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Bank Risk Management Based on Three Risk Measurement Models

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ABSTRACT
In order to explore the feasibility of the bank's management methods for market risk, credit risk and operational risk, the paper analysis specific management measures based on the measurement model of the above three risks, combined with the concept of internal control of the bank, and finally quotes the failure of Bahrain Bank The case illustrates the real impact of the above-mentioned risks on the banking system, thus knowing that bank risk management is inseparable from accurate measurement and efficient internal control systems. In addition, at the end of the paper, on the one hand, it mentioned the necessity and best practices of risk data and risk report selection, and on the other hand, it emphasized the important role of risk culture as a rational dimension in risk management. Therefore, the measurement and management of risks in the bank requires the participation of all staff and the overall situation, making decisions and applying them to all aspects related to the risk of the entire company, uniformly measuring and managing risks, focusing on major risks, optimizing the cost of risk measurement and management, and ensuring the company to achieve the goals.

Keywords: *Risk management, Risk measurement, Internal control, Bank.*

1. INTRODUCTION

With the ever-changing economic situation and the outbreak of financial crisis, financial institutions are paying more and more attention to risks. As representatives of financial institutions, banks also need to measure and manage various risks. Traditional risks are mainly divided into three major sectors: market risk, credit risk and operational risk. Regardless of the type of risk, it needs to be realized through the four steps: identification, analysis (measurement), evaluation and management [1]. Among these four steps, measurement and management are extremely important and worthy of deep excavation. In today's research, each management team has begun to gradually make transition from expected loss to unexpected loss, and from normal scenarios to tail extreme events. Taking banks as an example, many risk management teams have introduced Scenario Analysis, Stress Testing, Extreme Value Theorem, Stressed Var and other measurement and management tools to evaluate unexpected loss and extreme events to determine the corresponding amount of economic capital [2].

2. MARKET RISK

Market risk is a common risk in banks' daily business activities. It is mainly divided into four aspects: equity risk, interest rate risk, commodity risk and foreign exchange risk. Generally speaking, each type of market risk has its own driving risk factors, which often reflect the current market conditions. Therefore, the impact of this risk on assets and liabilities of the bank cannot be ignored.

2.1. Market Risk Measurement

In addition, the use of mathematical models to consider the significance of risk factors (take market risk for an example) is also a quantitative verification method for risk factors. Next, we will give an example of this method to illustrate this method.

2.1.1. Univariate or Multivariate Linear Regression

Assuming that the value of a bank's portfolio of assets that contain multiple positions is V_P, the portfolio contains three risk factors X_1, X_2, and X_3. The

sensitivity of the portfolio value to each risk factor is β_1, β_2 and β_3, and the intercept term is μ, the residual term is e. Then we can obtain the Equation (1):

$$v_p = \mu + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \mathrm{e} \quad (1)$$

Through the inventory of historical data in previous years, multiple sets of sample data of V_P, X_1, X_2 and X_3 can be obtained. The corresponding estimated value of β_1, β_2 and β_3 was calculated using OLS method. Finally, it is necessary to perform hypothesis testing on the regression coefficients to judge the significance of each risk factor.

2.1.1.1. Attachment: The Process of Hypothesis Testing

Single coefficient test (taking β_1 for an example, the confidence level is set to 1-α, the same below)

H_0: $\beta_1=0$ H_1: $\beta_1\neq 0$

$$\mathrm{t}_{statistic} = (\beta_1 - 0) / SE_{\beta_1} \quad (2)$$

Compare t-statistic calculated by Equation (2) with the critical value under the confidence level. If t-statistic>critical value, we reject H_0. If t-statistic<= critical value, we do not reject H_0.

2.1.1.2. Joint Coefficient Test

$$ESS = \sum_{i=1}^{n} (y_i - \bar{y})^2 \quad (3)$$

$$SSR = \sum_{i=1}^{n} (y_i - y_i)^2 \quad (4)$$

The Equation (3) is part of the denominator of the F test statistic, and the ESS refers to the Sum of Squared Regression. And the Equation (4) is part of the F test statistics molecule, and the SSR refers to Sum of Squared Errors.

