Mathematics in Credit Risk Management: Some Issues in the CreditMetrics Model Application

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Abstract: By providing an introduction to the credit risk measurements, this paper focuses on CreditMetrics. It decomposes the credit measurement into 3 steps and introduces some solutions for calculation process. The intention of this paper is to facilitate further discussions on the credit risk measurement.

Keywords: credit risk; Value at Risk; CreditMetrix; transition mestrix

1 Literature Review on Credit Risk Management

Following Modigliani and Miller[1] (1958), economists have devoted much effort to analysis on financing decisions within qualitative models. Recent researches try to provide quantitative guidance ever since the pioneering works of Black and Scholes, Merton and Markowitz. Quantitative methods in finance are becoming more complex, causing high leverage and higher risk. Among those major risks is the credit risk.

Credit risk is mostly defined as the potential that a bank borrower or counterparty will fail to meet its obligations in accordance with agreed terms[2]. Credit risk does not happen frequently. Being associated with risk transfer, however, credit risk is one of the catastrophes in financial market.(e.g. the 2008 subprime crisis from the U.S. caused the global financial crisis)

The following techniques are the main tools to measure credit risk:

1.1 Classical Classification Models

1) the Expert Systems

The typical models include: 5C principles(character, capacity, capital/cash, collateral, cycle and condition); 5W(who, why, when, what, how); 5P(personal, purpose, payment, protection, perspective).

Those models are qualitative research, they are also called the Expert Systems.

2) the accounting-based credit scoring systems

After an instructive paper by Fisher[3] (1936) there mushroomed quantitative analysis on credit risk measuring. In 1968, Altman[4] set up Z-score model, and in 1977 he modified this model and presented ZETA credit risk model. Those models focus on financial ratios such as a).Working Capital/Total Assets, b).Retained Earnings /Total Assets, c).Earnings Before Interest and Taxes/Total Assets, d).Market Value of Equity/Book Value of Total Liabilities, e).Sales/Total Assets, providing a more sophisticated measurement on credit risk. They are then called the accounting-based credit scoring systems.

1.2 Modern Credit Risk Measuring

1) VaR

Associated with the globalisation of the financial market, the quantitative management on credit risk, such as MDA (Multivariate Discriminant Analysis), logistic regression and artificial neural networks, has evolved dramatically in 1990's. In order to compete with thinner margins on loans, many financial institutions have invested much on credit risk measurement. Most of the advanced quantitative measurements are based on Value at Risk by Linsmeier, Thomas and Neil Pearson (1996)[5]. Value-at-Risk (VaR) measures the worst expected loss under normal market conditions over a specific time interval at a given confidence level.

There are three basic approaches to compute Value at Risk, though each approach descends numerous variations.

a) The historical simulation method

This method catches the most recent market crashes, but is very time consuming.

b) The variance covariance method

This method is the quickest way to estimate VaR, but it relies heavily on the distribution of the market data.

c) The Monte Carlo simulation method

This is the most flexible and powerful method, also very complicated and slow.

The fatal flaw of VaR is its assumption. VaR assumes the normal distribution of asset price. Empirical study shows that credit returns generally profit from net interest earning with a small chance of losing a large amount of investment. This feature causes a skewed distribution, a long tail on the "losses" side and a relative short tail on the "gains" side as shown in Figure 1.

Another limit of VaR approach is that all measures of Value at Risk use historical data. History, unfortunately, is not always a good pred

Following the concept of VaR, financial institutions have developed more accurate approaches to estimate credit risk, among which are 5 important methodological

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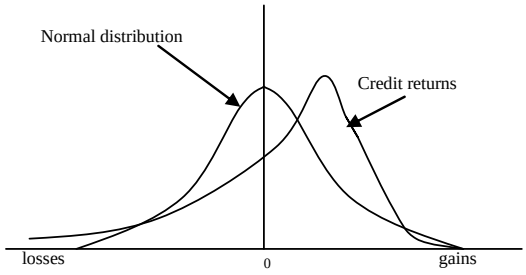

Figure 1. Comparation

approaches during 1990's:

time	company	Credit risk measurement tools
1994	J.P.Morgen	RiskMetrics
1997	J.P.Morgen	CreditMetrics[6]
1997	CSFP	CreditRisk +[7]
1997	KMV company	KMV model based on EDF[8]
1998	McKinsey & Company	CreditPortfolioView[9]

For those approaches, Crouchy, Galai and Mark[10] (2000) put comments as:

The JP Morgan CreditMetrics approach is based on a credit migration approach;

KMV uses a methodology based on Merton's[11] (1974) asset value model;

CreditRisk +, developed by Credit Suisse Financial Products (CSFP), uses a so called "actuarial" approach;

McKinsey uses an approach based on modeling default rates using macroeconomic variables.

More specifically,

1) RiskMetrics is used to evaluate the maximum lost could ever happen on a tradable financial assets (for example, stocks, bonds and other securities).

2) In 1997 J. P. Morgen developed CreditMetrics. CreditMetrics is a framework for measuring credit risk of portfolios of traditional credit investments (for example, loans, commitments to lend, financial letters of credit), fixed income products, and market-driven instruments subject to counterparty default (swaps, forwards, etc.).

3) The CreditRisk + model was developed by Credit Suisse Financial Products. It is based on insurance actuary, thus it is also called an actuarial model. The CreditRisk+ model is one of the financial industry's benchmark models in the area of credit risk management.

4) In order to translate the public information into probability of default, KMV corporation developed KMV model. The KMV model calculates the Expected Default Frequency(EDF) based on the firm's capital structure, the volatility of the assets returns and the current asset value.

