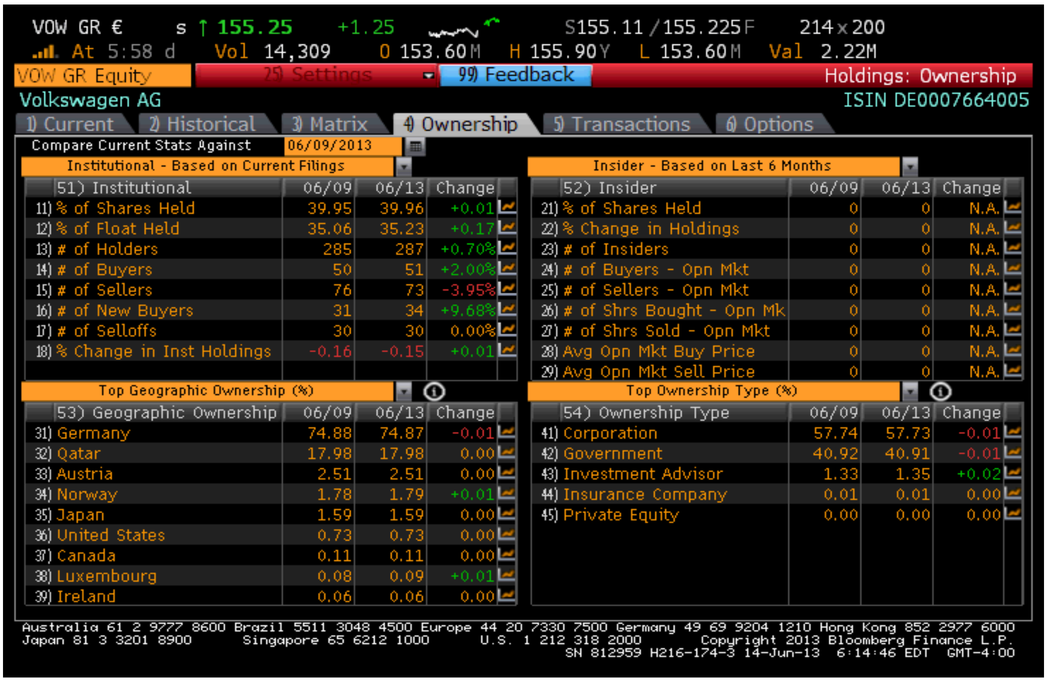
Operating Efficiency, Strategy and Management

On its strategy to become the world's largest car manufacturer in 2018, VW is reducing costs by around € 1 bn in 2013 (Asumendi et al. 2013:4). Additionally, launching the MQB platform will lead to cost savings in the following years (ibidem). Nevertheless, the high cost structure remains challenging (Streda and Hon 2012:3). The track record and management performance over the last years can be regarded as a success. VW's executives are experienced managers who have proven their capabilities in leading firms many times (Volkswagen 2013b). Besides that, problems may occur with the integration of recently acquired firms like MAN, Porsche, Scania or Ducati (Streda and Hon 2012:3).

Ownership and Governance

As it can be seen from the figure below, the main shareholders of VW have not changed between 2009 and 2013.

Figure 9: Ownership Structure



VOW GR € s ↑ 155.25 +1.25 S155.11 / 155.225F 214 x 200
At 5:58 d Vol 14,309 O 153.60M H 155.90Y L 153.60M Val 2.22M
VOW GR Equity 25) Settings 99) Feedback Holdings: Ownership
Volkswagen AG ISIN DE0007664005
1) Current 2) Historical 3) Matrix 4) Ownership 5) Transactions 6) Options
Compare Current Stats Against 06/09/2013

Institutional - Based on Current Filings

51) Institutional	06/09	06/13	Change
11) % of Shares Held	39.95	39.96	+0.01
12) % of Float Held	35.06	35.23	+0.17
13) # of Holders	285	287	+0.70%
14) # of Buyers	50	51	+2.00%
15) # of Sellers	76	73	-3.95%
16) # of New Buyers	31	34	+9.68%
17) # of Selloffs	30	30	0.00%
18) % Change in Inst Holdings	-0.16	-0.15	+0.01

Insider - Based on Last 6 Months

52) Insider	06/09	06/13	Change
21) % of Shares Held	0	0	N.A.
22) % Change in Holdings	0	0	N.A.
23) # of Insiders	0	0	N.A.
24) # of Buyers - Opn Mkt	0	0	N.A.
25) # of Sellers - Opn Mkt	0	0	N.A.
26) # of Shrs Bought - Opn Mk	0	0	N.A.
27) # of Shrs Sold - Opn Mkt	0	0	N.A.
28) Avg Opn Mkt Buy Price	0	0	N.A.
29) Avg Opn Mkt Sell Price	0	0	N.A.

Top Geographic Ownership (%)

53) Geographic Ownership	06/09	06/13	Change
31) Germany	74.88	74.87	-0.01
32) Qatar	17.98	17.98	0.00
33) Austria	2.51	2.51	0.00
34) Norway	1.78	1.79	+0.01
35) Japan	1.59	1.59	0.00
36) United States	0.73	0.73	0.00
37) Canada	0.11	0.11	0.00
38) Luxembourg	0.08	0.09	+0.01
39) Ireland	0.06	0.06	0.00

Top Ownership Type (%)

54) Ownership Type	06/09	06/13	Change
41) Corporation	57.74	57.73	-0.01
42) Government	40.92	40.91	-0.01
43) Investment Advisor	1.33	1.35	+0.02
44) Insurance Company	0.01	0.01	0.00
45) Private Equity	0.00	0.00	0.00

Australia 61 2 9777 8600 Brazil 5511 3048 4500 Europe 44 20 7330 7500 Germany 49 69 9204 1210 Hong Kong 852 2977 6000
Japan 81 3 3201 8900 Singapore 65 6212 1000 U.S. 1 212 318 2000 Copyright 2013 Bloomberg Finance L.P.
SN 812959 H216-174-3 14-Jun-13 6:14:46 EDT GMT-4:00

Source: Bloomberg

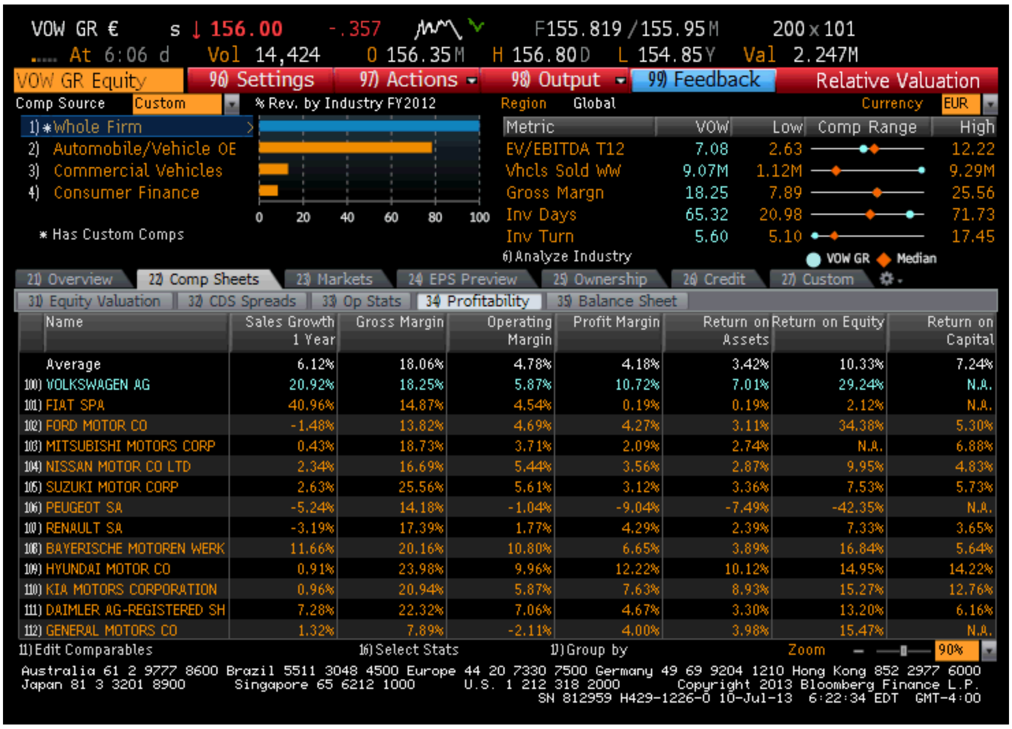
According to RP-online (2013) this is an important factor for the success in recent years. In contrast to the quarterly focused US market the German car manufacturers have long-term growth strategies supported by their owners. These can negatively affect sales in the short-term but leads to success in the long run. The reason is that firms can keep investments on a high level even if results are bad, as the crisis in 2008 has shown (ibidem).

Another point to consider is the 20% ownership of Lower-Saxony. More than 80,000 employees are working for VW and 110,000 jobs are directly related to the automotive industry in the state[13] (Niedersaechsisches Ministerium fuer Wirtschaft, Arbeit und Verkehr 2008). Together with the special rights of Lower-Saxony, it further supports the long-term strategy.

Profitability and Peer Comparison

It is expected that VW will outperform the market again in 2013 (Sigrist 2013:2). From the Bloomberg screenshot below it can be seen that VW is leading or among the leading automotive firms with respect to profitability ratios.

Figure 10: Profitability Ratios at a Glance



Name	Sales Growth 1 Year	Gross Margin	Operating Margin	Profit Margin	Return on Assets	Return on Equity	Return on Capital
Average	6.12%	18.06%	4.78%	4.18%	3.42%	10.33%	7.24%
100) VOLKSWAGEN AG	20.92%	18.25%	5.87%	10.72%	7.01%	29.24%	N.A.
101) FIAT SPA	40.96%	14.87%	4.54%	0.19%	0.19%	2.12%	N.A.
102) FORD MOTOR CO	-1.48%	13.82%	4.69%	4.27%	3.11%	34.38%	5.30%
103) MITSUBISHI MOTORS CORP	0.43%	18.73%	3.71%	2.09%	2.74%	N.A.	6.88%
104) NISSAN MOTOR CO LTD	2.34%	16.69%	5.44%	3.56%	2.87%	9.95%	4.83%
105) SUZUKI MOTOR CORP	2.63%	25.56%	5.61%	3.12%	3.36%	7.53%	5.73%
106) PEUGEOT SA	-5.24%	14.18%	-1.04%	-9.04%	-7.49%	-42.35%	N.A.
107) RENAULT SA	-3.19%	17.39%	1.77%	4.29%	2.39%	7.33%	3.65%
108) BAYERISCHE MOTOREN WERK	11.66%	20.16%	10.80%	6.65%	3.89%	16.84%	5.64%
109) HYUNDAI MOTOR CO	0.91%	23.98%	9.96%	12.22%	10.12%	14.95%	14.22%
110) KIA MOTORS CORPORATION	0.96%	20.94%	5.87%	7.63%	8.93%	15.27%	12.76%
111) DAIMLER AG-REGISTERED SH	7.28%	22.32%	7.06%	4.67%	3.30%	13.20%	6.16%
112) GENERAL MOTORS CO	1.32%	7.89%	-2.11%	4.00%	3.98%	15.47%	N.A.

