Chapter 1

Introduction

Financial institutions, corporations and individual investors are exposed to many different types of risk, see for example Crouhy, Galai, and Mark (2006) for an overview. This ranges from financial risks, like market and credit risk, to risks related to daily operations, like business and operational risk.

The research conducted and described in this thesis is solely related to credit risk. Credit risk refers to the risk that the value of a portfolio or an individual security changes due to unexpected changes in the credit quality of issuers. This subsumes both losses due to defaults and losses due to changes in credit quality, such as downgrades of counterparties in an internal or external rating system.

This thesis contains four related studies on aspects of credit risk and credit risk models. To put these studies into perspective, Section 1.1 of this introduction describes the developments that led to a renewed interest in credit risk during the last decade, and particularly since the recent 2007-2008 credit crisis. Section 1.2 discusses the most important credit risk models used in the academic and professional literature. Finally, Section 1.3 gives a detailed outline of the research chapters found in the rest of this thesis.
1.1 Developments

Several developments have spurred interest in credit risk modeling during the last decade. First, default rates rose sharply at the turn of the century, see Cantor, Hamilton, Ou, and Varma (2006). Moreover, since the end of the U.S. recession, by the end of 2001, investors have witnessed some of the largest bankruptcy filings in U.S. history.\textsuperscript{1} This has certainly led to an increased awareness of credit risk among market participants.

Awareness of credit risk has been triggered again during the recent financial crisis, where even several large financial institutions collapsed, most notably Lehman Brothers in 2008. Apart from outright defaults, national authorities bailed out financial institutions, like three major Iceland banks at the end of 2008. The turn of events raised questions about the solvency of financial institutions around the world. It also led to a severe reduction of activity in specific financial markets. Governments and central banks responded by extensive liquidity provisioning, fiscal stimulus and monetary policy expansion to counteract the real and financial impact of the crisis.

More recently, several European countries have become subject to the threat of sovereign default. Though the threat predominantly relates to Greece, other countries with weak underlying fundamentals could be threatened as well. This has even led to the creation of the European Financial Stability Facility (EFSF), which came into existence in May 2010, see EFSF (2010). The EFSF aims to preserve financial stability in Europe by providing financial assistance to Eurozone countries that run into difficulties.

Apart from recent developments, interest in credit risk modeling has increased also

\textsuperscript{1}Enron Corp. (December 2001), Global Crossing Ltd. (January 2002), Worldcom Inc. (July 2002), United Airlines (UAL) Corp. and Conseco Inc. (December 2002).
due to the proliferation of credit derivatives. Credit derivative markets have grown significantly in size and product range since the late 1990s. This led to the development of additional credit risk models for pricing and risk management purposes.

Credit risk has also been at the heart of many developments aimed at the regulation of financial institutions over the years, which regained momentum from the year 2000 onwards. In 1992 the 1988 Basel Accord was implemented under auspices of the Basel Committee on Banking Supervision (BCBS), see BCBS (1988). The 1988 accord intended to raise capital ratios, accounting more consistently for risk in balance and off-balance-sheet-activities of financial institutions. The international scope of the accord created a more level playing field, harmonizing minimum capital ratios for banks in all major jurisdictions around the world.

The accord was initially predominantly aimed at credit risk, perceived as the dominant risk factor in banking. The 1996 market risk amendment to the 1988 accord, see BCBS (1996), established consistent risk-based capital requirements for incurred market risk as well.

The 1988 accord has been in existence for over a decade, and has proven to be quite successful in achieving its main goals. However, it gradually became clear that the accord left too much scope for regulatory arbitrage. In 1999 the BCBS issued consultative documents on a New Basel Capital Accord, see BCBS (1999). The new Basel II Accord was published in 2004, see BCBS (2004). Basel II consists of three pillars. Pillar I revises the 1988 accord by aligning minimum capital requirements more closely to the actual risk profile of a bank. Pillar II specifies the supervisory review process. This, for example, allows supervisors to scrutinize bank practices that look like regulatory arbitrage. Pillar
III deals with information disclosure to financial markets, such that investors can exert discipline on bank behavior.

The Basel II approach towards risk is more comprehensive. It not only takes into account more types of risk (e.g., operational risk), it also allows for a more sophisticated way to calculate minimum capital requirements. With respect to credit risk, banks can choose between a standardized approach, a foundation internal rating based (IRB) approach, and an advanced IRB approach.

