Springer Finance

Manuel Ammann

Credit Risk Valuation

Methods, Models, and Applications

Second Edition

Springer

Manuel Ammann

Credit Risk Valuation

Methods, Models, and Applications

Second Edition

With 17 Figures
and 23 Tables

Springer

Dr. Manuel Ammann
University of St. Gallen
Swiss Institute of Banking and Finance
Rosenbergstrasse 52
9000 St. Gallen
Switzerland

Originally published as volume 470 in the series "Lecture Notes in Economics and Mathematical Systems" with the title "Pricing Derivative Credit Risk".

Mathematics Subject Classification (2001): 60Gxx, 60Hxx, 62P05, 91B28

ISBN 3-540-67805-0 Springer-Verlag Berlin Heidelberg New York

Library of Congress Cataloging-in-Publication Data applied for
Die Deutsche Bibliothek - CIP-Einheitsaufnahme
Ammann, Manuel: Credit Risk Valuation: Methods, Models, and Applications; with 23 Tables/Manuel Ammann. - 2. ed. - Berlin; Heidelberg; New York; Barcelona; Hong Kong; London; Milan; Paris; Singapore; Tokyo: Springer, 2001
(Springer Finance)
Früher u.d.T.: Ammann, Manuel: Pricing Derivative Credit Risk
ISBN 3-540-67805-0

Springer-Verlag Berlin Heidelberg New York
a member of BertelsmannSpringer Science+Business Media GmbH

http://www.springer.de

Hardcover-Design: design & production, Heidelberg

SPIN 10775908 42/2202-5 4 3 2 1 0 - Printed on acid-free paper

Preface

Credit risk is an important consideration in most financial transactions. As for any other risk, the risk taker requires compensation for the undiversifiable part of the risk taken. In bond markets, for example, riskier issues have to promise a higher yield to attract investors. But how much higher a yield? Using methods from contingent claims analysis, credit risk valuation models attempt to put a price on credit risk.

This monograph gives an overview of the current methods for the valuation of credit risk and considers several applications of credit risk models in the context of derivative pricing. In particular, credit risk models are incorporated into the pricing of derivative contracts that are subject to credit risk. Credit risk can affect prices of derivatives in a variety of ways. First, financial derivatives can be subject to counterparty default risk. Second, a derivative can be written on a security which is subject to credit risk, such as a corporate bond. Third, the credit risk itself can be the underlying variable of a derivative instrument. In this case, the instrument is called a credit derivative. Fourth, credit derivatives may themselves be exposed to counterparty risk. This text addresses all of those valuation problems but focuses on counterparty risk.

The book is divided into six chapters and an appendix. Chapter 1 gives a brief introduction into credit risk and motivates the use of credit risk models in contingent claims pricing. Chapter 2 introduces general contingent claims valuation theory and summarizes some important applications such as the Black-Scholes formulae for standard options and the Heath-Jarrow-Morton methodology for interest-rate modeling. Chapter 3 reviews previous work in the area of credit risk pricing. Chapter 4 proposes a firm-value valuation model for options and forward contracts subject to counterparty risk, under various assumptions such as Gaussian interest rates and stochastic counterparty liabilities. Chapter 5 presents a hybrid credit risk model combining features of intensity models, as they have recently appeared in the literature, and of the firm-value model. Chapter 6 analyzes the valuation of credit derivatives in the context of a compound valuation approach, presents a reduced-form method for valuing spread derivatives directly, and models credit derivatives subject to default risk by the derivative counterpary as a vulnerable exchange option. Chapter 7 concludes and discusses practical implications of this work. The appendix contains an overview of mathematical tools applied throughout the text.

This book is a revised and extended version of the monograph titled *Pricing Derivative Credit Risk*, which was published as vol. 470 of the Lecture Notes of Economics and Mathematical Systems by Springer-Verlag. In June 1998, a different version of that monograph was accepted by the University of St.Gallen as a doctoral dissertation. Consequently, this book still has the "look-and-feel" of a research monograph for academics and practitioners interested in modeling credit risk and, particularly, derivative credit risk. Nevertheless, a chapter on general derivatives pricing and a review chapter introducing the most popular credit risk models, as well as fairly detailed proofs of propositions, are intended to make it suitable as a supplementary text for an advanced course in credit risk and financial derivatives.

