The Default Probability of Bank Loans in Taiwan: An Empirical Investigation by the Markov Chain Model

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Abstract

This paper presents the Markov chain methodology to derive the default probability of bank loans. The model is more elaborate than that of the previous model, which was developed by Jarrow, Lando and Turnbull (1997). In our model, through relaxing the assumption of the Jarrow, Lando and Turnbull (1997), we estimate the risk premium only when the default state has not occurred in the stochastic process of non-homogeneous Markov. In our model, the default probability for each borrower and its risk premium will be recursively endogenous. We estimate default probabilities of thirty-one banks in Taiwan. On the other hand, we also compare default probabilities of banks whether participate in financial holding companies or not. The empirical result indicates that banks participated in financial holding companies do not have better credit risk management. Consequently, in facing the Basel II Accord, we hope that this paper will be helpful for Taiwan’s financial institutions.

Keywords: Credit risk; Default probability; Markov chain model

1. Introduction

Financial institutions, such as banks, credit unions, insurance companies, and mutual funds, perform the essential function of channeling funds from those with surplus funds (supplier of funds) to those with shortages of funds (users of funds). Although we might separately categorize or group financial institutions as life insurance companies, banks, finance companies, and so on, they face many common risks such as credit, market, and operational risks. In particular, financial institutions accept the credit risk on these loans in exchange for a fair return sufficient to cover the cost of funding (e.g., covering the costs of borrowing, or issuing deposits) to household savers and the credit risk involved in lending. Therefore, the measurement of the credit risk on individual loans is crucial if a financial institution manager want to price a loan correctly and set appropriate limits on the amount of credit extended to any one borrower or the loss exposure it accepts from any particular counterpart.

For the past three decades, Taiwan has enjoyed the kind of growth that many countries envied, especially when most East Asian and Southeast Asian countries has experienced economic downturns. In the early 1990s, the Taiwan’s government decided to liberalize the financial market. Subsequently, the financial market in Taiwan developed very rapidly. Many new banks were set up after government deregulated financial restrictions in Taiwan. Therefore, Taiwan’s banking industry has been evolving from an oligopoly industry to a completely competitive industry. Unfortunately, Taiwan’s banks have suffered serious problem, such as an increase in the credit risk. For example, there were tremendous problems with bank loans in Taiwan such as the Chung Shing Bank credit quality problems. In the worst case, these problems can cause a financial institution to become insolvent or result in such a significant drain on capital and net worth that they adversely affect its growth prospects and ability to compete with other domestic and international financial institutions. On the other hand, the Taiwan’s Finance Ministry also planned to consolidate weak financial institutions into large, stable banks through mergers or acquisitions by the new Finance Act. As a result, in Taiwan, the Merger Law of financial institutions and the Financial Holding Company Act were signed into law on November 2000 and June 2001, respectively. The later Act allowed the financial institutions to diversify their services such as banks, insurance companies and securities firms. There are some advantages such as informational advantages, economy of scope and operational effectively, may be applicable to banks that engage in those non-banking activities. But, we do not know whether the credit risk management of a bank

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participating in a financial holding company is better than others. Consequently, for the topic of this paper, we not only consider the default probability of banks loans, but also analyze the credit risk management of banks taking part in financial holding companies and others.

Over a decade ago, the Basel Committee on Banking Supervision (“the Committee”)\(^1\) issued the “International Convergence of Capital Standard” (or “Capital Accord of 1988”) in 1988, which established regulations regarding the amount of capital banks should hold against credit risk. Furthermore, the treatment of market risk was incorporated in the Committee’s 1996 amendment, i.e., “Amendment to the Capital Accord to Incorporate Market Risks”. Therefore, Basel I was drawn up and provides a standard approach for measuring credit and market risks to determine minimum capital requirements.

More than a decade has passed since the Committee introduced its 1988 Capital Accord and the businesses of banking, risk management practices, supervisory approach and financial markets have seen significant changes over this period. In June 1999, the Committee released a proposal to replace the 1988 Capital Accord with Basel II, a new Accord that has a more risk-sensitive framework. For the first time, the Committee addressed operational risk and emphasized the alignment of actual risk with the allocation of capital. The Committee sought comments from interested parties by 31 May 2001 and finalized the new accord by the fourth quarter of 2003. The final version of the new Accord was published in 2004 and will be implemented by the end of 2006.

The new framework focuses on improvements in the measurement of credit risk, which are more elaborate than those in the 1988 Capital Accord. Specifically, the new framework proposes the internal rating based (IRB) approach, by which banks will be allowed to use their internal estimates of borrowers creditworthiness, including probability of default (PD), loss given default (LGD), and exposure at default (EAD) to assess the credit risk of loans, subject to strict methodological and disclosure standards.