The CreditPortfolio View model designed by Mckinsey & Company is a supplementary to CreditMetrics. It models an empirical relationship between obligor's default behavior and the macroeconomic indicators of the business cycle.

2 Some issues on CreditMetrics Model

By far, the dominant methodology has been CreditMetrics Model. The CreditMetrics model is based on VaR. Suppose that the market value of an asset is P, this value has a standard variation as σ, and its movement is subject to normal distribution. Figure 2 demonstrates that under the 99% confidential level, the value at risk is 2.58σ. i.e. there is 0.5% possibility for this asset to appreciate above P + 2.58σ; also there is 0.5% possibility for this asset depreciate below P - 2.58σ.

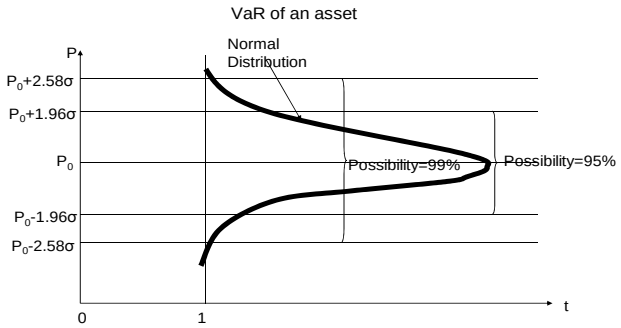

Figure 2. An example of an asset price distribution

Based on VaR, CreditMetrix measures credit risk in 3 steps: estimate migration, valuation and estimate volatility. It is essential to retrieve three matrixes in order to measure credit risk by CreditMetrics. They are transition matrix, default probability matrix and recovery rates for migration matrix.

The calculating process is in Figure 3.

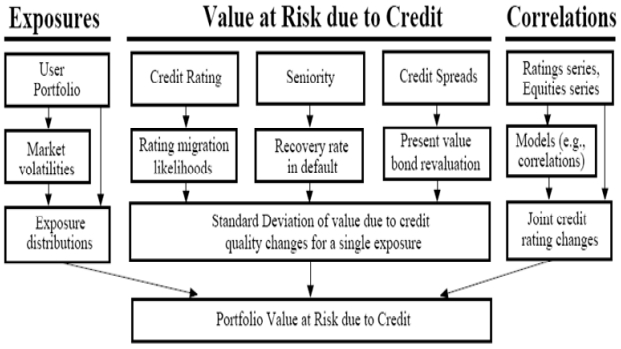

Figure 3. Process (Surce: J.P.Morgan, CreditMetricsTM Technical Document)

2.1 Migration

CreditMetrix model chooses a multivariate normal distri-

bution for asset values. To achieve more accurate calculation, it is necessary to estimate probability of changing rating level (credit rating migration). This estimation could be derived from corresponding transition matrix which represents moving probabilities from one rating level to all other rating levels for the period of one year.

The CreditMetrix Technical Document page 25 shows an 8 × 8 One-Year Transition Matrix provided by rating agencies Standard&Poor's. The problem is that the above probabilities are not always suitable for direct usage when analysis is about some specific markets or industry branches. In those cases, a procedure for synthetic transition matrix generation is needed. In order to adjust transition matrix to local financial and economic conditions, Antonov and Yanakieva[12] (2004) generated a new transition matrix using "best-fit" procedure by implementing a regression approach and an adjustment mechanism in the Software Package Risk Evaluator developed 2002 by Eurorisk Systems Ltd..

2.2 Valuation

Financial institutions, especially banks, generally employ two paradigms to define credit loss. The default mode, which is to evaluate the loss when a borrower defaults; the mark-to-market paradigm, which is to evaluate the credit loss due to the reduction in market value associated with a credit rating downgrade(migration).

1) Default

According to the study of Asarnow and Edwards[13] (1995), it is a skewed distribution of the recovery from bank loans. CreditMetrics, however, assumes a normal distribution for recovery rates in case of a default.

In the case of default, the likely residual value net of recoveries will depend on the seniority class of the debt. "CreditMetrics–Technical Document" by Gupton, Finger and Bhatia provides several historical studies of this dependence. Taking the possibility as an external data would also affect the accuracy of the model. There are diversified researches on how to model probability of default. For example, Altman and Kishore[14](1996) conditioned recovery rates on industry participations of the obligor in addition to seniority class.

2) Migration

CreditMetrics model is a typical mark-to-market stochastic simulation model. Because that CreditMetrics is conceived for bond portfolios and is heavily relying on market values, credit risk arises not only from the danger of issuer default, but also from a potential (market) value loss due to a downgrade in the credit rating of the debtor. An asset possible market Values at Risk can be calculated using forward zero curves which can be obtained via bootstrapping from spot rates for each rating category. Even with adjustment, this step is problematic because:

- The migration matrix data have to be approximated. During the approximation, precision is sacrificed.
- Generated from averaged historical data, migration matrixes do not take into account the current macroeconomic conditions.
- Debtors from different business should have been differentiated even they are of the same rating category.

2.3 Estimate the Volatility

CreditMetrics provides two paradigms to calculate the risk estimate. One is standard deviation, the other is percentile level. CreditMetrics assumes the multiple asset returns are multi-normally distributed. This is a strong assumption. For better simulation, it is suggested to adopt Copula function instead of binomial normal distribution to express the dependence structure between two default events.

3 Conclusions and Further Work

Among diversity of credit risk measurement approaches, CreditMetrics model is a milestone for the framework of credit risk measurement, however, some problematic issues arise due to its assumption. This paper outlines those issues and facilitates further research on this field.

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