K: degree of freedom

H_0: $\beta_1= \beta_2= \beta_3= 0$ H_1: At least one of them is not equal to 0

$$F_{statistic} = (ESS / K) / (SSR / (n - K - 1)) \quad (5)$$

Compare F-statistic calculated by Equation (5) with the critical value under the confidence level. If F-statistic>critical value, we reject H_0. If F-statistic<= critical value, we do not reject H_0.

Explanation for the effectiveness of regression: Since the OLS method is used when estimating the coefficients of the corresponding regression factors, it is necessary to check whether the initial assumptions of the method are met through back-testing. The two most important aspects are the verification of the homoscedasticity of the residuals and the detection of multicollinearity. This article focuses on the theoretical verification process of the two aspects.

2.1.1.3. Attachment: Description of White Inspection Process

Estimate the model and compute the residuals (e_i)

Regress the squared residuals on a constant of all explanatory variables, and the cross-product of all explanatory variables (including the product of each variable with itself).

For example, if the original model has three explanatory variables:

$$V_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + e_i \quad (6)$$

Then the first step is to compute e_i through OLS parameter estimations according to Equation (6).

We can get

$$e_i = V_i - (\alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3) \quad (7)$$

The second step is to regress squared residuals on a constant according to Equation (7)

$$e_i^2 = V_i^2 + \alpha^2 + \gamma_1 X_1^2 + \gamma_2 X_1 X_2 + \gamma_3 X_1 X_3 + \gamma_4 X_2^2 + \gamma_5 X_3^2 + \gamma_6 X_2 X_3 \quad (8)$$

We can make the following hypothesis:

H_0: $\gamma_1=\gamma_2=\gamma_3=\gamma_4=\gamma_5=\gamma_6=0$ H_1: At least one of them is not zero

We use nR^2 to be the statistic, and it has a $\chi^2_{k(k+3)/2}$ distribution. If p-value is more than significance level, we do not reject H_0 which means it is homoscedasticity. Otherwise, it is heteroscedasticity.

2.1.2. Multicollinearity Detection

After completing the t-test and F-test for the linear regression model, the results of the corresponding two sets of tests will be obtained. If the null hypothesis is not rejected in the t-hypothesis test of the regression coefficient, but the null hypothesis is rejected in the F test, and R2 is high (indicating that the regression coefficient is single and insignificant, the joint is significant, and the explanation is strong), it indicates that the regression model exists multicollinearity, one of the solutions to this problem is to delete redundant variables to enhance the accuracy of regression coefficient estimation.

2.1.3. Non-linear Model Processing

In real life, most positions held have a relatively non-linear relationship with risk factors. Therefore, for the measurement of risk exposure of this type of

positions, there are pricing models or Monte Carlo Simulations that can be used for calculation. For example, the BSM model measures the risk exposure of the corresponding option through changes in the value of the underlying asset, and bonds are often measured by the impact of interest rate fluctuations based on the pricing model. Monte Carlo Simulation is mainly for some non-linear and extremely complex products, such as MBS.

2.2. Market Risk Management Strategy

The common way to manage market risk is to hedge. Hedging refers to the operation of hedging existing positions through derivative products such as options and futures to reduce risks. However, when choosing hedging tools, hedging costs and hedging effects need to be taken into consideration, and the evaluation must be made from the perspective of the entire bank [3]. Imagine that an American import and export company will export a batch of goods in 3 months and get cash payment denominated in pounds sterling, but at the same time, it will also import a batch of raw materials from a British bank in 3 months and pay cash in pounds sterling. When facing such a situation, we first need to choose a suitable hedging tool. If options are used for hedging, then the option premium should be considered as the hedging cost, while the hedging cost of futures is zero without considering service fees. In terms of hedging effects, buying options locks in the maximum loss of the hedging instrument (option premium), whereas signing a futures contract has an unlimited upward and downward trend for the hedging instrument. These two tools have their own advantages and need to be selected according to the bank's status and risk appetite. Secondly, the bank's hedging strategy should be evaluated from the overall perspective. In this example, if the financial departments of import and export are considered separately, they will be hedged twice. However, when looking at the company as a whole, if the amount is the same, the import and export parts have formed a natural hedge, meaning no additional hedging tool is needed.