From the viewpoint of the Committee, it encourages banks to construct an internal rating approach to measuring credit risk endogenously. Generally, lending policies that ignore basic principles of analysis are those responsible for debacles as in the case of Chung Shing Bank. We should form the essential components of credit risk management structures as fundamental analysis, or return to basics and ongoing stress testing that help to predict the borrower’s ability to repay. The purpose of this paper is to provide an appropriate model, the Markov chain model, to measure the default probability of bank loans. We also want to ensure that credits are made in accordance with bank policy and to provide an independent judgment of asset quality that is unaffected by relationships with the borrower. A model that provides an effective credit risk review not only helps to detect borrowers in difficulty, but also helps present weak credits from being granted. This is due to the reason that credit officers are likely to be more diligent when they know their work will be subject to review. The Markov chain model in this paper represents the core of credit risk management, which has been applied to valuing the default probability of bonds in Jarrow, Lando and Turnbull (1997), but never applied to the bank loans. Since the method and model to assess the default probability of bonds and loans is similar, we extended the Markov chain model to bank loans.\(^2\) For Jarrow, Lando and Turnbull (1997), they assume that the risk premium is independent, including default state. However, it is not necessary to estimate the risk premium in default state. As a result, we relax the assumption of Jarrow, Lando and Turnbull (1997) and estimate risk premium only before going into default state. In particular, the default probability is endogenously determined for bank loans in this paper.

In this paper, we contribute to the literature in the following aspect. First, this paper serves as one of the first studies to adopt a Markov chain model estimating the default probability of bank loans\(^3\) Second, the model relaxes the assumption of Jarrow, Lando and Turnbull (1997) and estimate the risk premium of every borrower’s credit rating process before entering default state. Third, we also compare differences of the default probability as to whether banks take part in financial holding companies or not. The empirical results indicate that credit risk management is indifferent between banks participate in financial holding companies and others. The issue is never discussed in previous studies. On the whole, dealing with the

\(^1\) The Basel Committee on Banking Supervision is a committee of banking supervision authorities that was established by a group of banking regulators from leading industrialized nations, i.e., the central bank governors of the G-10 countries. Originally intended to apply only to internationally active banks based in G-10 nations, the Capital Accord quickly became the standard for regulatory bodies worldwide.

\(^2\) In essence, both loans and bonds are contracts that promise fixed payments in the future. Loans and bonds stand before the claims of a firm’s equity holders if the firm goes into default. In addition, the rates of loans are similar to bond yields, usually reflecting risk premiums that vary with the perceived quality of the borrowers and the collateral or security backing of the debt. As a result, we can use similar methods and models to assess the credit risk on a bank’s loans and bonds.

\(^3\) There have been extensive literatures on Markov chain model such as Hamilton (1989), Turner, Staritz and Nelson (1989), Engle and Hamilton (1990), Kaminsky and Peruga (1990), Li and Lin (2000), Chae and Lee (2005), Chang, Tu and Tsai (2005) and Kuo and Lu (2005). Chae and Lee (2005) propose a method for stationary probabilities of the embedded Markov chain of a class of GI/M/1 queueing systems. Chang, Tu and Tsai (2005) suggest a numerical method that relies on the Markov chain approximation to compute the optimal strategies. For Taiwan’s cases, Li and Lin (2000) adopt Markov chain model to examine the return variability for major East Asian market indices. Kuo and Lu (2005) investigate the stock behavior of financial holding companies via Markov chain model. Despite this method has been applied to estimate the default risk of bonds, it never applied to evaluate the default probability of bank loans in Taiwan.
new of Basel Capital Accord, we expect that the model proposed in this paper will be helpful for Taiwan’s financial institutions.

This paper is organized as follows. Section 1 provides motivation. In Section 2 reviews literature concerning models of credit risk. Section 3 presents the formal methodology of this paper, i.e., the Markov chain model. Section 4 describes the sample data used in this paper. Section 5 shows the main empirical results. In this section, we estimate default probability of bank loans and also compare credit risk management of banks whether participate in financial holding companies or not. Finally, Section 6 includes a discussion of our findings and a conclusion.

2. Literature Review

Many credit risk models have been developed over the last thirty years. These models can be divided into two main categories: the structural-form model and the reduced-form model. Historically, the first class of credit models adopted was the structural-form model, which was based on the original framework developed by Merton (1974), using the principles of option pricing in Black and Scholes (1973). Subsequently, many generations of structural-form models have tried to refine the original Merton framework by removing one or more of Merton’s assumptions as above. Shimko, Tejima and van Deventer (1993) have extended the Merton model to include stochastic interest rates. Jones, Mason and Rosenfeld (1984) attempted an empirical test of the Merton technology. However, Longstaff and Schwartz (1995) recall Jones, Mason and Rosenfeld (1984) have shown this kind of model produces credit spreads are lower than the actual credit spreads in the market. Therefore, Zhou (1997) proposes a framework with a jump diffusion process. He supposes that a firm can suddenly default because of a downward drop in its value. There are also many researches based on the Merton’s assumptions, such as Balck and Cox (1976), Brennan and Schwartz (1978), Vasicek (1984), Ogden (1987), Kim, Ramaswamy and Sundaresan (1989), and Titman and Torous (1989). This class of models imposes assumptions on the evolution of the value of a firm’s underlying assets. The liability structure of the firm in conjunction with the firm’s asset value determines the occurrence of bankruptcy and the payoffs of default. Despite these improvements to Merton’s original framework, these models still suffer from some significant drawbacks. First, they still require estimates for the parameters of the unobservable aspects of a firm’s asset value. Second, structural-form models cannot incorporate credit-rating changes, although most corporate bonds undergo credit downgrades before they actually default.