St. Gallen, March 2001 *Manuel Ammann*

Contents

1. Introduction

Credit risk can be defined as the possibility that a contractual counterparty does not meet its obligations stated in the contract, thereby causing the creditor a financial loss. In this broad definition, it is irrelevant whether the counterparty is unable to meet its contractual obligations due to financial distress or is unwilling to honor an unenforceable contract.

Credit risk has long been recognized as a crucial determinant of prices and promised returns of debt. A debt contract involving a high amount of credit risk must promise a higher return to the investor than a contract considered less credit-risky by market participants. The higher promised return manifests itself in lower prices for otherwise identical indenture provisions. Table 1.1 illustrates this effect, depicting average credit spreads over the time period from January 1985 until March 1995 for debt of different credit ratings. The credit rating serves as a proxy for the credit risk contained in a security.

1.1 Motivation

Although the effect of credit risk on bond prices has long been known to market participants, only recently were analytical models developed to quantify this effect. Black and Scholes (1973) took the first significant step towards credit risk models in their seminal paper on option pricing. Merton (1974) further developed the intuition of Black and Scholes and put it into an analytical framework. A large amount of research followed the work of Black, Merton, and Scholes.

In the meantime, various other methods for the valuation of credit risk have been proposed, such as reduced-form approaches. Many of the current models, however, rely on the fundamental ideas of the early approaches or are extensions thereof. We give an overview over many of the credit risk models currently in use and discuss their respective advantages and shortcomings. However, we would like to focus our attention to applying credit risk models to derivative securities. The following sections outline the motivation of applying credit risk valuation models to derivative pricing.

Table 1.1. U.S. corporate bond yield spreads 1985-1995

Maturity class	Rating class	Average spread	Standard deviation	Average maturity
Short	Aaa	0.67	0.083	3.8
	Aa	0.69	0.083	4.0
	A	0.93	0.107	4.2
	Baa	1.42	0.184	4.4
Medium	Aaa	0.77	0.102	10.1
	Aa	0.71	0.084	9.2
	A	1.01	0.106	9.4
	Baa	1.47	0.153	9.1
Long	Aaa	0.79	0.088	23.9
	Aa	0.91	0.087	21.3
	A	1.18	0.125	21.7
	Baa	1.84	0.177	21.2

Averages of yield spreads of non-callable and non-puttable corporate bonds to U.S. Treasury debt, standard deviation of absolute spread changes from month to month, and average maturities. Source: Duffee (1998)

1.1.1 Counterparty Default Risk

Most of the work on credit risk appearing to date has been concerned with the valuation of debt instruments such as corporate bonds, loans, or mortgages. The credit risk of financial derivatives, however, has generally been neglected; even today the great majority of market participants uses pricing models which do not account for credit risk. Several reasons can be given for the neglect of credit risk in derivatives valuation:

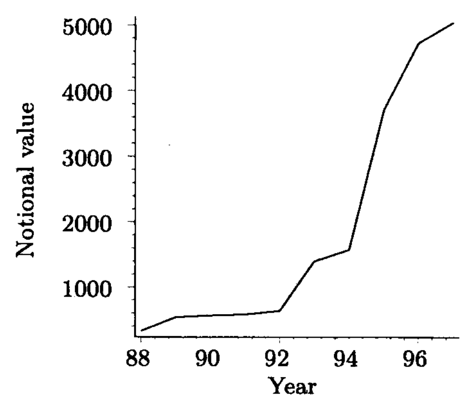
- Derivatives traded at major futures and options exchanges contain little credit risk. The institutional organization of derivatives trading at exchanges reduces credit risk substantially. Customarily, the exchange is the legal counterparty to all option positions. There is therefore no credit exposure to an individual market participant. Depending on the credit standing of the exchange itself, this may already reduce credit risk significantly. Furthermore, the exchange imposes margin requirements to minimize its risk of substituting for defaulted counterparties.
- For a long time, the volume of outstanding over-the-counter (OTC) derivative positions has been relatively small. Furthermore, most open positions were held in interest rate swaps. Interest rate swaps tend to contain relatively little credit risk[1] because contracts are designed such that only interest payments, or even only differences between interest payments, are exchanged. Principals are not exchanged in an interest rate swap and are therefore not subject to credit risk.