The standardized approach is comparable to the 1988 approach, but is designed to be more risk sensitive. Risk weights of assets depend on the broad background of the borrower (i.e., sovereign, corporate, or bank), and on the rating provided by an external rating agency. In the foundation IRB approach, a bank uses its own estimate of default probabilities to determine risk weights associated with different assets. The advanced IRB approach allows banks to use their own estimates of other vital risk parameters as well, like $EAD$ and $LGD$.

Banks have a natural incentive to implement the (advanced) IRB approach. First, the BCBS studies the potential impact of the Basel II framework by means of quantitative impact studies (QIS), see for example BCBS (2006). These studies reveal that the IRB approaches on average lead to reductions in regulatory capital requirements as compared to the standardized approach. Second, the IRB approaches allow banks to bridge the gap between external and internal risk management systems. Third, adhering to more advanced approaches could provide an important signal of bank quality.

The recent crisis has led to amendments of the Basel II accord, see BCBS(2010a)(2010b). Basel II and these amendments culminate in Basel III. Basel III intends to further
strengthen microprudential, or bank-level, regulation. There is also more attention for macroprudential, or system-wide, risk management. More specifically, Basel III aims to: raise the quality and transparency of the capital base of banks; enhance the risk coverage of the accord; supplement the risk-based capital requirement with a leverage ratio; reduce procyclicality and promote countercyclical buffers; address systematic risk and interconnectedness. The accord also introduces global liquidity standards. During the crisis central banks supported both the functioning of money markets and individual banks. This has underlined the importance of prudent liquidity management. The overall objective of the recent reforms is to further enhance global capital and liquidity standards to promote a more resilient banking sector.

1.2 Credit Risk Models

Credit risk models are used for credit risk management as well as for pricing credit risky securities. There are two main classes of credit risk models, structural and reduced form models.

In structural models or firm value models a firm defaults when its asset value surpasses a certain threshold. In the seminal papers of Black and Scholes (1973) and Merton (1974) debt is represented as a zero coupon bond.\footnote{We predominantly refer to Merton (1974) only in the remainder of this thesis. The reader could add Black and Scholes (1973) as well at each instance. Merton (1974) more explicitly deals with the pricing of corporate liabilities in a contingent claims setting.} The firm defaults at a future time $T$ if firm value ends up below the notional debt value. In that case equity holders hand the firm over to bondholders, who distribute the remaining company value among themselves.
When no default occurs, equity holders pay the notional debt value to bond holders to retain ownership of the assets. These payoff structures are consistent with a contingent claims interpretation. Equity can be viewed as a call option on the firm’s assets, while debt holders hold a portfolio of riskless debt and a written put option on the firm’s assets.

In line with option pricing theory, the seminal structural models analyze a market with continuous trading, which is competitive and frictionless (e.g., no bankruptcy costs). Moreover, the debt structure is very simplistic, and the company can only default at maturity. In practice companies issue coupon bearing bonds, with possibly different seniority, and can default at any moment in time. Notwithstanding these simplifying assumptions, the models provide useful insight into the default mechanism. The recovery rate in case of default is endogenously determined as well. This helps to identify explanatory variables related to credit risk, which turn out to have significant explanatory power in empirical models, including the ones specified in this thesis.

Several studies have extended the seminal structural models to address some of their strong assumptions. In the Black and Cox (1979) model default occurs when the asset value hits a boundary prior to default, representing bond safety covenants. Geske (1977) and Geske and Johnson (1984) allow for coupon bearing bonds and a more general capital structure. Longstaff and Schwartz (1995) modify the model by introducing stochastic default-free interest rates. Mason and Bhattacharya (1981) and Zhou (2001) consider an asset value process with jumps. These extensions deal with specific implications of the seminal structural models. For example, if firm value is described by a geometric Brownian motion, yield spreads between corporate bonds and default-free bonds go to zero as time to maturity goes to zero. This is a result of the fast rate at which the probability of
default goes to zero when both firm value exceeds the face value of debt and maturity goes to zero. This implication can to some extent be addressed by introducing jumps in the model specification.

In reduced form models or intensity models the mechanism leading to default is left unspecified. The models stem directly from the statistical theory of point processes. Though the question what exactly triggered the default event is left aside, intensity models may specify factors influencing transition intensities of issuers over time.