The attempt to overcome these shortcomings gave rise to reduced-form models, including Jarrow and Turnbull (1995), Jarrow, Lando and Turnbull (1997), Duffie and Singleton (1997) and Lando (1998) and others. Unlike structural-form models, reduced-form models are not conditioned on the value of the firm. They impose their assumptions directly on the prices of the firm’s traded liabilities, primarily its debt, and on the risk-free term structure of interest rates. Intuitively, the assumptions of the firm’s debt prices are related to the credit spread, which is decomposable into the probability of bankruptcy multiplied by the loss in the event of bankruptcy. In addition, reduced-form models can extract credit risks from actual market data and do not depend on asset volatility and leverage. Therefore, parameters that are related to the firm’s value need not be estimated in order to implement them.

The next step is the review of the literature of recovery. Recovery is the overall amount reimbursed at default, while the recovery rate is the fraction of the remaining quantity or security that is given back to the creditor. Most of the models substantially summarize this process through a straight formula for the recovery rate at default. The approach still allows for uncertain behavior if designed as a function of the assets value. Crouhy and Galai (1997), whose study stresses some very useful interpretations of Merton’s model, shown that the recovery implicit in Merton’s model is in fact stochastic. However, the firm’s value is nonobservable. On the other hand, Longstaff and Schwartz (1995) assume a constant recovered amount equal to a constant time the price of a risk-free zero-coupon bond. Briys and de Varenne (1997) propose a constant recovery rate. Consequently, we simulate the re-
cover rate from 0.1 to 0.9 as the exogenous variable in this paper.

3. Model Specification

Credit ratings of firms are published in a timely manner by rating agencies, such as Standard & Poor’s or Moody.7 They provide investors with invaluable information to assess firms’ abilities to meet their debt obligations. For many reasons, credit ratings change from time to time to point out firms’ with unpredictable credit risks. In recent years, it has become common to use a Markov chain model to describe the dynamics of firm’s credit ratings.

In general, rating agencies categorize corporate issues into several classes according to their perceived credit quality. Different quality ratings are reflected in the degree to which a corporate bond yield exceeds government’s yield, i.e., the risk-free rate. As a result, if sufficient issues are available, it may be possible to extract the required credit risk premiums and implied probability of default. If the borrower’s initial rating class in state 1 (i=1), then state 1 will transfer to state j (j=1,2,...,C+1) at next period. Therefore, the summation of first row in equation (1) is equal to 1, that is

$$\sum_{j=1}^{C+1} m_{ij} = 1, \forall i.$$

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$$m_{11} + m_{12} + \ldots + m_{1C} + m_{1,C+1} = 1.$$  

The submatrix $A$ defined on non-absorbing states $\hat{S} = \{1,2,\ldots,C\}$. The components of submatrix A denote the regime-switching of credit classes for the bank’s borrower; however, it excludes default state C+1. $D$ is the column vector with components $m_{i,C+1}$, which represent the transition probability of banks’ borrower for any credit class, i.e., i=1, 2, ... ,C, switch to default class, i.e., j=C+1. We assume for the sake of simplicity that bankruptcy (state C+1) is an absorbing state, so that $O_{(i\mid C)}$ is the zero column vector giving a transition probability from the default state at initial time until final time. Once the process enters the default state, it would never return to credit class state, so that $m_{C+1,C+1} = 1$. In such a case, we would say that default state C+1 is an absorbing state.

The risk premium is not time-invariant but is actually always time-variant. Because of this, for the pricing of the defaultable borrower, we need to consider the corresponding stochastic process $\tilde{x} = \{\tilde{x}_t, t = 0,1,2,\ldots\}$ of credit rating under the risk-neutral probability measure or equivalent martingale measure. An equivalent martingale measure is a probability measure in which today’s fair (or arbitrage-free) price of a derivative security is equal to the discount expected value of the future payoff of the derivative security. This is in contrast to the actual probability measure where more risky asset has a greater expected rate of return than less risky assets.

As a result, the matrix of equation (1) needs to be transformed into a risk-neutral transition matrix under the equivalent martingale measure where we let $\bar{M}$ denote such a matrix. Without further assumptions, it is well known that the transition matrix under the new measure need not be Markovian. However, we assume that it is an absorbing Markov chain, which may not be time-homogeneous and is called non-homogeneous Markov chain. That is, the transition matrix under the equivalent martingale measure is time-varying and influenced by risk premium. This matrix is written as

$$M = \begin{bmatrix}
m_{11} & m_{12} & \cdots & m_{1C} & m_{1,C+1} \\
m_{21} & m_{22} & \cdots & m_{2C} & m_{2,C+1} \\
\vdots & \vdots & \ddots & \vdots & \vdots \\
m_{C1} & m_{C2} & \cdots & m_{CC} & m_{C,C+1} \\
0 & 0 & \cdots & 0 & 1
\end{bmatrix}$$(1)