In addition, the core of managing market risk lies in matching the bank's risk appetite. Banks are broadly divided into two categories: commercial banks and investment banks. For commercial banks, because they are engaged in deposit and loan business, they need higher ratings and lower risk appetites. They prefer a more conservative strategy in the management of market risks. If they have relatively high-risk assets, they will use hedging tools to execute a full hedge. By contrast, investment banks are more flexible in the choice of market risk management. Since their main business is financing and investing, they bear relatively high risks. When using hedging tools, they will also try to hedge at a certain level, which means they will take certain risks to gain extra profits.

3. CREDIT RISK

Credit risk usually refers to the risk of loan default and increased probability of loan default. Generally speaking, banks mainly use internal rating method to consider the credit qualities of borrowers or institutions and the purpose of the loan, thus determine the corresponding lending rate based on the level of risk. Since banks' main profit activities are supported by obtaining low-interest deposits and issuing large amounts of loans to various enterprises or individuals, in order to earn interest rate spread from them. The measurement and management of such risks are very important in banks.

3.1. Credit Risk Measurement

In the bank's daily lending business, credit risk is a risk that has to be considered, because the recovery value of loans is closely related to the bank's profitability. Among the credit risk measurement models commonly used by banks, Hazard Rate measures the probability of default, the KMV model judges the default probability of loan companies, and the Vasicek model measures the unexpected loss of credit risk [4]. This article uses the KMV model as an example to introduce its mechanism for estimating the default probability of a loan company. In essence, the KMV model can be approximated by an option pricing model. According to the BSM model, we can know the Equation (9) (without considering dividends) [5].

$$C = S * N(d_1) - X * e^{-rt} * N(d_2) \tag{9}$$

Since the asset structure of a company is composed of assets = owner's equity + liabilities, a company only has enough funds to pay for liabilities when its assets are greater than its liabilities. Therefore, when calculating the company's credit risk, it can be approximated by the equation (10)

$$E = A * N(d_1) - L * e^{-rt} * N(d_2) \tag{10}$$

The $N(d_2)$ in Equation (10) represents the probability of not exercising in the option, represents the probability of the company not defaulting in the new formula, so the probability of default can be represented by $1\text{-}N(d_2)$.

3.2 Credit Risk Management Methods

Prepare capital. For expected loss, banks can usually add loss to loan pricing or set aside certain reserves to deal with it. As for unexpected loss, banks can only calculate the value through existing models and prepare a certain amount of capital to deal with it. Two concepts of economic capital and regulatory capital

needed to be explained here. According to the regulations of the Basel Committee, banks should retain at least the same amount as regulatory capital to deal with loss in extreme circumstances. In other words, the amount of economic capital reserved by banks should be greater than regulatory capital.

Control customer reputation. Before accepting any credit business, established procedures should be followed to check the creditworthiness of customers. Before any credit expansion, there should be procedures to obtain appropriate guarantees, such as requiring companies to make predictions on future cash flows and granting loans as a precondition to ensure that the credit setting limit is properly authorized and at a reasonable amount. For a company that cannot recover its debts in time and may have to use bank overdraft to repay its debts, banks should take corresponding measures such as raising loan interest rates or changing credit decisions to ensure the security of loans.

4. OPERATIONAL RISK

The definition of bank operational risk is that banks suffer loss due to internal system defects. In a broad sense, bank operational risk can be divided into four types: internal fraud of employees, imperfect system facilities, improper control process and external events. This part focuses on the management methods of operational risk from the perspective of internal control.