[1] Nonetheless, empirical work, e.g., by Sun, Suresh, and Ching (1993) and Cossin and Pirotte (1997), indicates that swap rates are also affected by credit risk.

- Pricing models which take counterparty risk into account have simply not been available. Credit risk models for derivative instruments are more complex than for standard debt instruments because the credit risk exposure is not known in advance.

Of course, even an exchange may default in unusual market situations[2] and OTC derivative volume has been considerable for a while, so these reasons only partially explain the lack of concern over credit risk in derivative markets. In any case, this lack of concern has given way to acute awareness of the problem, resulting in a slow-down of market activity.[3]

Fig. 1.1. Outstanding OTC interest rate options



Notional value in billions of U.S. dollars. Data are from the second half of the year except in 1997, where they are from the first half. Data source: International Swaps and Derivatives Association (1988-1997).

An important reason for this change of attitude is certainly the growth of the OTC derivatives market. As Figure 1.1 shows, off-exchange derivatives have experienced tremendous growth over the last decade and now account for a large part of the total derivatives contracts outstanding. Note that Figure 1.1 only shows outstanding interest rate option derivatives and does not include swap or forward contracts.

OTC-issued instruments are usually not guaranteed by an exchange or sovereign institution and are, in most cases, unsecured claims with no collateral posted. Although some attempts have been made to set up OTC clearing

---

[2] In fact, the futures and option exchange in Singapore (Simex) would have been in a precarious position if Barings had defaulted on its margin calls. Cf. Falloon (1995).

[3] Cf. Chew (1992)

houses and to use collateralization to reduce credit risk, such institutional improvements have so far remained the exception. In a reaction recognizing the awareness of the threat of counterparty default in the marketplace, some financial institutions have found it necessary to establish highly rated derivatives subsidiaries to stay competitive or improve their position in the market.[4] It would, however, be overly optimistic to conclude that the credit quality of derivative counterparties has generally improved. In fact, Bhasin (1996) reports a general deterioration of credit quality among derivative counterparties since 1991.

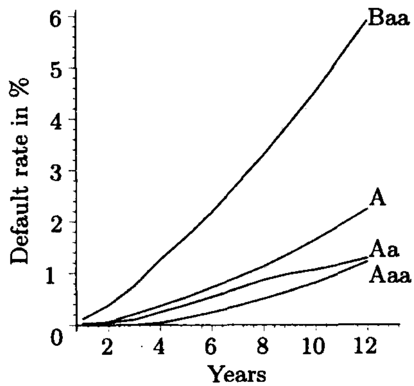
Historical default rates can be found in Figures 1.2 and 1.3. The figures show average cumulated default rates in percent within a given rating class for a given age interval. The averages are based on default data from 1970-1997. Figure 1.2 shows default rates for bonds rated Aaa, Aa, A, Baa. It can be seen that, with a few exceptions at the short end, default rate curves do not intersect, but default rate differentials between rating classes may not change monotonically. A similar picture emerges in Figure 1.3, albeit with tremendously higher default rates. The curve with the highest default rates is an average of defaults for the group of Caa-, Ca-, and C-rated bonds. While the slope of the default rate curves tends to increase with the age of the bonds for investment-grade bonds, it tends to decrease for speculative-grade bonds. This observation indicates that default risk tends to increase with the age of the bond for bonds originally rated investment-grade, but tends to decrease over time for bonds originally rated speculative-grade, given that the bonds survive.

Given the possibility of default on outstanding derivative contracts, pricing models evidently need to take default risk into account. Even OTC derivatives, however, have traditionally been, and still are, priced without regard to credit risk. The main reason for this neglect is today not so much the unquestioned credit quality of counterparties as the lack of suitable valuation models for credit risk. Valuation of credit risk in a derivative context is analytically more involved than in a simple bond context. The reason is the stochastic credit risk exposure.[5] While in the case of a corporate bond the exposure is known to be the principal and in case of a coupon bond also the coupon payments, the exposure of a derivative contract to counterparty risk is not known in advance. In the case of an option, there might be little exposure if the option is likely to expire worthless. Likewise, in the case of swaps or forward contracts, there might be little exposure for a party because the contract can have a negative value and become a liability.