where $m_{ij} > 0, \forall i,j$. The row of equation (1) denotes initial rating class, i=1,2,...,C+1, and the column denotes ending rating class, j=1,2,...,C+1. On the other hand, each of the $m_{ij}$ probabilities represents the probability of getting from class i to class j in one period of time. Thus, the summation of each row is equal to 1, that is

$$\sum_{j=1}^{C+1} m_{ij} = 1, \forall i.$$  

7 The rating agencies are Taiwan rating and Taiwan Economic Journal in Taiwan.

\[ \tilde{M}(t,t+1) = \begin{bmatrix} \tilde{m}_{11}(t,t+1) & \ldots & \tilde{m}_{1C}(t,t+1) \\ \tilde{m}_{21}(t,t+1) & \ldots & \tilde{m}_{2C}(t,t+1) \\ \vdots & \ddots & \vdots \\ \tilde{m}_{C1}(t,t+1) & \ldots & \tilde{m}_{CC}(t,t+1) \end{bmatrix} \]

\[ \tilde{A}(t,t+1) = \begin{bmatrix} \tilde{A}_{11}(t,t+1) \\ \vdots \\ \tilde{A}_{C1}(t,t+1) \end{bmatrix}, \quad \tilde{D}(t,t+1) = \begin{bmatrix} \tilde{D}_{11}(t,t+1) \\ \vdots \\ \tilde{D}_{C1}(t,t+1) \end{bmatrix} \]

where \( \tilde{m}_{ij}(t,t+1) = \tilde{p}_{ij}(t,\tau = i), \quad i, j \in S \), \( \tilde{m}_{ij} \) and \( \tilde{p} \) represent the risk-neutral transition probability and risk-neutral probability measure. The conditions for equation (1) must be satisfied here, together with the equivalence condition that \( \tilde{m}_{ij}(t,t+1) > 0 \) if and only if \( m_{ij} > 0 \). For equation (2), the risk-neutral probability measure is equal to equation (1) multiplied by risk premium. That is, \( \tilde{m}_{ij}(t,t+1) = \lambda_{ij}(t) \cdot m_{ij}, \quad i, j \in S \), and \( \lambda_{ij} \) denotes risk premium that will be discussed later.

Secondly, to gauge the default probability of the bank’s borrower, we have to consider the zero risk rate, i.e., risk-free rate, in order to assess the value of the bank’s loans for every rating class with the risk-neutral probability measure. Let \( V_0(t,T) \) be the time-t price of a risk-free unit discount bond maturing at time T, and let \( V_i(t,T) \) be higher risk than \( V_0(t,T) \), i.e., risky counterpart for the rating class, i. That is, if \( i = 1 \), then \( V_1(t,T) \) denotes the time-t value of the loan maturing at time T, whose borrower in highest credit class or state 1. Similarly, \( V_2(t,T) \) denotes the time-t value of bank’s loan maturing at time T in second highest credit class or state 2. Thus, the index “i” represents the credit class of borrower that in state space as above.

Since a bank’s loan does not lose all interest and principal if the borrower defaults, we realistically consider that a bank will receive some partial repayment even if the borrower goes into bankruptcy. Let \( \delta \) be the proportions of the loan’s principle and interest, which is collectable on default, \( 0 < \delta \leq 1 \), where in general \( \delta \) will be referred to as the recovery rate. If there is no collateral or asset backing, then \( \delta = 0^8 \).

We assume the indicator function to be

\[ I_{(\tau)} = \begin{cases} 1, & \text{if } \tau > T \quad \text{(not default before time } T) \\ \delta, & \text{if } \tau \leq T \quad \text{(default before time } T) \end{cases} \]  

As shown by Jarrow, Lando and Turnbull (1997), under the assumptions that the Markov processes and the interest rate are independent under the equivalent martingale measure. The value of the loan is equal to

\[ V_i(t,T) = V_0(t,T) \left\{ \mathbb{E}_t \left[ \mathbb{E}_T [\tau > T] \right] + \delta \mathbb{E}_T [\tau > T] \right\} \]

\[ = V_0(t,T) \left\{ \mathbb{E}_T [\tau > T] \cdot \delta \mathbb{E}_T [\tau > T] \right\} \]

where \( \tilde{Q}_i^1(\tau > T) \) is the probability under the risk neutral probability measure that the loan with rating i will not be in default before time T. It is clear that

\[ \tilde{Q}_i^1(\tau > T) = \frac{V_i(t,T) - \delta V_0(t,T)}{(1 - \delta) V_0(t,T)} \]

which holds for time \( t \leq T \), including the current time, \( t = 0 \). Similarly, the probability that default occurs before time T as

\[ \tilde{Q}_i^j(\tau \leq T) = \frac{V_0(t,T) - V_i(t,T)}{(1 - \delta) V_0(t,T)} \]  

\[ \text{for } i = 1, \ldots, C \text{ and } T = 1, 2, \ldots \]