The payoff of credit risky securities frequently depends on the timing of credit events. For valuation purposes, it is therefore necessary to understand the dynamic evolution of probabilities related to certain credit events. Intensity based models provide a natural framework to analyze these instruments. For instance, doubly stochastic random times are an important example of random times with a stochastic hazard rate. In a single-firm setting, where the default time is given by a doubly stochastic random time, pricing models of credit risky securities are in line with well known pricing models of default-free securities, see Lando (2004) or Embrechts et al. (2005). Though the underlying default mechanism is unclear, let alone the recovery rate once a default occurs, this is certainly an appealing feature of intensity models.

In case of risk management, credit risk models are used to determine loss distributions of individual exposures or a portfolio of exposures over fixed time intervals. Given these loss distributions one can derive risk measures, allocate capital, and so on. When loss distributions are projected at a future point in time, there will be less need to describe the evolution of risk over time. As a result, credit risk management models with different statistical backgrounds have been developed over the years.
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Portfolio Manager of Moody’s KMV, see Kealhofer (2001), is most closely related to structural models. It first determines the distance to default (DD) of each firm. DD is defined as the number of standard deviations between the expected future asset value and a default point, which is a function of the firm’s debt structure. The DD are subsequently mapped to default probabilities based on historical default experience of firms with similar DD. The model allows for losses due to changes in credit quality as well. CreditMetrics of the RiskMetrics Group, see Bhatia, Finger, and Gupton (1997), is directly based on credit migration matrices published by rating agencies, which specify transition probabilities from one rating class to another (or default). In CreditPortfolioView, as developed by Wilson (1997a, 1997b), default and transition probabilities are conditioned on macroeconomic developments. The CreditRisk+ model of Credit Suisse Financial Products (1997) is more closely related to intensity based models. A more extensive overview and discussion of portfolio credit risk models can be found in Crouhy, Galai, and Mark (2000) or Bluhm, Overbeck, and Wagner (2003).

1.3 Outline

Before discussing the individual chapters separately, it is useful to put them in perspective. Credit risk is a broad area, which can be subdivided into three main themes: individual counterparty credit risk, portfolio credit risk, and credit risk pricing. Each of these themes has given rise to an extensive literature.

Individual counterparty credit risk largely concerns the determination of the default risk of individual exposures. One way to discern issuers on credit quality is to look at credit ratings or credit scores, whether provided by external rating agencies or by
internal models. Credit scoring dates back to pioneering studies like Altman (1968). A very important issue in this context concerns the information provided by credit rating agencies, and the timely provision of this information. The first two research chapters of this thesis deal with this topic.

Rating agencies assign ratings using both public and private information, where the latter is obtained from private consultations with individual companies, see Moody’s Investors Service (2004) and Standard & Poor’s (2005). An important question is whether rating agencies predominantly summarize publicly available information, or whether they actually provide superior information in term of credit scoring, see for example Altman and Rijken (2006). We extend this literature in the first research chapter (Chapter 2) by looking at the dynamics of price changes surrounding rating agency announcements. We incorporate publicly available information about the companies involved in the analysis. In this way we get a better understanding of the real information provided by rating agencies.

In the second research chapter (Chapter 3), we study whether rating agencies only include the financial performance of companies in their rating assignments, or whether they also consider the companies’ governance structure. Particularly with respect to more soft factors like governance structures, rating agencies might be able to add value compared to purely statistical rating models based on financial ratios.

Portfolio credit risk is the second important theme in the credit risk literature. It studies the risk factors in portfolios of credit exposures when all idiosyncratic risk has been diversified. The portfolio credit risk literature therefore abstracts from many issues that are relevant for the determination of individual counterparty credit risk.
Important questions for portfolio credit risk relate to the size, origin, and dynamics of systematic credit risk factors. Recent literature argues that business cycle risk is an important systematic credit risk factor, but not the only one, see Duffie, Eckner, Horel, and Saita (2009) and Koopman, Kräussl, Lucas, and Monteiro (2009). In particular, these studies claim that there are additional unobserved systematic credit risk factors, also denoted as frailty components. In the third research chapter (Chapter 4), we investigate this class of (frailty) models. We try to determine whether the claimed importance of frailty systematic credit risk factors can be partially ascribed to misspecified non-linear business cycle dynamics or non-Gaussian distributions. This is particularly relevant, as underestimation of systematic credit risk might lead to insufficient capital buffers in the financial system.