Source: Bloomberg

[13] 30% of all jobs in Lower-Saxony are related to the automobile industry (Niedersaechsisches Ministerium fuer Wirtschaft, Arbeit und Verkehr 2008).

Profitable market share as well as brand loyalty are further fostered by VW's leading technologies (Streda and Hon 2012:3). Moreover the expected margin recovery in North America and synergies from the take-over of Porsche will lead to higher margins (Dieng et al. 2013:1).

5.3 Financial Risk

5.3.1 Application of Empirical Models

5.3.1.1 Single Ratio Analysis

Before analysing some financial ratios a general framework about the interpretation of the numbers by S&P and Moody's is shown to the reader. Table one illustrates that the overall default risk consists of business and financial risk as well as their interaction.

Table 1: S&P Rating Classification Guideline

Business And Financial Risk Profile Matrix

Business Risk Profile	--Financial Risk Profile--					
	Minimal	Modest	Intermediate	Significant	Aggressive	Highly Leveraged
Excellent	AAA/AA+	AA	A	A-	BBB	--
Strong	AA	A	A-	BBB	BB	BB-
Satisfactory	A-	BBB+	BBB	BB+	BB-	B+
Fair	--	BBB-	BB+	BB	BB-	B
Weak	--	--	BB	BB-	B+	B-
Vulnerable	--	--	--	B+	B	B- or below

These rating outcomes are shown for guidance purposes only. Actual rating should be within one notch of indicated rating outcomes.

Financial Risk Indicative Ratios (Corporates)

	FFO/Debt (%)	Debt/EBITDA (x)	Debt/Capital (%)
Minimal	greater than 60	less than 1.5	less than 25
Modest	45-60	1.5-2.0	25-35
Intermediate	30-45	2-3	35-45
Significant	20-30	3-4	45-50
Aggressive	12-20	4-5	50-60
Highly Leveraged	less than 12	greater than 5	greater than 60

Source: Puccia (2012:2-3)

From table two Moody's approach can be seen in allocating companies to their rating category. Nevertheless the metrics is an aggregation of all considered industries. This means that the specific level of one sector can be different in comparison to the other sectors examined.

Table 2: Moody's aggregate Metrics by Rating Category

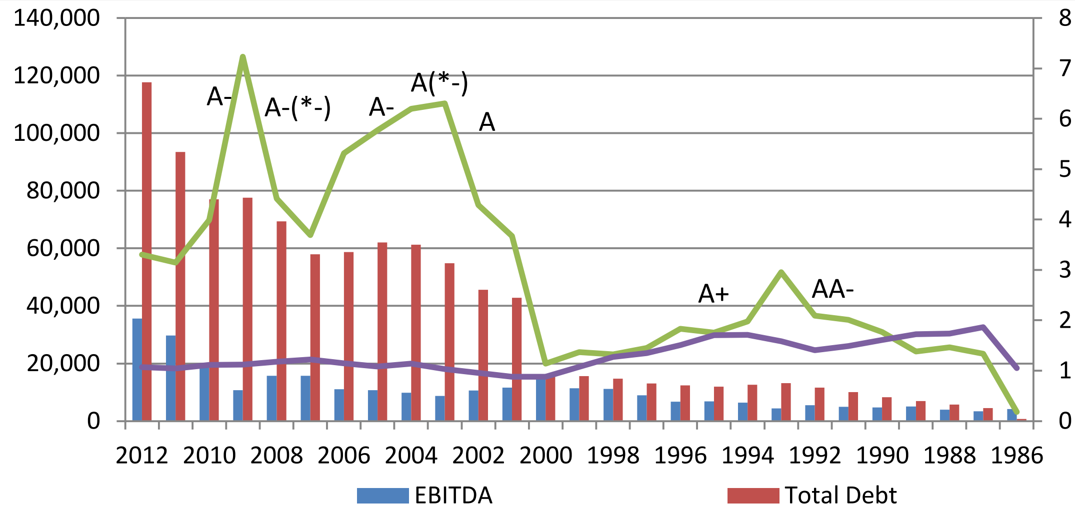
	EBITA / Average Assets	Operating Margin	EBITA Margin	EBITA / Interest Expense	(FFO + IntExp) / IntExp	
Aaa	21.1%	21.7%	25.1%	27.0	23.2	
Aa	13.5%	16.1%	19.8%	14.7	16.3	
A	12.0%	14.3%	15.4%	9.3	10.7	
Baa	9.9%	13.0%	14.6%	5.2	6.8	
Ba	9.3%	12.4%	13.8%	3.4	4.7	
B	7.3%	8.6%	10.0%	1.6	2.6	
Caa-C	3.2%	3.7%	5.0%	0.5	1.4	
	Debt / EBITDA	DEBT / Book Capitalization	FFO / Debt	Retained Cash Flow / Net Debt	CAPEX / Depreciation	Revenue Volatility
Aaa	0.6	21.1%	109.0%	209.9%	1.3	9.4
Aa	1.5	34.3%	45.0%	28.0%	1.3	11.3
A	2.0	40.0%	38.8%	30.1%	1.3	10.3
Baa	2.6	45.7%	28.4%	26.0%	1.3	13.2
Ba	3.2	51.9%	23.1%	22.6%	1.2	16.8
B	4.8	69.9%	11.6%	11.8%	1.0	16.5
Caa-C	7.6	100.6%	3.5%	3.3%	0.7	15.2

Source: Zhang et al. (2013:4)

In the following VW's financial ratios are analysed. Data are retrieved from Bloomberg, Thomson Reuters, Datastream, Morningstar and annual reports[14].

The graph below illustrates coverage, current ratios and the company ratings at different points in time[15].

Figure 11: Debt(in m), Cash Flow(in m), Solvency-, Liquidity Ratio and S&P Ratings (Outlook)

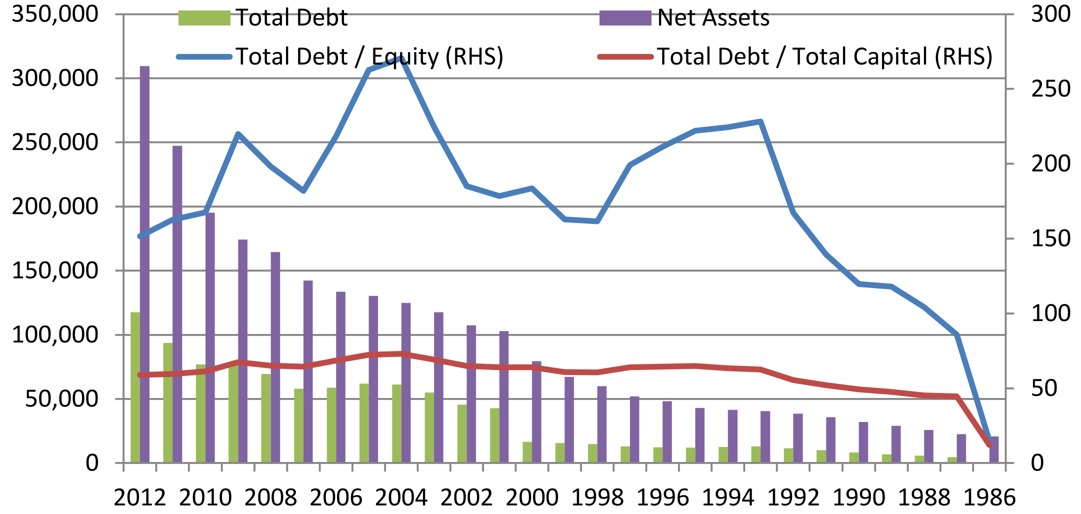


Source: Own representation

[14] Risk-free interest rates for the required maturities (maturity matching) are taken from Datastream. Since the whole term structure is not needed linear interpolation leads to less deviation than applying Nelson and Siegel (1987).
[15] Moody's and Fitch's ratings of VW are very similar.

As it can be seen VW's rating was higher when the current ratio was high and the inverse coverage ratio was low. This was the case in the 1980s, remained relatively stable during the 1990s and worsened in the twenty-first century. With the exception of the financial crisis the coverage ratio improved significantly after 2007 whereas the current ratio is nearly unaffected around one. The reason is that total debt and EBITDA increased but the percentage change in the cash flow was higher than in debt. Similar information can be taken from figure 12.

Figure 12: Debt(in m), Net Assets(in m) and Leverage Ratios

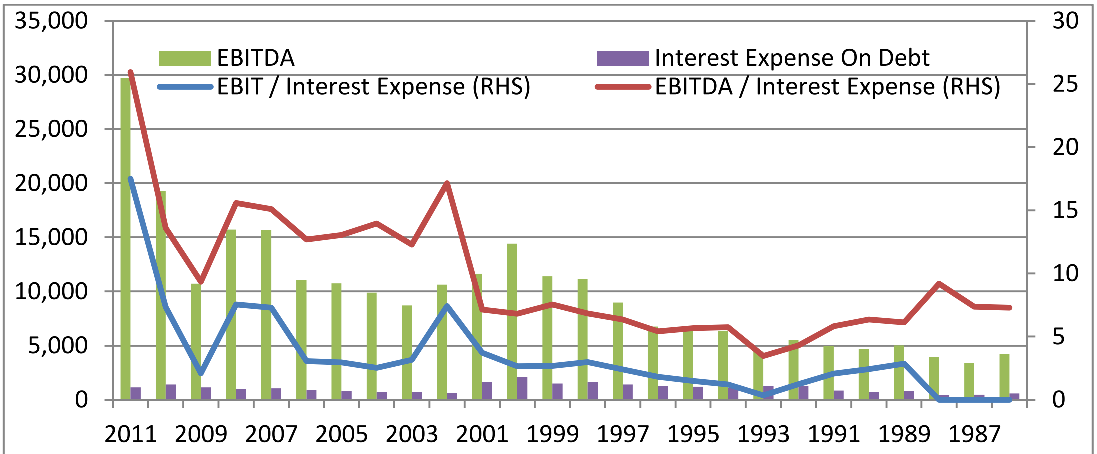


Source: Own representation

There was fluctuation of the total debt/equity ratio while the total debt/total capital ratio was almost constant around 60. Leverage ratio decreased in recent years resulting in a higher rating by S&P. Therefore the financial risk associated with insolvency issues lowered. This can also be inferred by looking on the relation of net assets to total debt. Starting with a value of around 27, the ratio declined to less than 2.1 in 2005 before increasing to approximately 2.7 at the end of 2012.