Table 1.1 depicts yield spreads for corporate bonds of investment grade credit quality. Because the yield spread values are not based on the same data set as the default rates, the figures are not directly comparable, but they can still give an idea of the premium demanded for credit risk. Although a yield

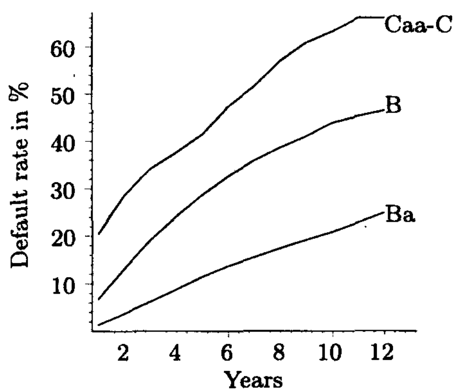
[4] Cf. Figlewski (1994).
[5] Cf. Hull and White (1992).

Fig. 1.2. Average cumulated default rates for U.S. investment-grade bonds



Average cumulated default rates during 1970-1997 depending on the age (in years) of the issue for investment-grade rating classes. Data source: Moody's Investors Services.

Fig. 1.3. Average cumulated default rates for U.S. speculative-grade bonds



Average cumulated default rates during 1970-1997 depending on the age (in years) of the issue for speculative-grade rating classes. Rating class Caa-C denotes the average of classes Caa, Ca, C. Data source: Moody's Investors Services.

spread of, for instance, 118 basis points over Treasury for A-rated long term bonds seems small at first sight, it has to be noted that, in terms of bond price spreads, this spread is equivalent to a discount to the long-term Treasury of approximately 21% for a 20-year zero-coupon bond. Although not all of this discount may be attributable to credit risk,[6] credit risk can be seen to have a large impact on the bond price. Although much lower, there is a significant credit spread even for Aaa-rated bonds.[7]

Moreover, many counterparties are rated below Aaa. In a study of financial reports filed with the Securities and Exchange Commission (SEC), Bhasin (1996) examines the credit quality of OTC derivative users. His findings contradict the popular belief that only highly rated firms serve as derivative counterparties. Although firms engaging in OTC derivatives transactions tend to be of better credit quality than the average firm, the market is by no means closed to firms of low credit quality. In fact, less than 50% of the firms that reported OTC derivatives use in 1993 and 1994 had a rating of A or above and a significant part of the others were speculative-grade firms.[8]

If credit risk is such a crucial factor when pricing corporate bonds and if it cannot be assumed that only top-rated counterparties exist, it is difficult to justify ignoring credit risk when pricing derivative securities which may be subject to counterparty default. Hence, derivative valuation models which include credit risk effects are clearly needed.

1.1.2 Derivatives on Defaultable Assets

The valuation of derivatives which are subject to counterparty default risk is not the only application of credit risk models. A second application concerns default-free derivatives written on credit-risky bond issues. In this case, the counterparty is assumed to be free of any default risk, but the underlying asset of the derivative contract, e.g., a corporate bond, is subject to default risk. Default risk changes the shape of the price distribution of a bond. By pricing options on credit-risky bonds as if the underlying bond were free of any risk of default, distributional characteristics of a defaultable bond are neglected. In particular, the low-probability, but high-loss areas of the price distribution of a credit-risky bond are ignored. Depending on the riskiness of the bond, the bias introduced by approximating the actual distribution with

[6] It is often argued that Treasury securities have a convenience yield because of higher liquidity and institutional reasons such as collateral and margin regulations and similar rules that make holding Treasuries more attractive. The real default-free yield may therefore be slightly higher than the Treasury yield. On the other hand, even Treasuries may not be entirely free of credit risk.

[7] Hsueh and Chandy (1989) reported a significant yield spread between insured and uninsured Aaa-rated securities.

[8] Although derivatives can be a wide range of instruments with different risk characteristics, according to Bhasin (1996), the majority of instruments were interest-rate and currency swaps, for investment-grade as well as for speculative-grade users.

the default-free distribution can be significant. A credit risk model can help correct such a bias.