4.1 Operational Risk Measurement Method

For the operational risks faced by banks, three methods can be used to measure: basic indicator approach, standardized approach and advanced measurement approach. Since operational risks include many types of risks, the quantification of the risks is more complicated. This article focuses on advanced measurement approach (AMA) which is a more accurate measurement method. In order to use AMA, the enterprise must be able to estimate unexpected loss based on an analysis of relevant internal and external data. After that, the process can be carried out. Assuming that a bank has 8 business lines and each business line has 7 types of loss events on the line, so there are 56 types of loss events. The measurement of each loss event is divided into two dimensions: loss frequency distribution and loss severity distribution. The former is calculated by Poisson distribution, and the latter is characterized by lognormal distribution. The 112 loss distributions obtained are integrated into the overall distribution of the bank's operational risk loss through Monte Carlo simulation. In the Figure 1., we can know that by finding the one-year VAR value and expected loss with a confidence level of 99.9% and then subtracting the two value to get the bank’s unexpected loss, and multiplying it by the relevant capital multiplier, the bank can calculate the minimum capital that the bank needs to prepare.

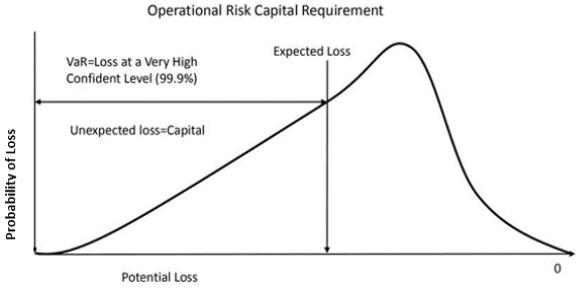

Figure 1 Operational Risk Capital Requirement

4.2 Operational Risk Management (Analysis from the Perspective of Internal Control)

Bank internal control is a series of activities or processes adopted by the management to help organizations avoid risks, ensure the quality of reports and comply with laws and regulations, and provide reasonable assurance for the realization of goals [6].

The main purposes of internal control include: (1) Promote the effective and efficient operation of all levels of the bank's activities and achieve the objectives of operation, finance and risk management, including the protection for assets from improper use as well as the confirmation and management of debts. (2) Ensure the quality of internal and external reports, so that timely, relevant and reliable information can flow within and outside the organization. (3) Ensure that the bank complies with applicable laws and regulations, and internal policies related to business operations [7].

In order to implement effective management of the several types of operational risks mentioned above, higher requirements are put forward on the bank's internal control system. Traditional internal control is not suitable for the internal environment of commercial banks and therefore the banks require a higher degree of risk identification and management measures. Specific strategies can be adopted by the management:

4.2.1 Human Resource Control

Attention should be paid to personnel selection and training. The quality of any system depends on the ability and integrity of the personnel performing the control. Especially use qualified personnel as internal auditors. In the absence of a risk management framework in the bank, auditors will have to rely on their own risk assessments and recommend an appropriate risk management framework. Therefore, the quality of auditors is critical to the effectiveness of risk identification.

4.2.2 Separation of Duties

In order to minimize the risk of errors and fraud, the relevant departments of the bank need to have a clear separation of duties and division of labour system, including the separation of authorized business, assets and responsibilities for recording transactions [8]. For example, the daily business of a bank should separate front-office transactions and back-office settlements. Internal audits should be managed independently of the auditable departments within the scope of their rights and directly submit reports to the board of directors or audit committee. Responsibilities in the payroll management department need to be separated. Certain well-planned frauds, such as hiring "shadow" employees, are designed because of colluding with two or more people. Clear separation of responsibilities can reduce the possibility of such king of fraud.

4.2.3 Clear Organizational Structure

Different businesses must be divided into appropriate departments and lower-level departments, and specialized personnel must be appointed to be responsible for the work of each department. The leisure activities between departments require the overall coordination of managers. Each department and subordinate departments should maintain clear lines of responsibility with the board of directors.

4.2.4 Authorization and Approval

All business activities must be authorized or approved by the person in charge, including: (1) Keep the bank's funds properly. Access to assets (directly or through files) should be restricted to authorized personnel. (2) Expenses must be approved before they can occur, and all expenditures as well as income must be properly accounted. In addition, there should be clear authorization restrictions, for example, the directors' remuneration should be determined by a remuneration committee composed of non-executive directors [9].