Consequently, risk premium plays an important role in gauging the credit risk of banks. As shown by Jarrow, Lando and Turnbull (1997), they assume that \( \tilde{m}_{ij}(t,t+1) = \lambda_{ij}(t) \cdot \tilde{m}_{ij} \) and \( \lambda_{ij}(t) = \lambda_{ij}(t) \), for \( j \neq i \), \( i, j = 1, 2, \ldots, C + 1 \). The procedure for risk premium in Jarrow, Lando and Turnbull (1997) is given by

\[ \lambda_{ij}(0) = \frac{V_0(0,1) - V_{ij}(0,1)}{(1 - \delta) V_0(0,1)} m_{ij(C+1)} \]

\[ \lambda_{ij}(t) = \sum_{k=1}^{C+1} \tilde{m}_{ij}^{-1}(0,t) \cdot \frac{V_0(0,t+1) - V_{ij}(0,t+1)}{(1 - \delta) V_0(0,t+1)} m_{ij(C+1)} \]

The rationale behind equation (7) and (8) are a zero or near-zero default probability would cause the risk premium to explode. That is, if \( m_{ij(C+1)} = 0 \), then equation (7) and (8) will be unidentified. Furthermore, the implication of equation (7) and (8) indicate that the credit rating process we have to estimate risk premium of every borrower, including the default state, \( C+1 \).

However, if the borrower defaults, then we should never estimate the default probability in the future. As a result, we assume that \( \tilde{m}_{ij}(t,t+1) = \lambda_{ij}(t) \cdot \tilde{m}_{ij} \), for \( j = 1, 2, \ldots, C, j \neq C+1 \) and \( \tilde{m}_{ij(C+1)}(t,t+1) = 1 - \lambda_{ij}(1 - m_{ij(C+1)}) \), for \( j = C+1 \). Then, we redefine the risk premium as

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8 The best borrowers do not need to post collateral because they are good credit risks, whereas higher risk borrowers need to post collateral. That is, posting collateral may be a signal of more rather than less credit risk. In this paper, we assume the recovery rate in term of exogenous variables from 0.1 to 0.9. The same assumption of the recovery rate also has been discussed in Lu and Kuo (2005).
\[ \ell_i(0) = \frac{1}{1 - m_{i,C+1}} V_i(0,1) - \delta V_i(0,1), \quad \text{for } i=1,2,\ldots,C \]
and \(t=0\)  
\[ \ell_i(t) = \frac{1}{1 - m_{i,C+1}} \sum_{j=1}^{C} \tilde{m}_{ij}^{-1}(0,t) V_j(0,t) - \delta V_i(0,t), \quad i=1,2,\ldots,C \text{ and } t=1,\ldots,T \]  
\[ \tilde{A}(0,t+1) = \tilde{A}(0,t) \tilde{A}(t,t+1) \]  
where \( \tilde{m}_{ij}^{-1}(0,t) \) are the components of the inverse matrix \( \tilde{A}^{-1}(0,t) \) and \( \tilde{A}(0,t) \) will be invertible. For equation (10), \( \tilde{A}(t,t+1) = \Lambda(t) \cdot A \) and \( \Lambda(t) \) is the \((C \times C)\) diagonal matrix with diagonal components being the risk premium adjusted to \( \ell_j(t), \quad j \in S \). The above framework assumes that the average, empirical transition matrix under actual probability measure as equation (1) remains constant over time. However, the risk-neutral transition probability matrix as equation (2), varies over time to accompany the changes in the risk premium by equation (9) and (10).

4. Data

The sample data come from two databases of the Taiwan Economic Journal (TEJ) includes the Taiwan Corporate Risk Index (TCRI) and long and short-term bank loans. The sample period is between 1997 and 2003. It should be noted that TCRI database of TEJ is a complete history of their short- and long-term rating assignments for Taiwan’s corporations. The definitions of the ratings categories of TCRI for long-term credit are similar to Standard & Poor’s and Moody. TEJ applies numerical definition from 1 to 9 and D for each rating classification. The categories are defined in terms of default risk and the likelihood of payment for each individual borrower. Obligations rated as the four highest (i.e., numbers from 1 to 4) are generally considered as being the lowest in terms of default risk, which is the investment grade for Standard & Poor’s and Moody. Obligations rated from number 5 to 6 are regarded as having significant speculative characteristics. Obligations rated from number 7 to 9 are the most risky and the rating class D denotes the default borrower. Since borrowers’ obligation rated numbers of banks are not consistent, we have to redefine rating classification. According to the aforementioned, we combine the four highest (i.e., number from 1 to 4) as a new rating class, which is denoted by “1”. Similarly, we combine number 5 to 6 and number 7 to 9 as two new rating classes, “2” and “3”, respectively. Therefore, we redefine a new numerical class from 1’ to 3’ and D. As a whole, the rating categories used by TEJ, Standard & Poor’s and Moody are quite similar, though differences of opinion can lead in some cases to different ratings for specific debt obligations.

Second, short- and long-term bank loan database of TEJ records all debts of corporations in Taiwan, including lender names, borrower names, rate of debt, and debt issuance dates, etc. From the viewpoint of banks, we can analyze the credit rating class of borrowers to investigate the credit risk of each bank.