Coverage ratios are presented by figure 13.

Figure 13: Cash Flow(in m), Interest expense(in m) and Coverage Ratios

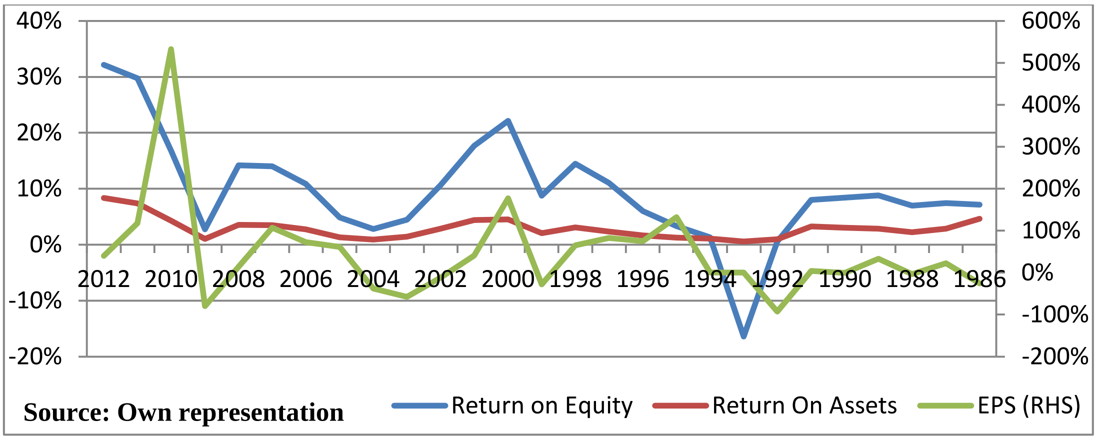


Source: Own representaion

Both ratios moved similar over the whole period. From 2001 to 2008 the difference between the ratios was increased due to higher relative depreciation expenses. Another observation is that average interest expense during the 1990s was higher than at the beginning of the twenty-first century. This was caused by the higher overall interest rate level in previous years.

In the next graph (Fig. 14) return on assets and equity as well as EPS are diagrammed. The movement of the return ratios clearly exhibit the leverage effect. Positive return on assets leads to positive return on equity which is larger because of the debt financing. The opposite effect occurs for small return on asset.

Figure 14: Profitability Ratios and EPS

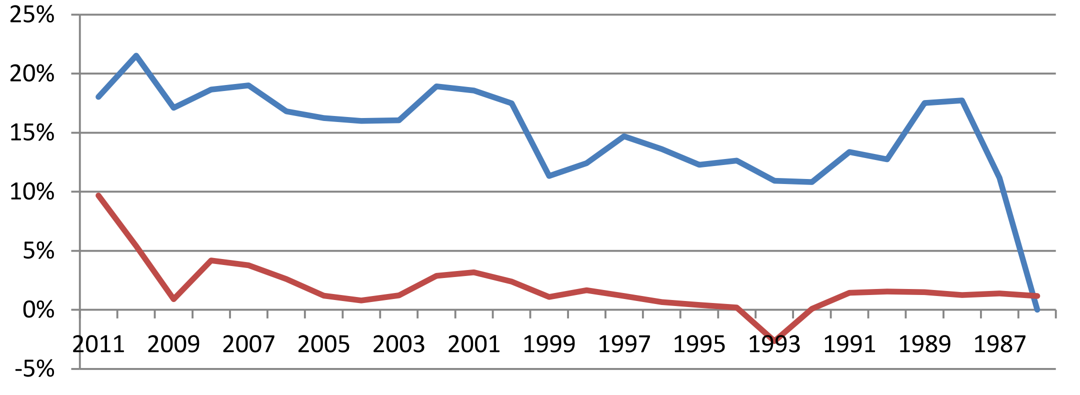


Source: Own representation

Moreover the co-movement of EPS and asset ratio can be examined. It seems that EPS can be regarded as an indicator for return on equity in the following year. EPS and return on equity are more volatile than return on assets.

The last figure (Fig. 15) about single ratios further considers the profitability. Comparing the movement of the two margins it can be concluded that VW successfully managed to reduce indirect costs by increasing net margin. The reason could be higher car sales[16]. A negative sign is that gross margin decreased recently. It means that car sales prices remained stable whereas direct cost for cars increased. In other words suppliers may have increased their prices and VW has not increased their prices so far or cannot increase it due to few market power.[17]

Figure 15: Profitability Ratios

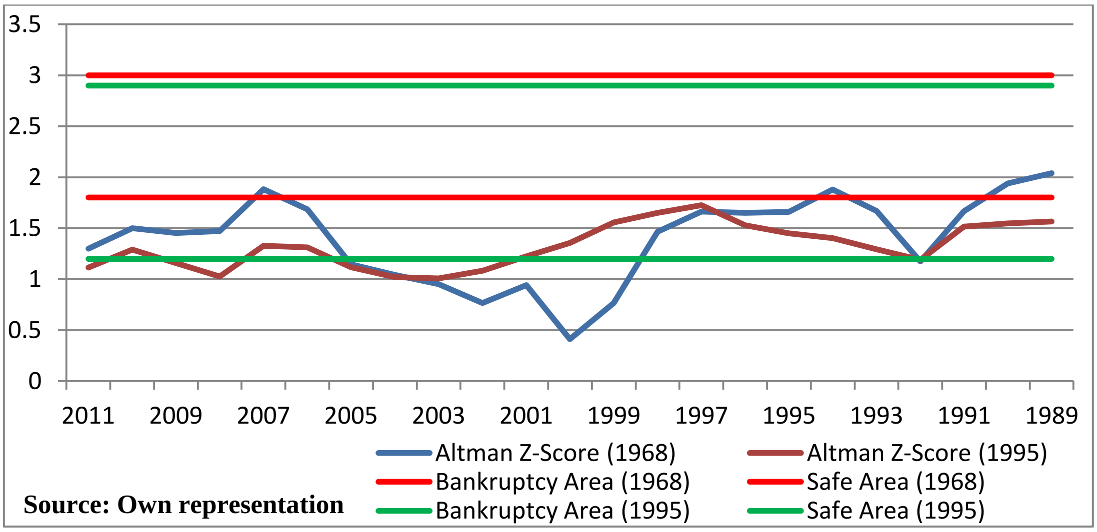


Source: Own representation

5.3.1.2 Multi-ratio Analysis

In the following multi-ratio models presented in the first part are applied. Figure 16 shows the Altman Z-Score and the revisited one in 1995 (Altman 1995).

Figure 16: Altman Z-Score and revisited Z-Score



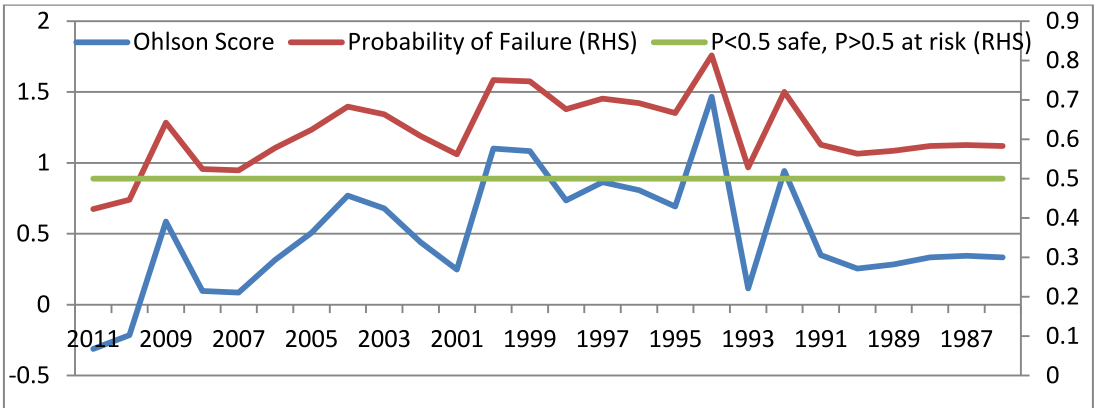
Source: Own representation

[16] Higher car sales with the same number of employees mean also an increase in efficiency.
[17] It means that VW's market power is not enough.

It can be seen that the Z-Score is, except five years, the whole time in the bankruptcy area. To avoid arguing that the Z-Score is outdated the revisited Z-Score is applied to compare and doublecheck the results. Regarding its movement it is different to the 1968 Z-Score since it is most of the time in the area where no decision can be made. Nevertheless it is closer to the bankruptcy area contradicting the results from the single ratio analysis.

The next model used to analyse the default risk of VW is developed by Ohlson (1980). Besides the years 2010 and 2011 VW is all the time in the risky area. It means that the probability of default is more than 50%. At the end the risk of failure is around 42%.