1.1.3 Credit Derivatives

Very recently, derivatives were introduced the payoff of which depended on the credit risk of a particular firm or group of firms. These new instruments are generally called credit derivatives. Although credit derivatives have long been in existence in simpler forms such as loan and debt insurance, the rapid rise of interest and trading in credit derivatives has given credit risk models an important new area of application.

Table 1.2. Credit derivatives use of U.S. commercial banks

Notional value	1997 1Q	1997 2Q	1997 3Q	1997 4Q	1998 1Q	1998 2Q	1998 3Q	1998 4Q
Billion USD	19	26	39	55	91	129	162	144
%	0.09	0.11	0.16	0.22	0.35	0.46	0.50	0.44
Notional value	1999 1Q	1999 2Q	1999 3Q	1999 4Q	2000 1Q	2000 2Q	2000 3Q	2000 4Q
Billion USD	191	210	234	287	302	362	379	426
%	0.58	0.64	0.66	0.82	0.80	0.92	0.99	1.05

Absolute outstanding notional amounts in billion USD and percentage values relative to the total notional amount of U.S. banks' total outstanding derivatives positions. Figures are based on reports filed by all U.S. commercial banks having derivatives positions in their books. Data source: Office of the Comptroller of the Currency (1997-2000).

Table 1.2 illustrates the size and growth rate of the market of credit derivatives in the United States. The aggregate notional amount of credit derivatives held by U.S. commercial banks has grown from less than $20 billion in the first quarter of 1997 to as much as $426 billion in the fourth quarter of 2000. This impressive growth rate indicates the increasing popularity of these new derivative instruments. In relative terms, credit derivatives' share in derivatives use has been increasing steadily since the first quarter of 1997, when credit derivatives positions were first reported to the Office of the Comptroller of the Currency (OCC). Nevertheless, it should not be overlooked that credit derivatives still account for only a very small part of the derivatives market. Only in the fourth quarter of 2000 has the share of credit derivatives surpassed 1% of the total notional value of derivatives held by commercial banks. Moreover, only the largest banks tend to engage in credit derivative transactions.

Because the data collected by the OCC includes only credit derivative positions of U.S. commercial banks, the figures in Table 1.2 do not reflect actual market size. A survey of the London credit derivatives market undertaken by the British Bankers' Association (1996) estimates the client market share of commercial banks to be around 60%, the remainder taken up by securities firms, funds, corporates, insurance companies, and others. The survey also gives an estimate of the size of the London credit derivatives market. Based on a dealer poll, the total notional amount outstanding was estimated to be approximately $20 billion at the end of the third quarter of 1996. The same poll also showed that dealers were expecting continuing high growth rates. It can be expected that, since 1996, total market size has increased at a pace similar to the use of credit derivatives by commercial banks shown in Table 1.2.

Clearly, with credit derivatives markets becoming increasingly important both in absolute and relative terms, the need for valuation models also increases. However, another aspect of credit derivatives should not be overlooked. Credit derivatives are OTC-issued financial contracts that are subject to counterparty risk. With credit derivatives playing an increasingly important role for the risk management of financial institutions as shown in Table 1.2, quantifying and managing the counterparty risk of credit derivatives, just as any other derivatives positions, is critical.

1.2 Objectives

This monograph addresses four valuation problems that arise in the context of credit risk and derivative contracts. Namely,

- The valuation of *derivative securities which are subject to counterparty default risk.* The possibility that the counterparty to a derivative contract may not be able or willing to honor the contract tends to reduce the price of the derivative instrument. The price reduction relative to an identical derivative without counterparty default risk needs to be quantified. Generally, the simple method of applying the credit spread derived from the term structure of credit spreads of the counterparty to the derivative does not give the correct price.
- The valuation of default-free *options on risky bonds.* Bonds subject to credit risk have a different price distribution than debt free of credit risk. Specifically, there is a probability that a high loss will occur because the issuer defaults on the obligation. The risk of a loss exhibits itself in lower prices for risky debt. Using bond option pricing models which consider the lower forward price, but not the different distribution of a risky bond, may result in biased option prices.
- The valuation of *credit derivatives.* Credit derivatives are derivatives written on credit risk. In other words, credit risk itself is the underlying variable of the derivative instrument. Pricing such derivatives requires a model of credit risk behavior over time, as pricing stock options requires a model of stock price behavior.