Finally, we take the government bonds’ yield as a proxy for the risk-free rate. The yields of government bonds for various maturities are obtained as published by the Central Bank in Taiwan. The period of the government bond’s yield is from 1998 to 2003. Because the maturity of loans and government bonds are different, we have to adjust the yields of government bonds. Hence, we interpolate the yields of government bonds, whose maturity are closest, and take them as the risk-free rates. Additionally, we analyze default risk for at least a one-year horizon and therefore exclude observations whose loan-terms are short or whose data are incomplete. We also exclude the loans that have an overly low rate, since they are likely to have resulted from aggressive accounting politics and will bias the estimated results. Since the data without posting collateral is insufficient for gauging credit risk, we don’t consider these bank loans. Therefore, we analyze the credit risk of mid- and long-term loans, which are have posted collateral in this paper. In other words, the recovery rate is greater than zero and from 0.1 to 0.9.

5. Empirical Results

5.1 The Default Probability for Bank Loans

The non-performing loan (NPL)
 refers to loan accounts the principle and/or interest of which have become past due or those which exceeded the due date, and
 the NPL ratio is equal to NPL divided by the total loan portfolio. Table 1 and 2 shows the NPL ratio and amount of Taiwanese financial institutions, including domestic banks, local branches of foreign banks, credit cooperatives, and credit departments of farmer’s and fishermen’s associations from 1998 to 2003, respectively. From Table 1 and 2, we find that Taiwan’s NPL problem has increasingly become a serious question of the financial institutions recently.

\[ \text{To effectively reduce the NPL ratio, the Ministry of Finance (MOF) of Taiwan reduced the Gross Business Receipt Tax (GBRT) for banks from 5% to 2% in 1999 and is planning to further reduce it to zero. Banks are required to use the resulting tax savings to write off bad debts.} \]

These efforts appear to have improved the health of...
the system, indicating that the NPL ratio for banks in Taiwan had fallen to 5.7% by the end of November 2003.

However, many banks have suffered serious credit risk problem in Taiwan.

Although Taiwanese financial institutions include domestic banks, local branches of foreign banks, credit cooperatives, and credit department of farmer’s and fisherman’s associations, this paper focus on the credit risk of domestic banks, which not include Trust and Investment corporations. Therefore, we estimate the default probabilities of thirty-one banks in Taiwan. For the model as above, there are four steps to estimate default probability. First, we calculate transition probability matrix by equation (1) for thirty-one banks. We show the average transition probability matrix of thirty-one banks from 1998 to 2003 in Table 3.

Table 1. Non-performing Loan Ratios (%)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Domestic Banks</th>
<th>Local Branches of Foreign Banks</th>
<th>Credit Cooperatives</th>
<th>Credit departments of farmer’s and fisherman’s associations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>4.93</td>
<td>4.37</td>
<td>1.65</td>
<td>7.55</td>
<td>13.10</td>
</tr>
<tr>
<td>1999</td>
<td>5.67</td>
<td>4.88</td>
<td>3.20</td>
<td>10.54</td>
<td>16.03</td>
</tr>
<tr>
<td>2000</td>
<td>6.20</td>
<td>5.34</td>
<td>3.22</td>
<td>12.45</td>
<td>17.91</td>
</tr>
<tr>
<td>2001</td>
<td>8.16</td>
<td>7.48</td>
<td>3.53</td>
<td>11.66</td>
<td>19.37</td>
</tr>
<tr>
<td>2002</td>
<td>6.84</td>
<td>6.12</td>
<td>2.36</td>
<td>10.34</td>
<td>18.62</td>
</tr>
<tr>
<td>2003</td>
<td>5.00</td>
<td>4.33</td>
<td>1.51</td>
<td>6.91</td>
<td>15.57</td>
</tr>
</tbody>
</table>

Note-1. Source: Bureau of Monetary Affairs, Financial Supervisory Commission, Executive Yuan, R.O.C.
2. Domestic banks do not include Trust and Investment Corporations here.
3. The data are adopted the end, December, of this year.

Table 2. Non-performing Loan Amounts

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Domestic Banks</th>
<th>Local Branches of Foreign Banks</th>
<th>Credit Cooperatives</th>
<th>Credit Departments of Farmer’s and Fishermen’s Associations</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>7303</td>
<td>5478</td>
<td>91</td>
<td>520</td>
<td>1075</td>
<td>139</td>
</tr>
<tr>
<td>1999</td>
<td>8833</td>
<td>6602</td>
<td>172</td>
<td>615</td>
<td>1273</td>
<td>171</td>
</tr>
<tr>
<td>2000</td>
<td>10211</td>
<td>7735</td>
<td>186</td>
<td>662</td>
<td>1380</td>
<td>248</td>
</tr>
<tr>
<td>2001</td>
<td>13274</td>
<td>10870</td>
<td>185</td>
<td>497</td>
<td>1316</td>
<td>406</td>
</tr>
<tr>
<td>2002</td>
<td>10747</td>
<td>8644</td>
<td>113</td>
<td>406</td>
<td>1134</td>
<td>450</td>
</tr>
<tr>
<td>2003</td>
<td>8028</td>
<td>6306</td>
<td>70</td>
<td>262</td>
<td>995</td>
<td>395</td>
</tr>
</tbody>
</table>

Note-1. Source: Bureau of Monetary Affairs, Financial Supervisory Commission, Executive Yuan, R.O.C.
2. Unit is NT$100 million.
3. Domestic banks do not include Trust and Investment Corporations here.