Figure 17: Ohlson Bankruptcy Prediction Model

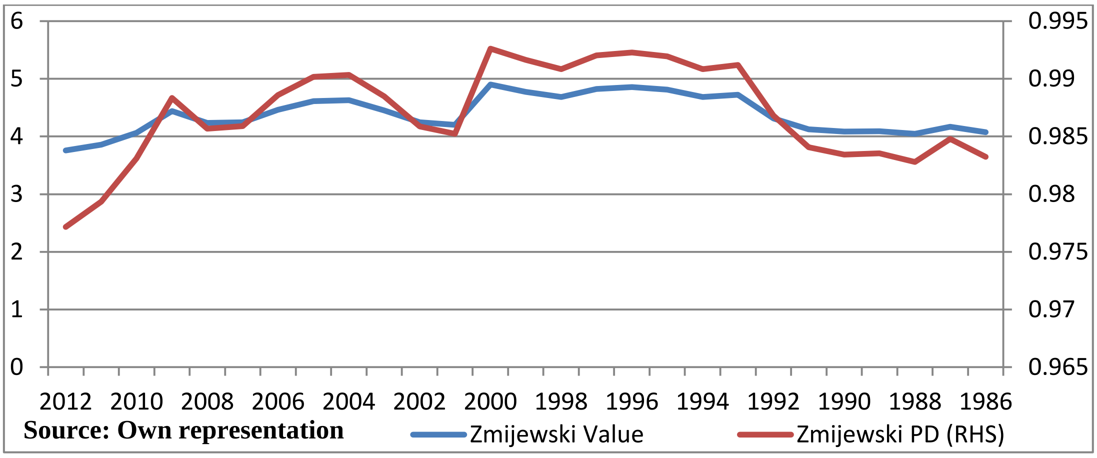


Source: Own representation

Economic crisis like the financial one in 2008 or periods in which the company experienced difficulties are visible through increased bankruptcy probabilities.

Since the results of the first two models are contrary to the expectations based on the single ratio analysis, the model by Zmijewski (1984) is calibrated to further verify results.

Figure 18: Zmijewski Bankruptcy Prediction Model



Source: Own representation

Considering the PD illustrated by the graph (Fig. 18) it has to be said that it is on a very high level. It means that even in the economically successful years the PD is still above 97.7%. During the time period considered the PD increased to the maximum of more than 99.2%.

Due to the fact that even the third model PD does not seem reasonable, the hybrid CHS model is employed for the year 2013. Therefore the model provided by Dollarwise (2012) is calibrated and the probability of default for the one, twelve and 36 months are more than 99.9%. These results are not reasonable and the author does not further calibrate the model[18].

5.3.2 Application of Structural Models

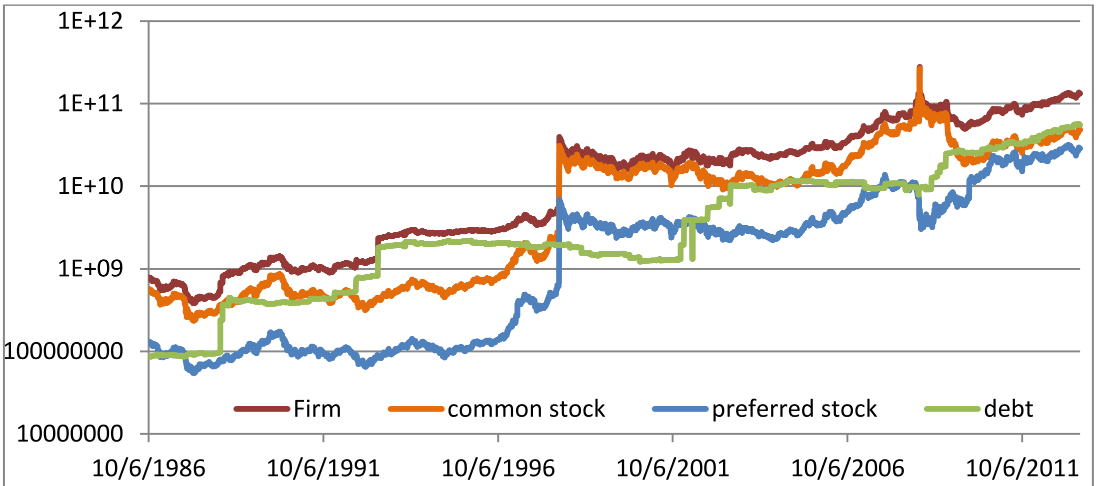
5.3.2.1 Merton Model

Before applying the Merton model by following Loeffler and Posch (2011)[19], the movement of capital structure through time is analysed. The reason is that effects resulting from changes in firm value due to bond issues have to be excluded in the calculations of volatility, for instance.

[18] "Not reasonable" means that it is very unlikely that VW's PD is 99.9%. Only looking on the rating and the CDS-spread gives an indication about how realistic the CHS model values are. It seems that this model is heavily affected by recent changes in stock price and net income. VW, for example, had such effects.

[19] All calculations are performed by using the Excel solver approach. Results and inputs (est.) are shown in the appendices. The methodology is exactly the same as described by the two authors.

Figure 19: Evolution of Firm Value



Source: Own representation

Two jumps which are not driven by stock price changes occurred in 1993 and 1998. The reason for the peak[20] in 2008 is the short squeeze by Porsche. It resulted from Porsche's attempt to take over VW which started in 2005 (Hertle 2013). The Baden-Wuerttemberg based luxury carmaker continuously increased its stake in Volkswagen by purchasing shares (Ibidem). Besides that, the carmaker bought stock options to further increase its influence on VW (Ibidem). It is important to mention that the options were cash-settled and therefore Porsche was not required by German law to announce its overall stake in VW[21] (Wiwo 2009). In October 2008 Porsche officially reported that its stake in VW is almost 75% consisting of 42.6% common shares and the right to buy further 31.5% of common shares by exercising the cash-settled options (Hertle 2013).

In 2008 the market participants expected a declining stock market resulting from the financial crisis (Marsh 2008). Therefore hedge funds and other investors sold short VW's stocks. After the Porsche announcement it was clear that VW's free float was very small since Lower Saxony held the remaining 20% (Hertle 2013)[22]. That means that investors who wanted to close their short positions in order to reduce losses had not as many stocks available as thought to execute their trades. The low supply and the high demand lead to a significant increase in VW's stock price making it the

[20] The returns on the 27th and 28th October 2008 increased the equity volatility computed over a ten year period by 7% (23rd to 27th Oct.) and 11.6% (23rd to 28th Oct.).
[21] In 2007 Porsche officially announced that its stake in VW was more than 30% and the carmaker was required to make a take-over offer to the remaining shareholders of VW. Here combined means common shares and stock options together.
[22] According to Hertle (2013) the free float was around 6% and the short interest was about 13%.

most valuable company in the world by market capitalization (Marsh 2008). At the 28th October 2008 the highest price observed of one common share of VW was € 1005.01 (Hertle 2013). Considering all common shares outstanding VW's value was $ 370 bn and therefore higher than Enron's market capitalization which was $ 343 bn (Marsh 2008)[23].

Merton model results over the one, five and weighted time horizon are shown below. It is assumed that CL and LTL have maturities of 0.5 and 10 years respectively.

Equation 53: (Loeffler and Posch 2011:40) Weighted Time Horizon

$$Weighted\ Time\ Horizon = \frac{[0.5 * CL + 10 * LTL]}{[CL + LTL]}.$$

Due to the fact that VW issued floating rate notes, the income statement is considered to determine the overall interest expense on interest-bearing traded debt. After that straight bonds have to be converted into zero coupon bonds and dividends are adjusted as well. The assumption is that both are due at maturity even though their payment is earlier (Loeffler and Posch 2011:39).

Equation 54: (Loeffler and Posch 2011:40) Accrued Dividends

$$accrued\ Div(T) = \sum_{\vartheta=t+1}^{T} D(0) * (1+g)^{\vartheta-t} * \exp\big(r * (T-\vartheta)\big).$$

Equation 55: (Loeffler and Posch 2011:40) Accrued Interest

$$accrued\ Int(T) = \sum_{\vartheta=t+1}^{T} c * \exp\big(r * (T-\vartheta)\big).$$

Moreover Macaulay duration is considered for computing the weighted-average time until the outstanding debt has to be repaid.

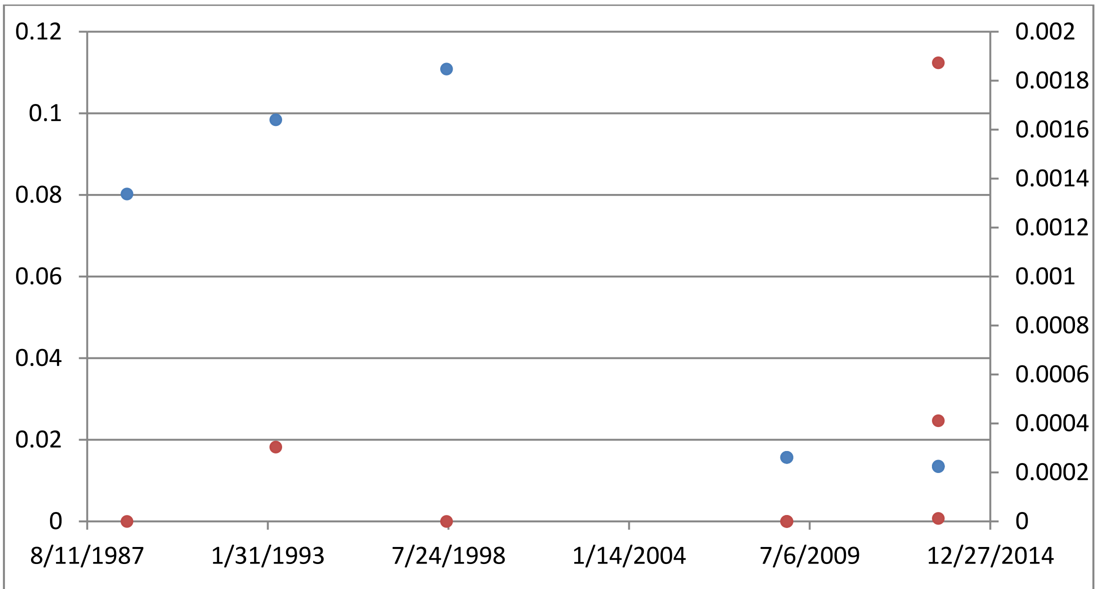
Equation 56: Macaulay Duration

$$Macauly\ Duration = \frac{\sum_{i=1}^{T} t(i) * c}{P(0)} + \frac{N(T)}{P(0)}.$$

Credit spreads and default probabilities over the one year horizon are shown.

[23] Enron was the second most valuable company in the world by market capitalization on that day.

Figure 20: Merton Model Credit Spread and PD short-term Horizon (1 yr.)