The third theme in credit risk is credit risk pricing. The literature on credit risk pricing is large and can be subdivided into two streams: mathematical pricing models, and empirical pricing research. Mathematical models for credit risk pricing start with a concise formulation of default dynamics, either by modeling the assets of the firm directly, or by modeling default as a separate process, see for example Lando (2004). The empirical pricing literature relates these models to empirical data to test their specifications, or it builds empirical models for credit risk that cannot be mapped one-on-one to a theoretical model. Chapter 5 contains a contribution to this last area of the literature.

Several studies have determined to what extent credit spreads reflect average historical default losses in a static setting, see for example Altman and Bencivenga (1995), Amato and Remolona (2003), Hull, Predescu, and White (2005), or in a dynamic setting, see Barnhill, Joutz, and Maxwell (2000). The focus of these studies is predominantly on
The probability of default is only one ingredient of credit risk, however. In particular, we would expect the loss-given-default to be important as well. Therefore, we build a time-series model to study the joint behaviour of credit spreads, default frequencies, and losses-given-default. As a main contribution, we use a dynamic specification of the model with an error correction component. In particular, we test whether there is a long-term relationship between the variables mentioned, and whether the data can be adequately described as transitory deviations around this long-term relationship. This should help us to obtain a clearer insight into the interrelation between credit risk factors and credit risk prices.

We now discuss the contributions of each individual research chapter in more detail.

As noted, the first part of this thesis is devoted to default probabilities of individual issuers. In practice, it may not be straightforward to accurately determine the credit quality of specific companies. Apart from the difficulty of obtaining relevant counterparty data, default events are relatively scarce. Additionally, the management of a firm is usually better informed about default risk than individual lenders. This informational asymmetry might lead to adverse selection and moral hazard. Along the lines of Akerlof (1970) this may even give rise to a total collapse of credit markets.

Rating agencies are important institutions in today’s financial markets. They might facilitate in bridging the gap between informed and uninformed market participants. The most important rating agencies in terms of size and scope are U.S. based Standard & Poor’s and Moody’s. Their opinion about creditworthiness of companies is summarized
in a letter grade ranking, or credit rating. The credit quality of companies is assessed using public and private information, where the latter is obtained from private consultations with individual companies, see Moody’s Investors Service (2004) and Standard & Poor’s (2005).

Besides credit ratings, rating agencies also publish watchlist additions and outlooks. A rating outlook represents an opinion regarding the likely direction of an issuer’s credit rating over the medium term, typically 18 to 36 months. Watches can be considered as a subset of rating outlooks. They give a much stronger indication about a possible future rating change, and are usually resolved within 90 days.

Chapter 2 looks at the information content of rating agency announcements. First, surveys reveal that market participants believe that agency ratings adjust slowly to changes in corporate credit quality, see Ellis (1998) and Baker and Mansi (2002). This is confirmed by studies that benchmark agency ratings to alternative measures of creditworthiness using public data, like Altman and Rijken (2005). Second, several studies have examined return reactions surrounding rating agency announcements using equity, bond, or CDS data, see Chapter 2. These studies typically find significant return reactions within large time windows surrounding the actual announcements of deteriorating credit quality.

Given these findings it seems necessary to account for information held by market participants about company creditworthiness prior to rating agency announcements. As a result, and contrary to plain event studies, the chapter conditions on pre-announcement changes in benchmark measures of company creditworthiness before estimating abnormal returns.

There are many statistical models to estimate company default probabilities, see Lando
We estimate default probabilities using logit specifications, making use of publicly available data only. This gives an alternative ranking of companies in terms of creditworthiness, so called credit model ratings. Subsequently, we not only estimate pooled return reactions surrounding agency announcements, we also look at return reactions conditional on credit model rating changes prior to the actual announcements. To better understand the rating process, the chapter first gives an overview of Moody’s watchlist and outlook assignments and corresponding resolution (periods).

Estimating pooled window abnormal returns (WAR) surrounding rating agency announcements reveals that WARs are largest and most significant in case of negative announcements. Similar return patterns are observed across negative announcement types. A significant part of the negative total abnormal return materializes prior to the announcement day window. Typically, we obtain a movement in the opposite direction in the post-announcement window, especially in case of downgrades and negative outlooks.