Table 3. Average Transition Probability Matrix, 1998-2003

<table>
<thead>
<tr>
<th>Initial Rating</th>
<th>Rating at the end of year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1+</td>
</tr>
<tr>
<td>1+</td>
<td>0.707</td>
</tr>
<tr>
<td>2+</td>
<td>0.035</td>
</tr>
<tr>
<td>3+</td>
<td>0.004</td>
</tr>
</tbody>
</table>

10 Over the past few years, there has been a steady increase in non-performing loans (NPL). At the end of December in 2000, the NPL ratio stood at 6.2%. If we also include the rollover loans to households affected by the 1999 September 21 earthquake and those to traditional industries that have been operating normally but are experiencing financing difficulties, this ratio could increase by 1.5 to 2 percentage points.
Second, we estimate risk premium to transform transition probability matrix into risk-neutral transition probability matrix by equation (9) and (10). Thus, we list average risk premium in Table 4. Third, owing to risk-neutral probability measure, equation (2) is equal to equation (1) multiplied by the risk premium. Table 5 represents average risk-neutral probability matrix of thirty-one banks from 1998 to 2003 and recovery rate from 0.1 to 0.9.11

Finally, we estimate the default probability by equation (6) and show the empirical result in Table 6.

### Table 4. Average Risk Premium

<table>
<thead>
<tr>
<th>Rating</th>
<th>Maturity (Years)</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 *</td>
<td></td>
<td>0.955</td>
<td>0.967</td>
<td>0.977</td>
<td>0.975</td>
<td>0.968</td>
<td>0.935</td>
</tr>
<tr>
<td>2 *</td>
<td></td>
<td>0.951</td>
<td>0.918</td>
<td>0.944</td>
<td>0.944</td>
<td>0.871</td>
<td>0.773</td>
</tr>
<tr>
<td>3 *</td>
<td></td>
<td>0.941</td>
<td>0.983</td>
<td>0.994</td>
<td>0.987</td>
<td>0.974</td>
<td>0.978</td>
</tr>
</tbody>
</table>

### Table 5. Average Risk-Neutral Transition Probability Matrix

<table>
<thead>
<tr>
<th>Initial Rating</th>
<th>Rating at the End of Year</th>
<th>11</th>
<th>2 *</th>
<th>3 *</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td></td>
<td>0.679</td>
<td>0.189</td>
<td>0.022</td>
<td>0.110</td>
</tr>
<tr>
<td>2 *</td>
<td></td>
<td>0.031</td>
<td>0.667</td>
<td>0.164</td>
<td>0.138</td>
</tr>
<tr>
<td>3 *</td>
<td></td>
<td>0.004</td>
<td>0.064</td>
<td>0.801</td>
<td>0.131</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

### Table 6. The Default Probability of Domestic Banks in Taiwan (%)

<table>
<thead>
<tr>
<th>Bank of Taiwan</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Trust of China</td>
<td>35.989</td>
<td>52.378</td>
<td>30.210</td>
<td>32.131</td>
<td>30.270</td>
<td>30.250</td>
</tr>
<tr>
<td>Cosmos Bank, Taiwan</td>
<td>34.639</td>
<td>31.910</td>
<td>40.858</td>
<td>31.886</td>
<td>38.532</td>
<td>41.324</td>
</tr>
<tr>
<td>First Commercial Bank</td>
<td>5.870</td>
<td>6.209</td>
<td>5.490</td>
<td>5.797</td>
<td>5.146</td>
<td>16.994</td>
</tr>
<tr>
<td>Land Bank of Taiwan</td>
<td>7.303</td>
<td>4.767</td>
<td>5.773</td>
<td>6.903</td>
<td>11.223</td>
<td>16.394</td>
</tr>
<tr>
<td>Taiwan Cooperative Bank</td>
<td>5.513</td>
<td>4.153</td>
<td>5.081</td>
<td>4.748</td>
<td>8.006</td>
<td>12.218</td>
</tr>
<tr>
<td>Taichung International Bank</td>
<td>2.983</td>
<td>2.750</td>
<td>7.869</td>
<td>2.361</td>
<td>6.241</td>
<td>2.538</td>
</tr>
<tr>
<td>The Farmers Bank of China</td>
<td>7.532</td>
<td>5.940</td>
<td>5.911</td>
<td>7.682</td>
<td>12.223</td>
<td>12.496</td>
</tr>
<tr>
<td>The Shanghai Commercial and Saving Bank</td>
<td>5.852</td>
<td>4.001</td>
<td>15.294</td>
<td>3.268</td>
<td>13.817</td>
<td>17.181</td>
</tr>
</tbody>
</table>

Note: This table was summarized by the author.