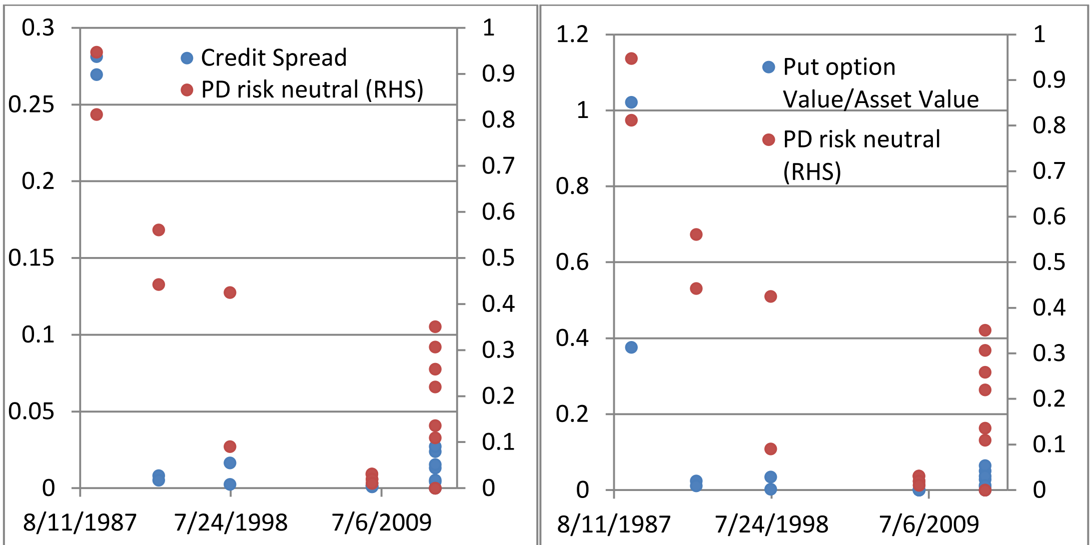


Source: Own representation

Since the graph shows some credit spreads at the same point in time but with inputs of different time periods, detailed information about the abscissa values are included in the appendices[24]. It can be seen that there is fluctuation and PD and credit spread are not consistent. This is due to the fact that average annual interest expense was considered which leads to problems for different debt face values. In order to mitigate this problem longer time horizons are examined in figure 21[25].

[24] This also applies for the graphs shown in the following. Moreover the reader is encouraged to view the electronic version of the dissertation since some points in the graphs are pretty close to other ones and therefore not visible on the hardcopy.
[25] That results for longer maturities are more reasonable is also shown by Teixeira (2007).

Figure 21: Merton Model Results long-term Horizon I



Source: Own representation **Source: Own representation**

The high spread and PD values at the beginning can be explained by problems with the availability of data. Nevertheless PD and credit spread movement are consistent. Besides the mentioned issue the curve has some similarities to the graphs of the multratio models, but on a lower PD level. Put option value/asset value is above one for high PDs which means that the option is in the money. For low credit spreads the bondholder's put option is only worth the time value.

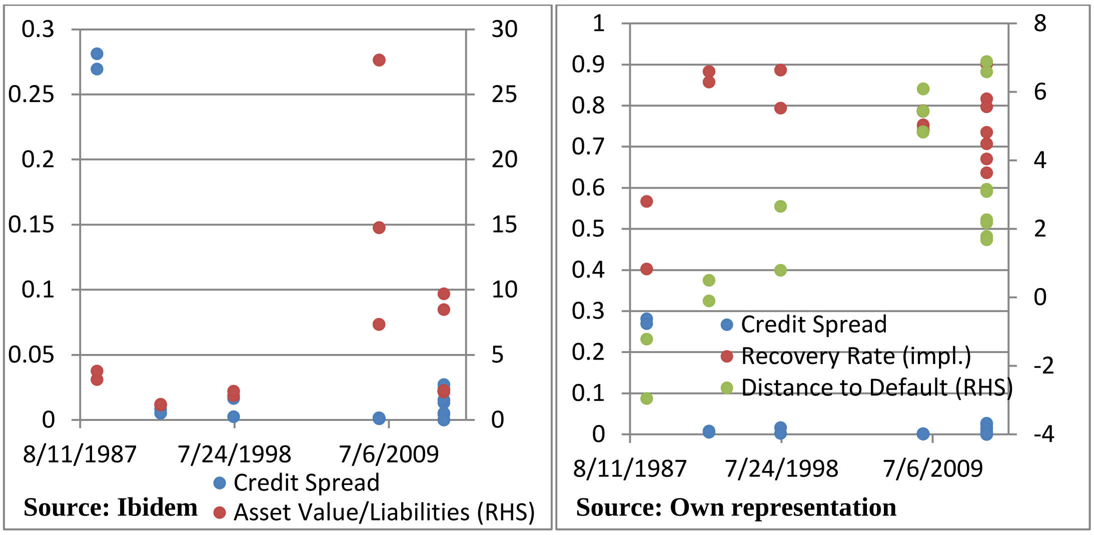
Figure 22 illustrates the relationship between spread, DD and implied recovery rate. A high spread is accompanied by low DD and recovery rate[26]. Moreover the co-movement of spread and asset/liabilities ratio is presented. The ratio can be considered as the main driver of the spread.

Another input worth to consider is the equity volatility. Asset value/liabilities ratio is constant for numbers 13 to 18. The only inputs which are changed is equity volatility and maturity.

Therefore it can be said that longer maturity increases the spread whereas higher equity or asset volatility decreases it.

[26] A DD of 0 means that the asset value is equal to the debt value.

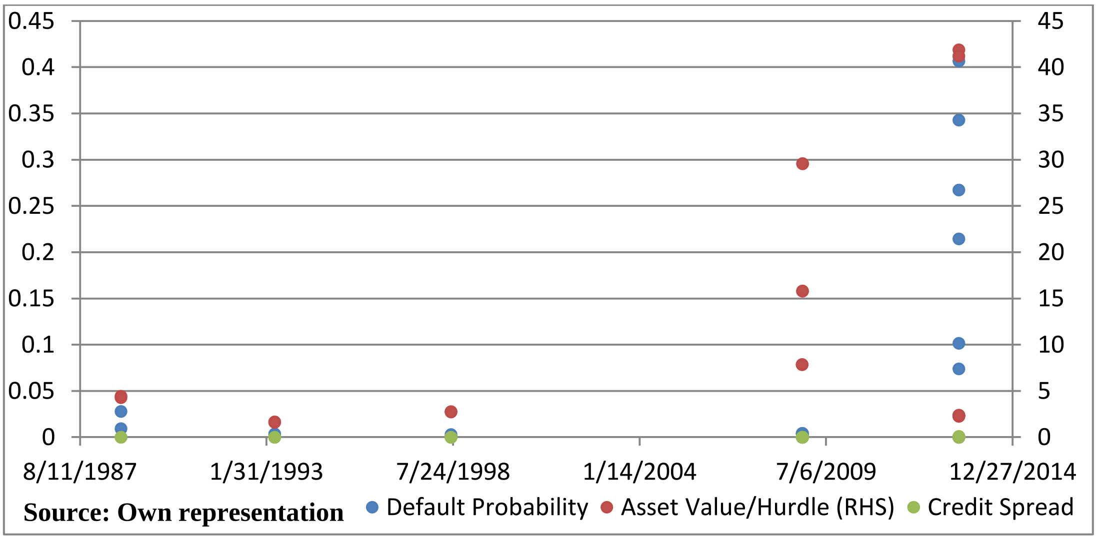
Figure 22: Merton Model Results long-term Horizon II



5.3.2.2 Black & Cox Model

In the next graph the Black & Cox model is applied by taking the same data as in the long-term Merton model. Fixed hurdle is defined as the portion of liabilities due in one year (Fig. 20).

Figure 23: Black & Cox Model Default Probability and Credit Spread



As in the Merton model, asset value/hurdle is the main driver. Increasing the hurdle leads to a higher spread and PD. The relationship between spread and maturity and spread and volatility is the same as mentioned above (Fig. 22). Another observation is that default probability in the financial crisis is by more than 5% higher than in the Merton model. This is based on the assumption that default can occur at any time. Therefore spread is higher as well.

5.3.2.3 Leland Model

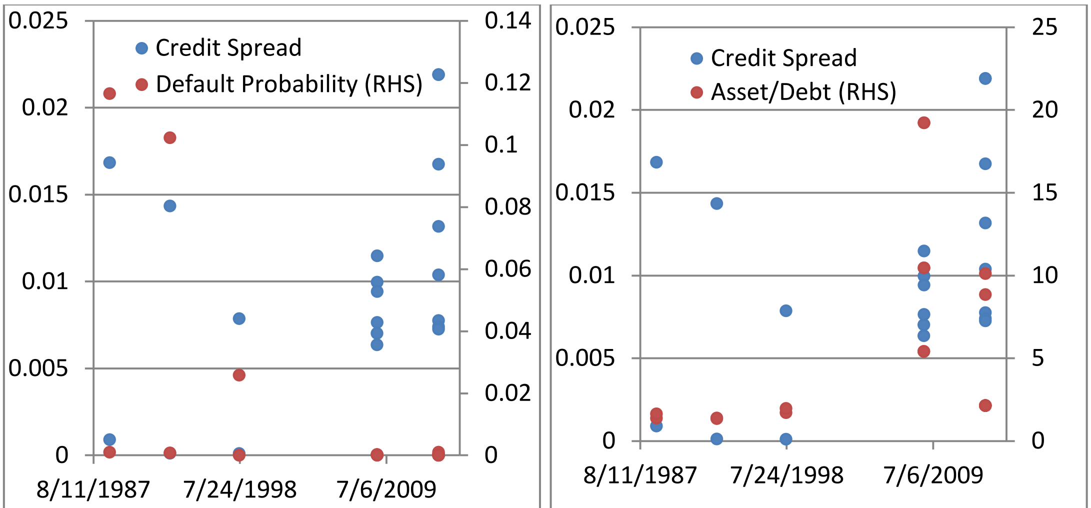
The Leland Model is calibrated by using Excel solver and the formulas presented in the literature review. The perpetual coupon payment is determined by the following formula:

Equation 57: Leland perpetual Coupon Payment

$$Face\ Value\ Debt * Risk - free\ rate = Perpetual\ Coupon\ Payment.$$

For a better comparison to the Merton model, taxes and bankruptcy costs are assumed to be zero. Their influence and level (Taxfoundation 2012) will be presented later.

Figure 24: Leland Model Credit Spread, PD and Asset Value/Debt Value



Source: Own representation **Source: Own representation**

It can be seen that in the first years a higher PD is associated with a higher spread. The same relationship holds for the asset/debt ratio and can also be observed in the Merton model. From number seven onwards, which represents the year 2008, there seems a break in the time series[27]. Investors require higher risk premia for similar PD-levels than in previous years. This is further supported by the leverage ratio.