Conditioning on credit model precedence, we find no significant positive post-announcement returns if announcements are not in line with pre-announcement changes in benchmark measures of company creditworthiness. This indicates that new information is fully absorbed once it is revealed. On the other hand, significant positive post-announcement returns typically materialize when announcements are in line with pre-announcement point-in-time credit quality deteriorations. This suggests a pre-announcement excessive response once market participants’ concerns about specific companies grow. Formal rating agency announcements might then predominantly resolve underlying uncertainty, resulting on average in a positive post-announcement abnormal return reaction.
Chapter 3 looks at the relation between corporate governance and both firm value and credit quality. In general statistical models rely heavily on financial statement information to construct explanatory variables related to default risk. However, past experience has shown that weak governance could be an important driver of default risk. For example, the large U.S. bankruptcy filings in 2001 and 2002 were frequently associated with management scandals, most clearly the Enron filing by the end of 2001.

Corporate governance refers to the set of mechanisms that direct and control management activities within companies. The analysis in the chapter is confined to two control mechanisms, shareholder rights and blockownership.

The presence of large shareholders can theoretically either have a positive or negative effect on firm and debt value, see for example Bhojraj and Sengupta (2003) and references therein. The shared benefits hypothesis suggests that large shareholder presence can be beneficial to all company stakeholders if it mitigates the agency problem between management and stakeholders as a group. The private benefits hypothesis states that large shareholders can be detrimental to value. If blockholders pursue their own objectives, they can expropriate value from other stakeholders, such as minority shareholders and debt holders. Effects related to both hypothesis can be strengthened or diminished when there are multiple blockholders, see Chapter 3.

Chapter 3 is predominantly concerned with the relation between blockholder dispersion and both firm value and credit quality. Though the data set reveals that blockholding by multiple blockholders is quite common in the U.S., blockholder dispersion has not received explicit attention in the existing literature.

Using a large dataset of about 3,500 U.S. firm year observation from 1996-2001, we
find a negative relation between aggregate blockholding and both firm value and debt quality. On top of that, we consistently obtain a negative relation between blockholder dispersion and firm value. These results are robust to a variety of model specifications, including controlling for shareholder rights. In line with this result, we obtain a negative relation between blockholder dispersion and credit quality.

With respect to shareholder rights we find opposite results. Shareholder rights are positively related to firm value, but negatively related to debt quality. This suggests that a shift in balance of power towards shareholders is considered as a negative signal by credit rating agencies.

In Chapter 4 attention is shifted from credit risk of individual exposures to the identification of systematic credit risk factors. As idiosyncratic risk can be diversified to a large extent, it is predominantly systematic risk that should impact upon pricing and portfolio risk management decisions.

In line with recent papers, daily rating transitions and default events of on average about 2,500 U.S. companies are modeled by reduced form intensity models. The sample period stretches from 1981 to 2009. Assuming a conditionally independent doubly stochastic modeling setup, transition times are allowed to correlate only due to correlation of common factors associated with underlying transition intensities.

It is relatively easy to price credit-risky instruments and to generate loss distributions given conditionally independent transition times, see Embrechts et al. (2005) or Lando (2004). In that case, pricing formulas obtained in a single-firm model, which are in line with pricing formulas of default-free securities, remain valid in a portfolio context.
When conditionally independent transition models are not supported by the data, one may alternatively rely on models that explicitly incorporate interaction between defaults, see for example Azizpour and Giesecke (2008). Within these models the default of one firm influences the estimated conditional survival probability of other firms in the portfolio. This can, for example, be a result of direct economic links between firms.

Existing literature suggests that common changes in default probabilities correlate with macroeconomic conditions, see Chapter 4. However, Das, Duffie, Kapadia, and Saita (2007) show that the conditionally independent doubly stochastic assumption is rejected when they only consider observable covariates.

More recent studies include one or several latent factors on top of observable covariates, see Koopman, Lucas, and Schwaab (2008a), Koopman, Lucas, and Monteiro (2008b), Koopman, Kräussl, Lucas, and Monteiro (2009), Duffie, Eckner, Horel, and Saita (2009). These studies reveal that latent factors make an important, if not dominant contribution to systematic credit risk modeling.