4.2.5 Supervise the Recording and Operation of Daily Transactions

Make sure everyone is aware that their work will be checked to reduce the risk of errors. For example, the supervision of budget tables, variance reports, and performance management.

5. CASE STUDY

As the most well-known example in the past, the case of the Bank of Barings is an extremely important experience and lesson in analysing risk management. This case originated from a trader named Lechrison who changed his trading strategy without authorization when his peers suffered loss and used virtual accounts to hide the loss. When he was finally discovered by his superiors, he had caused huge loss. The bank declared bankruptcy [10].

In this incident, there are many aspects worth exploring and reflecting. From the perspective of market risk, traders privately gave up the previous less risky arbitrage operations and chose very risky speculative operations (short straddle and long-long futures). The measurement of relevant risk was not accurate enough, making the risk exposure too large, which obviously exceeds the risk limitation assigned by the bank.

From the perspective of operational risks, banks have large loopholes in internal control and corporate governance, which are mainly divided into the following three aspects.

5.1 Ignore the Dual Identities of Traders

In this case, the trader is not only the person who conducts transactions at the front desk, but also the person who settles at the backstage, which greatly reduces the management's review of their trading behaviour. Therefore, when determining the personnel of the business line, the bank needs to clarify the responsibilities of each personnel and maximize the separation of power and responsibility on an independent basis, instead of multiple roles being played by one person.

5.2 Lack of Suspicion about Obtaining Huge Revenue Transactions

In this case, the speculative operation of traders made relatively large profits in the early stage, and the management did not question them rather than blindly praised them. Although huge profits are beneficial to the company, management should consider the risk capital allocated to its transactions and the risk of trading behaviour when evaluating it. For an arbitrage transaction, it is difficult to obtain huge profits, so management needs to have objective judgment and a spirit of questioning, instead of blindly focusing only on profit without considering the source.

5.3 Check the Lack of Update for the Relevant Trading System

In this case, the failure to close the virtual account in time was also a problem for the bank. When banks test transactions, they often use virtual accounts to simulate transactions, but the information in this account is used by the devil trader Nick Leeson to hide loss, making the management fail to detect risks and take action in time.

6. CONCLUSION

First of all, risk measurement and management should always consider the relevance of various risks, because when the economic situation is poor, the relevance of various risks will rise sharply and the effect of diversification will decrease. In order to cope with such an extreme situation, the bank needs to carry out stress testing and scenario analysis to supplement the original risk measurement indicators while measuring the loss normally. Generally speaking, the measurement of risk data needs to be summarized by the advanced automated risk information system with each department as the unit. In this process, risk data is an extremely important dimension. The management needs to maintain its independence and accuracy, while paying attention to the major risks that banks are currently facing. In addition, the update frequency of risk data under different economic situations also needs to be determined. After these data be presented to the management, the management needs to analyze and manage the overall risk exposure in a timely and accurate manner and compile risk reports accordingly. Risk reports also need to have a high degree of completeness and accuracy, as well as being reviewed by relevant auditing departments. When the risk report is completed, it needs to be uploaded to the board of directors for review. Therefore, risk measurement and management should be carried out from the entire bank level, rather than independently processing between various departments.

Compared with traditional risk measurement and management, in addition to the consideration of relevance, risk culture is also an extremely important factor for banks. If mechanism is the more rational part of risk measurement and management, risk culture is a relatively perceptual but indispensable for building block in the framework. A good risk culture requires regular education and guidance to employees within the bank and certain incentives to outstanding individuals, which encourage them to continue to persist and share experiences. Whether it is in a good economic situation or in a crisis, it is necessary to have a sense of risk and contribute to the development of the bank to the greatest extent.

AUTHORS' CONTRIBUTIONS

Jiadong Pu contributed to the quantitative measurement of market risk, credit risk and operational risk, as well as the management of the market risk. Junjie Cheng contributed to the analysis with the method of credit risk management and operational risk management.

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