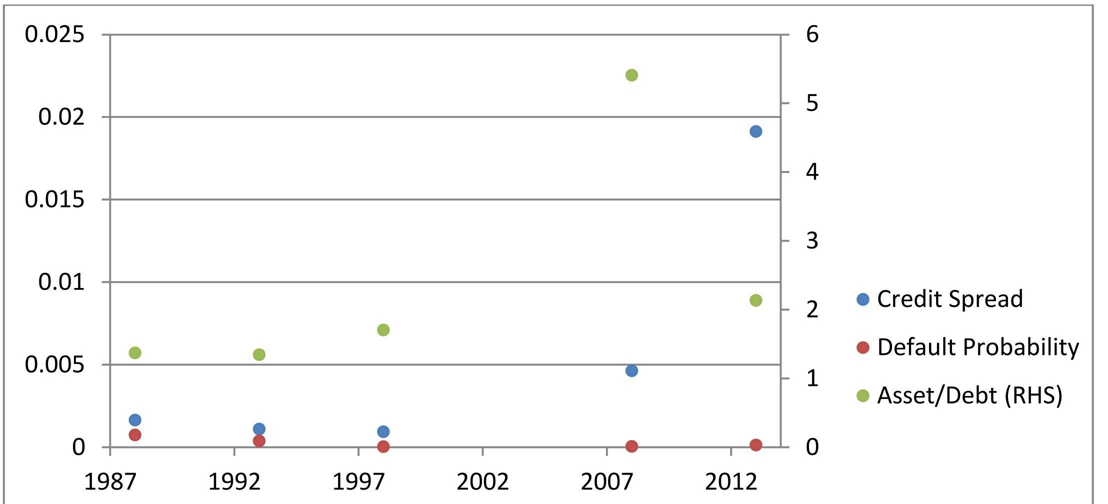
Another issue worth to consider is the low ECB interest rate. Debt which was issued a few years ago when interest rates have been higher, has higher coupon rates. Nowadays interest rates are low but interest expense in the income statement still

[27] It is important to mention that Excel solver is used by minimizing squared errors. Having run the solver several times, there still have been issues for some values which are incorporated in these results.

reflects the level of previous years. This also leads to an increased credit spread due to the calculation methodology.

Applying Leland model (Fig. 25) by using real world tax rate and bankruptcy data (Ou et al. 2011:7, Jankowitsch et al. 2013:35) it can be observed that credit spread is decreased at the beginning and increased at the end. This reflects the data problem and the increased risk premium. Freezing all variables and changing only tax rate and bankruptcy costs, higher tax rates lower the spread and higher bankruptcy costs increase it.

Figure 25: Leland Model with Tax and Bankruptcy Costs



Source: Own representation

In comparison to the other models Leland's credit spread (Fig. 25) is lower at the beginning and higher at the end. PD is lower throughout the whole time period and tends to zero from the financial crisis onwards.

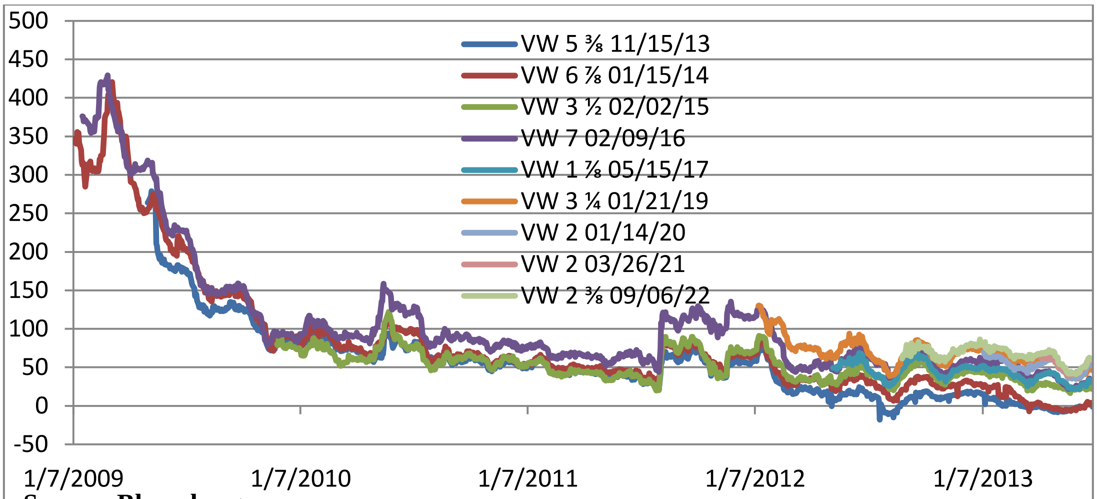
At last results of structural models are compared to the market model and ASW-spread. These models can be regarded as the markets official opinion about credit risk of VW[28]. Both ASW-spreads and CDS-spreads are shown but the former seem the better choice since they are subject to liquidity risk as VW's bonds.[29]

In 2008 spreads are lower in structural models except Black & Cox (Fig. 23). Considering the year 2013 all structural model spreads with the exception of Leland

[28] It is important to mention that the market opinion does not have to be right as the crisis in 2007/2008 has shown where most of the market participants underestimated credit risk.
[29] The reason is that credit spreads of structural models are calculated by using bond values. There availability is limited to the notional amount outstanding which is not the case for CDS-spreads.

model (Fig. 25) are below the credit and ASW-spreads in the market. That spreads of structural models are below the market spreads is nothing unusual as many studies have shown (e.g. Teixeira 2007:1141, Eom et al. 2004:499). The interesting thing is that the Leland model (Fig. 25 & Fig. 24) seems to work well in an environment with low interest rates.

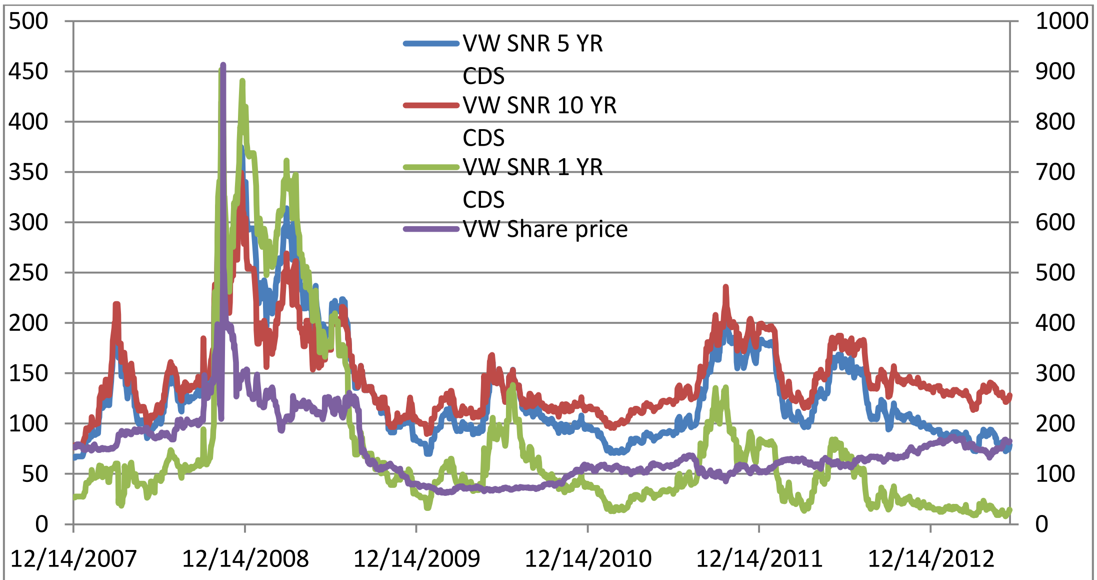
Figure 26: VW's Asset Swap-Spreads in BPS



Source: Bloomberg

It delivers spreads which are closer to market ones, especially to the ASW-spread, than in the Merton model. Latter model can be regarded as the appropriate choice under normal interest rate level conditions.

Figure 27: VW's CDS-Spreads in BPS and Share Price



Source: Datastream

6 Conclusion

The study has shown that there are differences between the models which positively or negatively affect the estimation of credit risk. Worst results are achieved by using the multi-ratio models. According to them VW would have been in default several times. Nevertheless the tendency they present reflects VW's credit risk movement, but on the wrong level. Structural models' credit risk assessment of VW is good in general but each model has its advantages and disadvantages through the examined period. Therefore combination of the models seems a good choice. The best results are obtained by the single ratio models. Even though their approach is simplistic, their performance is superior and reasonable with respect to prediction and tendency.

One reason of structural models' performance is the unavailability of data. Another one is the assumption on which they are based. This holds for the multi-ratio models as well. They have been developed 30 or more years ago under different economic conditions. Nonetheless structural models present PDs and their price for risk which most multi- or single ratio models do not show or only by using further calculations.

With respect to banks and their task to assess credit risk, they should at least consider structural and single ratio models for determining credit risk. Comparing these calculations with past data of different companies together with an analysis of the business will provide sufficient information about credit risk.

VW's credit risk has significantly improved in recent years and will continue in the next years if expectations are accurate. To sum up credit investments in VW are attractive but should be done soon in order to maximize gains from increase in bond prices or CDS PV[30].

[30] Credit investments by using CDS mean that protection is sold in order to receive higher protection fees. The expectation is that protection will be cheaper in the future and the value of the CDS will be increased. Another opportunity is to synthetically create a bond of VW.