Missing important factors would lead to a violation of conditional independence, invalidating corresponding pricing models. Missing important risk factors, or failing to incorporate them rightfully in risk management models, may also have serious consequences in terms of risk measurement, capital allocation and so on. As a result Chapter 4 focuses on three related questions regarding interpretation, distributional assumptions and significance of latent factors in credit risk modeling.

First, we investigate whether latent factors capture nonlinear responses of the credit cycle to macroeconomic variables. Koopman et al. (2009) reveal that latent factors are predominantly important at peaks and troughs of the credit cycle. These are periods
when macroeconomic variables also take their lowest or highest values. Latent factors could therefore predominantly pick up a nonlinear impact of explanatory variables.

We find that including relevant variables in a nonlinear way has no bearing on latent factor significance. We double check the latter finding using a simulation study. This confirms that it is unlikely that empirical results have been driven by a failure to incorporate nonlinearities adequately. The estimation methodology has no problem in identifying latent factors and nonlinear responses to observed variables separately.

Second, we examine whether or not skewness and excess kurtosis should be incorporated within latent factor specifications. For example, the impact on loss statistics, like extreme risk quantiles, ultimately depends on persistence of the latent factors and other distributional assumptions, like skewness and excess kurtosis, see Christodoulakis, Batiz-Zuk, and Poon (2009). Given our data set, we find no statistical evidence to incorporate skewness and excess kurtosis within latent factor specifications.

Third, we look at goodness-of-fit tests. This indicates whether doubly stochastic models with frailty components are adequately specified, or whether such models are rejected by the data. Common testing procedures reveal that latent factor specifications provide a better fit than models without latent components. However, results also indicate that there is a need to devise more powerful testing procedures to determine whether models are adequately specified.

Chapter 5 studies short- and long-run dynamics of speculative-grade bond yields. When underlying credit quality decreases rational investors will require an increasingly higher yield to compensate for potential losses due to default. Averaging historical time
series on loss given default and default probabilities of different rating categories reveals that investors in corporate debt on average require a spread over the risk-free rate in excess of expected default losses, see Altman and Bencivenga (1995), Amato and Remolona (2003), Hull, Predescu, and White (2005). Moreover, average excess returns of corporate bonds over Treasuries increase when ratings decrease. There are many possible explanations for these average excess returns, such as differential tax treatment, bond liquidity, priced idiosyncratic risk, and so on.

In Chapter 5 we take a different perspective. Instead of studying averages of historical data, we look at time series behavior of bond yields. Even when investors require a spread over the risk-free rate in excess of expected default losses, we still expect that a unit change in expected default loss would be fully reflected in corporate bond yields in the long-run.

In general, when variables are integrated of order one but cointegrated, differencing would be counterproductive. A cointegrated system can never be represented by a finite-order autoregressive relation, see Hamilton (1994). As a result we first estimate a fundamental long-term relationship between corporate bond yields on the one hand, and Treasury yields and historically estimated default losses on the other. Subsequently an error-correction model is formulated that describes the variation in yields around long-run values in terms of a set of stationary variables, including the equilibrium error of the cointegration relation. In this way we preserve the information about both short- and long-run relations between variables.

Estimation results are obtained using rated subindices of the Merrill Lynch U.S. Corporate Master Index, the U.S. High Yield Master II Index and the U.S. Treasury Index.

Estimated long-term relationships reveal that the default loss coefficient is close to one when it is possible to use rating specific default rates to estimate default losses. This implies that default loss changes are fully incorporated in yields in the long-run. Estimated coefficients on the default loss variable are understated (overstated) when we are forced to use speculative-grade default rates that overestimate (underestimate) rating specific default rates related to the bond yield series considered.

Considering error-correction models next, the magnitude and significance of coefficients related to the cointegration equation residuals provide an additional indication of the importance of the long-run equilibria. Moreover, besides bond liquidity and changes in expected default loss, short-run dynamics of speculative-grade yields are driven by changes in short rates and stock market volatility. We also find a clear January effect with respect to speculative-grade bond yields.

Splitting bond indices up in terms of maturity ranges reveals similar patterns. Differences predominantly show up across different rating categories. The impact of explanatory variables is more uniform across maturity ranges within specific rating categories.

Finally, a summary and concluding remarks are presented in Chapter 6.