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Appendix

A. 1: Data of Figure 20: Merton Model Credit Spread and PD short-term Horizon (1yr)

Number	Period*	Date	PD risk neutral	Credit Spread	Put Option Value	Recovery Rate (impl.)	Distance to default
1	06/10/1986-24/10/1988	24/10/1988	1.39437E-09	0.080267838	0.005810125	0.958664816	5.943573946
2	25/10/1988-29/04/1993	29/04/1993	0.000303831	0.098456119	7749.90163	0.969884048	3.428171699
3	30/04/1993-03/07/1998	03/07/1998	5.29471E-08	0.110895872	3.37127441	0.96943771	5.316307351
4	06/07/1998-23/10/2008	23/10/2008	5.24756E-11	0.015702894	0.021266515	0.954733574	6.459641695
5	06/07/1998-27/10/2008	27/10/2008	1.0422E-11	0.015701981	0.005148515	0.944796642	6.699986241
6	06/07/1998-28/10/2008	28/10/2008	3.40405E-13	0.015697953	0.000179477	0.941338721	7.183234745
7	06/07/1998-31/05/2013	31/05/2013	0.00187374	0.01356434	8013265.92	0.923353069	2.898670835
8	29/10/2008-31/05/2013	31/05/2013	0.000411412	0.013462102	1404233.836	0.938827361	3.345000629
9	19/08/2009-31/05/2013	31/05/2013	1.22897E-05	0.013442126	28457.08688	0.958500442	4.218627291

Number	Asset Beta	Asset Value	Bond Yield	Equity Volatility	Equity Beta	Put Option Value/Asset Value
1	0.792662089	518647049.5	0.126674211	0.328390436	0.97415179	1.12025E-11
2	0.510803388	1293288432	0.163775585	0.298394235	1.3068825	5.9924E-06
3	0.68553256	5461424655	0.148312074	0.270718094	1.054488161	6.17288E-10
4	0.632844783	74332876182	0.067061186	0.362759487	0.722458427	2.86098E-13
5	0.687537573	1.49101E+11	0.066870267	0.433062876	0.732977126	3.45304E-14
6	0.795039818	2.79725E+11	0.065820562	0.478785199	0.822343833	6.41621E-16
7	0.485241841	1.32514E+11	0.018054245	0.486206592	0.831614143	6.04709E-05
8	0.496921429	1.3252E+11	0.017952008	0.426404406	0.851630782	1.05964E-05
9	0.606406583	1.32521E+11	0.017932031	0.342628654	1.039267945	2.14736E-07

Number	Risk-free rate	Equity Value	Asset Volatility	Debt Value	Liabilities+Interest	Asset Value/(Liab.+Int.)	
1	0.046406373	425616000	0.269486182	93031026.26	105594629.6	4.91168018	
2	0.065319466	525733848	0.121323564	767555493.8	904140872.4	1.430405893	* period refers to the
3	0.037416201	3596744004	0.178287435	1864686823	2162796109	2.525168523	time period which is
4	0.051358292	65519483469	0.319748158	8813385580	9424697619	7.887030352	considered for
5	0.051168287	1.40292E+11	0.407475609	8809416627	9418663603	15.83037994	determining the
6	0.050122609	2.70877E+11	0.463640448	8847939890	9449964301	29.60066414	equity volatility. Date
7	0.004489905	77469850400	0.284450365	55044696719	56047376742	2.364328565	is the point in time for
8	0.004489905	77469850400	0.249311838	55050216346	56047376742	2.364428978	the credit spread
9	0.004489905	77469850400	0.200296302	55051294785	56047376742	2.3644486	calculation

A. 2a: Data of Figure 21/22: Merton Model Results long-term Horizon I/II

Number	Time Period	Date	Horizon	PD risk neutral (RHS)	Credit Spread	Put Option Value	Asset Volatility	Put Option Value/MV Liabilities	Put option Value/Asset Value
1	06/10/1986-24/10/1988	24/10/1988	5	0.947205772	0.281279945	462404793.7	0.333123588	3.168788976	1.021402448
2	06/10/1986-24/10/1988	24/10/1988	3.290393769	0.811816713	0.269557773	176289618.4	0.338645437	1.413744048	0.376030012
3	25/10/1988-29/04/1993	29/04/1993	5	0.561082344	0.008222112	36470230.05	0.121606236	0.02774055	0.024158154
4	25/10/1988-29/04/1993	29/04/1993	4.373259912	0.442484882	0.005238618	16482059.2	0.117407672	0.013629984	0.011282315
5	30/04/1993-03/07/1998	03/07/1998		0.425115256	0.016515825	208187225.2	0.185329379	0.064542905	0.034614513
6	30/04/1993-03/07/1998	03/07/1998	3.381866734	0.090404255	0.00251584	14000922.98	0.167616657	0.005236047	0.002365541
7	06/07/1998-23/10/2008	23/10/2008	5	0.030693634	0.001640468	47606187.04	0.321873857	0.004718179	0.000643171
8	06/07/1998-23/10/2008	23/10/2008	5.053783511	0.031132904	0.001611258	52900900.85	0.321288951	0.005242931	0.00071324
9	06/07/1998-27/10/2008	27/10/2008	5	0.019363782	0.001398823	38797650.93	0.408529764	0.003848571	0.000260679
10	06/07/1998-27/10/2008	27/10/2008	5.053783511	0.019919963	0.001355161	43535340.43	0.408111625	0.004318531	0.000292187
11	06/07/1998-28/10/2008	28/10/2008	5	0.010502084	0.001010984	22772307.21	0.464150649	0.002251694	8.14804E-05
12	06/07/1998-28/10/2008	28/10/2008	5.053783511	0.010929858	0.000934512	25983827.62	0.463856102	0.002569244	9.29097E-05
13	06/07/1998-31/05/2013	31/05/2013	5	0.306736564	0.023896935	6507674808	0.326091664	0.110127464	0.050552853
14	06/07/1998-31/05/2013	31/05/2013	5.635246424	0.35087445	0.027199622	8194574876	0.334626851	0.138674377	0.064583115
15	29/10/2008-31/05/2013	31/05/2013	5	0.220023644	0.01322905	3695241676	0.272379009	0.062533487	0.028092462
16	29/10/2008-31/05/2013	31/05/2013	5.635246424	0.258678176	0.015435518	4796950216	0.278334574	0.081177376	0.036822842
17	19/08/2009-31/05/2013	31/05/2013	5	0.109488724	0.0043107	1229087606	0.206525943	0.020799488	0.009172013
18	19/08/2009-31/05/2013	31/05/2013	5.635246424	0.136021549	0.005282383	1686345406	0.209428232	0.028537527	0.012643148
19	19/08/2009-31/05/2013	31/05/2013	2.429071056	2.23819E-05	2.32135E-05	19011.84203	0.316875633	1.92448E-06	2.26964E-07
20	19/08/2009-31/05/2013	31/05/2013	2.429071056	9.61709E-06	1.6923E-05	6869.145375	0.322094864	8.07913E-07	8.33546E-08

A. 2b: Data of Figure 21/22: Merton Model Results long-term Horizon I/II

Number	Bond Yield	Recovery Rate (impl.)	Equity Value	Equity Volatility	Liabilities	Distance to default	Asset Value	Asset Value/Liabilities
1	0.336714652	0.402561362	425616000	0.328390436	145924767.2	-2.952480302	452715572	3.10239023
2	0.322150223	0.567025863	425616000	0.328390436	124696983.6	-1.216819002	468817947.6	3.759657483
3	0.057964204	0.857596922	525733848	0.298394235	1314690249	-0.100502295	1509644747	1.148289301
4	0.058779385	0.883266349	525733848	0.298394235	1209250093	0.500566533	1460875636	1.208083956
5	0.057657768	0.794106509	3596744004	0.270718094	3225563271	0.792882768	6014449025	1.864619764
6	0.041736553	0.88672643	3596744004	0.270718094	2673948877	2.660678646	5918697604	2.213467002
7	0.034330286	0.788068999	65519483469	0.362759487	10089948591	4.826750515	74017971861	7.335812586
8	0.030461071	0.786239595	65519483469	0.362759487	10089948591	4.842500942	74169801437	7.350860192
9	0.033139708	0.753481866	1.40292E+11	0.433062876	10081054223	5.439168447	1.48833E+11	14.7636628
10	0.028999511	0.75120025	1.40292E+11	0.433062876	10081054223	5.447875779	1.48998E+11	14.78003746
11	0.032306142	0.741367791	2.70877E+11	0.478785199	10113412792	6.088943927	2.79482E+11	27.63479891
12	0.02774196	0.738881059	2.70877E+11	0.478785199	10113412792	6.094535465	2.79668E+11	27.65314128
13	0.028436615	0.67045411	77469850400	0.486206592	59092206048	1.781670528	1.2873E+11	2.178461894
14	0.031739302	0.636764588	77469850400	0.486206592	59092206048	1.684636887	1.26884E+11	2.147223437
15	0.01776873	0.735254914	77469850400	0.426404406	59092206048	2.271255985	1.31539E+11	2.225988082
16	0.019975198	0.707335208	77469850400	0.426404406	59092206048	2.181977855	1.30271E+11	2.20453858
17	0.00885038	0.816828488	77469850400	0.342628654	59092206048	3.161742259	1.34004E+11	2.267712392
18	0.009822063	0.797424488	77469850400	0.342628654	59092206048	3.092759695	1.3338E+11	2.25715364
19	0.005806458	0.901372228	77469850400	0.342628654	9878962096	6.587486828	83765950006	8.479225772
20	0.005800168	0.903333415	77469850400	0.342628654	8502330746	6.890758176	82408674255	9.692480417

A. 3: Data of Figure 23: Black & Cox Model Default Probability and Credit Spread

Number	Time period	Date	Default Probability	Credit Spread	Equity Value	Horizon	Hurdle	Bond Yield	Asset Value	Equity Volatility	Asset Volatility	Asset Value/Hurdle
1	06/10/1986-24/10/1988	24/10/1988	0.027984471	0.0056767	425616000	5	105594630	0.0626767	452715572	0.328390436	0.333123588	4.287297
2	06/10/1986-24/10/1988	24/10/1988	0.009370158	0.002861157	425616000	3.29039	105594630	0.05686116	468817948	0.328390436	0.338645437	4.43979
3	25/10/1988-29/04/1993	29/04/1993	0.003678885	0.000737134	525733848	5	904140872	0.05173713	1509644747	0.298394235	0.121606236	1.669701
4	25/10/1988-29/04/1993	29/04/1993	0.002508152	0.00057424	525733848	4.37326	904140872	0.05557424	1460875636	0.298394235	0.117407672	1.615761
5	30/04/1993-03/07/1998	03/07/1998	0.002990765	0.000599049	3596744004	5	2162796109	0.04259905	6014449025	0.270718094	0.185329379	2.780867
6	30/04/1993-03/07/1998	03/07/1998	0.000200974	5.9433E-05	3596744004	3.38187	2162796109	0.04005943	5918697604	0.270718094	0.167616657	2.736595
7	06/07/1998-23/10/2008	23/10/2008	0.003701271	0.000741628	65519483469	5	9424697619	0.03397163	7.4018E+10	0.362759487	0.321873857	7.853618
8	06/07/1998-23/10/2008	23/10/2008	0.004226206	0.000838018	65519483469	5.05378	9424697619	0.03010802	7.417E+10	0.362759487	0.321288951	7.869727
9	06/07/1998-27/10/2008	27/10/2008	0.003760146	0.000753447	1.40292E+11	5	9418663603	0.03300345	1.4883E+11	0.433062876	0.408529764	15.80195
10	06/07/1998-27/10/2008	27/10/2008	0.004321917	0.000857038	1.40292E+11	5.05378	9418663603	0.02888704	1.49E+11	0.433062876	0.408111625	15.81948
11	06/07/1998-28/10/2008	28/10/2008	0.002332438	0.000467033	2.70877E+11	5	9449964301	0.03225703	2.7948E+11	0.478785199	0.464150649	29.57494
12	06/07/1998-28/10/2008	28/10/2008	0.002726278	0.00054019	2.70877E+11	5.05378	9449964301	0.02771019	2.7967E+11	0.478785199	0.463856102	29.59457
13	06/07/1998-31/05/2013	31/05/2013	0.342989746	0.084011131	77469850400	5	5.6047E+10	0.08856113	1.2873E+11	0.486206592	0.326091664	2.296809
14	06/07/1998-31/05/2013	31/05/2013	0.406843005	0.092683821	77469850400	5.63525	5.6047E+10	0.09723382	1.2688E+11	0.486206592	0.334626851	2.263873
15	29/10/2008-31/05/2013	31/05/2013	0.214537035	0.048296394	77469850400	5	5.6047E+10	0.05284639	1.3154E+11	0.426404406	0.272379009	2.346917
16	29/10/2008-31/05/2013	31/05/2013	0.267403305	0.055216741	77469850400	5.63525	5.6047E+10	0.05976674	1.3027E+11	0.426404406	0.278334574	2.324302
17	19/08/2009-31/05/2013	31/05/2013	0.073972034	0.015370169	77469850400	5	5.6047E+10	0.01992017	1.34E+11	0.342628654	0.206525943	2.390908
18	19/08/2009-31/05/2013	31/05/2013	0.10163865	0.019020091	77469850400	5.63525	5.6047E+10	0.02357009	1.3338E+11	0.342628654	0.209428232	2.379776
19	19/08/2009-31/05/2013	31/05/2013	1.65055E-13	6.79656E-14	77469850400	2.42907	1999391869	0.0058	8.3766E+10	0.342628654	0.316875633	41.89571
20	19/08/2009-31/05/2013	31/05/2013	5.40343E-13	2.22464E-13	77469850400	2.42907	1999391869	0.0058	8.2409E+10	0.342628654	0.322094864	41.21687

A. 4a: Data of Figure 24: Leland Model Credit Spread, PD and Asset Value/Debt Value

Number	Time period	Date	Credit Spread	Default Probability	Asset/Debt	Horizon	Equity Vola. (est.)	Asset Volatility	Coupon
1	06/10/1986-24/10/1988	24/10/1988	0.016836979	0.116525088	1.371657819	5	0.328390436	0.233462955	65275397.9
2	06/10/1986-24/10/1988	24/10/1988	0.000898386	0.000986144	1.63673175	3.290393769	0.328355856	0.129298626	36095677.7
3	25/10/1988-29/04/1993	29/04/1993	0.014342991	0.102303549	1.346572859	5	0.298394235	0.210375275	77364472
4	25/10/1988-29/04/1993	29/04/1993	0.000115888	0.00076258	1.384299316	4.373259912	0.298393846	0.082983294	75241772.3
5	30/04/1993-03/07/1998	03/07/1998	0.007861213	0.025810061	1.704675552	5	0.270718094	0.207552532	214372767
6	30/04/1993-03/07/1998	03/07/1998	0.000101851	6.55648E-08	1.962649691	3.381866734	0.208615199	0.134433847	149451832
7	06/07/1998-23/10/2008	23/10/2008	0.006355061	0.000247334	5.408109101	5	0.362759487	0.305222942	493910742
8	06/07/1998-23/10/2008	23/10/2008	0.007017287	0.000206108	5.408109101	5.053783511	0.362759487	0.307142383	435051682
9	06/07/1998-27/10/2008	27/10/2008	0.009960379	0.000170066	10.4537052	5	0.433062876	0.400836949	478585246
10	06/07/1998-27/10/2008	27/10/2008	0.007642428	2.5856E-05	10.4537052	5.053783511	0.433062876	0.402432183	415961068
11	06/07/1998-28/10/2008	28/10/2008	0.011475409	7.68112E-05	19.22205226	5	0.478785199	0.460272204	472569553
12	06/07/1998-28/10/2008	28/10/2008	0.00941924	1.30698E-05	19.22205226	5.053783511	0.478785199	0.461421524	403891625
13	06/07/1998-31/05/2013	31/05/2013	0.021899605	0.000389236	2.134652587	5	0.486206592	0.428674747	310657045
14	06/07/1998-31/05/2013	31/05/2013	0.021899605	0.000990787	2.134652587	5.635246424	0.486206592	0.428674747	310657045
15	29/10/2008-31/05/2013	31/05/2013	0.016745695	8.08596E-05	2.134652587	5	0.426404406	0.364234937	310657045
16	29/10/2008-31/05/2013	31/05/2013	0.013168211	4.48154E-05	2.134652587	5.635246424	0.426404406	0.364234937	310657045
17	19/08/2009-31/05/2013	31/05/2013	0.010380182	3.86536E-06	2.134652587	5	0.342628654	0.272965063	310657045
18	19/08/2009-31/05/2013	31/05/2013	0.007751112	1.12161E-06	2.134652587	5.635246424	0.342628654	0.272965063	310657045
19	19/08/2009-31/05/2013	31/05/2013	0.00739669	1.07248E-20	8.841901776	2.429071056	0.337157424	0.326132911	57297980.2
20	19/08/2009-31/05/2013	31/05/2013	0.007254955	1.27418E-21	10.1116016	2.429071056	0.337949976	0.32816801	49313518.3

A. 4b: Data of Figure 24: Leland Model Credit Spread, PD and Asset Value/Debt Value

Number	Risk-free rate	Equity Vola.	Equity Value	Tax in %	Bankruptcy Costs in %	Equity Value (est.)	Asset Value	Threshold	Tax Benefits	Bankruptcy Costs
1	0.057	0.638087802	510083221.7	0	0	425616000	1570798419	774759404.9	0	176667679.7
2	0.054	0.328355856	427082300.9	0	0	425616000	1094054475	578836073.5	0	9472378.228
3	0.051	0.607952353	626492555.8	0	0	525733848	2042684279	1057919579	0	232216657
4	0.055	0.298393846	525903311.3	0	0	525733848	1893766072	1287436068	0	2706992.993
5	0.042	0.438161323	3869536578	0	0	3596744004	8700857513	3373875527	0	531931560.2
6	0.04	0.270683229	3610870677	0	0	3596744004	7333039812	3047783926	0	62533485.26
7	0.03323	0.362138273	66912161616	0	0	65519483469	80382882256	6188541664	0	993520309.9
8	0.02927	0.361863537	1.43349E+11	0	0	65519483469	80382882256	5691546370	0	1100639311
9	0.03225	0.432664937	1.4279E+11	0	0	1.40292E+11	1.55131E+11	4250874398	0	1003078418
10	0.02803	0.432538946	1.43349E+11	0	0	1.40292E+11	1.55131E+11	3815952455	0	1058302385
11	0.03179	0.478626258	2.7391E+11	0	0	2.70877E+11	2.85743E+11	3431497598	0	910145975.2
12	0.02717	0.478578677	2.74586E+11	0	0	2.70877E+11	2.85743E+11	3022577306	0	946574269.1
13	0.00455	0.467011412	1.31334E+11	0	0	77469850400	1.45746E+11	3221546827	0	2667359424
14	0.00455	0.467011412	1.31334E+11	0	0	77469850400	1.45746E+11	3221546827	0	2667359424
15	0.00455	0.405839311	1.27712E+11	0	0	77469850400	1.45746E+11	4382639808	0	3446252845
16	0.00455	0.405839311	1.27712E+11	0	0	77469850400	1.45746E+11	4382639808	0	3446252845
17	0.00455	0.320385618	1.19772E+11	0	0	77469850400	1.45746E+11	7431104421	0	5166461833
18	0.00455	0.320385618	1.19772E+11	0	0	77469850400	1.45746E+11	7431104421	0	5166461833
19	0.0058	0.341199173	82923276293	0	0	77469850400	87348812496	971459485.6	0	594755067.1
20	0.0058	0.341541302	82124180548	0	0	77469850400	85972181146	826754369.3	0	501328837.9

A. 5: Data of Figure 25: Leland Model with Tax and Bankruptcy Costs

Number	Time period	Date	Credit Spread	Default Probability	Asset/Debt	Equity Vola.	Tax in %
1	06/10/1986-24/10/1988	1988	0.001648103	0.000747373	1.371657819	0.325934628	0.6
2	25/10/1988-29/04/1993	1993	0.001105376	0.000382378	1.346572859	0.296484826	0.565
3	30/04/1993-03/07/1998	1998	0.000940675	3.91659E-05	1.704675552	0.269206803	0.56
4	06/07/1998-23/10/2008	2008	0.004632558	5.50265E-05	5.408109101	0.361402796	0.302
5	06/07/1998-31/05/2013	2013	0.019126525	0.000137789	2.134652587	0.472887634	0.302

Number	Asset Value	Equity Value	Coupon	Equity Value (est.)	Asset Vola.	Horizon
1	1570798419	1117696357	65275397.88	425616000	0.233462955	5
2	2042684279	1387747519	77364471.97	525733848	0.202640702	5
3	8700857513	6474521378	214372767.4	3596744004	0.201257531	5
4	80382882256	70931941889	493910741.7	65519483469	0.321288259	5
5	1.45746E+11	1.35587E+11	310657044.6	77469850400	0.445184667	5

Number	Tax Benefits	Bankruptcy Costs	Threshold	Risk-free rate	Equity Vola (est.)	Bankruptcy Costs in %
1	664057722.1	4158765.452	309903762	0.057	0.328390436	0.4
2	834737739.5	4905028.5	470470848.4	0.051	0.298394235	0.4
3	2782118938	16154216.45	1515189358	0.042	0.270718094	0.4
4	3831777591	237885075.6	4063380618	0.03323	0.362759487	0.4
5	3650529670	688694494	2092134280	0.00455	0.486206592	0.4