11 According to equation (9) and (10), we find that the recovery rate plays an important role for estimating risk-neutral probability matrix and risk premium. Hence, Table 4 and 5 are average risk premium and risk-neutral transition probability matrix for recovery rate from 0.1 to 0.9.
Table 6 shows the estimated results of the default probability from 1998 to 2003\(^{12}\) including thirty-one banks in Taiwan. Since the recovery rate is given exogenous in this paper, we average the default probability of each simulated recovery rate from 0.1 to 0.9 in Table 6. Figure 1 reports the average default probability of domestic banks in Taiwan. In particular, many banks’ default probabilities in 1998 are higher than others years because of the Asian financial crisis which led to higher levels of problem loans. According to the above findings, the model in this paper for estimating default probability is accurate and can reflect the quality of Taiwanese banks. The weak banks should take care of the potential credit risk for their lending policies and review their internal machines for controlling risk to reduce their credit risk in the future.

Comparing Table 1 and Table 6, we find that there are differences between the default probability and the NPL ratio. Since the NPL refers to loan accounts the principle and interest of which have become past due or those which exceeded the due date. The NPL ratio is equal to NPL divided by the total loan. As a result, the NPL ratio and default probability are concepts of ex-ante and ex-post, respectively. On the other hand, some banks have insufficient data to analyze and we have excluded these banks. Consequently, the NPL ratio and default probability are not consistent.

5.2 The Default Probability of Banks belonging to Financial and Non-financial Holding Companies

The Taiwanese Government drafted the Financial Holding Company Law to allow financial holding companies to be established and own such subsidiaries as banks, insurance companies, and securities firms from the year 2001. Each financial holding company is likely to have two or more wholly owned subsidiaries involved in banks, insurance companies, securities firms, and other related activities. Tax and non-tax incentives will be offered to encourage local financial firms to set up financial holding companies. Within a financial group, a certain amount of cross-selling of financial products may be allowed if proper precautions are established\(^{13}\). As of December 31, 2003, there were fourteen financial holding companies in Taiwan including Fubon, Hua Nan, Cina Development, Cathay, Esun, Mega, Fuhwa, Taishin, Shin Kong, Waterland, Sinopac, Chinatrust, and the Jihsun financial holding company. A complete investigation of Taiwan’s financial holding companies was carried out by Kuo and Lu (2005). They presented a formal methodology using the two-state Markov regime switching approach to allow for the uncertainty event-date of financial holding companies’ stock behavior. They suggested that there are diversification benefits accruing from the existence of financial holding companies in Taiwan. However, they do not suggest that whether banks taking part in a financial holding company have better credit risk management.

First, we divided banks into two groups, including twelve banks belonging to financial holding companies

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\(^{12}\) Although the sample period runs from 1997 to 2003, the Markov chain model has to use the data from last year in 1997 and the empirical result begin in 1998.

\(^{13}\) This bill represents a major reform of our financial system and is consistent with international trends, especially following the enactment of the US Financial Modernization Act, i.e., Gramm-Leach-Bliley Act (“GLB Act”).
Table 7. The Default Probability of Banks Belonging to Financial and Non-financial Holding Companies

<table>
<thead>
<tr>
<th>Year</th>
<th>Banks belonging to Financial Holding Companies</th>
<th>Banks belonging to Non-financial Holding Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>0.064</td>
<td>0.159</td>
</tr>
<tr>
<td>2002</td>
<td>0.137</td>
<td>0.161</td>
</tr>
<tr>
<td>2003</td>
<td>0.186</td>
<td>0.184</td>
</tr>
</tbody>
</table>

Note: The number in parentheses denotes the amount of banks have participated in financial holding companies. In 2001, there are two banks participate in financial holding companies, including Fubon Commercial Bank and Hua Nan Commercial Bank. In 2002, there are nine banks participate in financial holding companies, including E. Sun Commercial Bank, Fubon Commercial Bank, Jih Sun International Bank, Taipei Bank, Chiao Tung Bank, The International Commercial Bank of China, Taishin International Bank, Chinatrust Commercial Bank and United World Chinese Bank. In 2003, there is only one bank, First Commercial Bank, participate in financial holding company. Therefore, the amounts of banks have participated in financial holding companies from 2001 to 2003 are two, eleven and twelve, respectively.

Figure 2. The Default Probability of Banks belonging to Financial and Non-financial Holding Companies and others belonging to non-financial companies. Then, we consider the differences in the default risk between banks belonging to financial and non-financial holding companies, as reported in Table 7. According to Table 7, we find that default probabilities for banks belonging to financial holding companies are lower than others in 2001 and 2002. However, the phenomenon is reversed in 2003. Although banks that do not take part in financial holding companies may fall behind others for controlling credit risk in the early stages, they will later catch up to others belonging to financial holding companies. Consequently, we recommend that credit risk management is not a significant advantage for banks to participate in financial holding companies.

6. Conclusions

Recently, many new banks were set up after the government deregulated financial restrictions in Taiwan. Taiwanese banking environment was transformed from an oligopoly industry to a completely competitive industry. Although the banking environment improved in the 1990s, banks faced more and more credit risks. This is an important consideration for most financial transactions. In particular, credit risk, or the probability of default, has always been a major topic of concern for banks and other financial institutions. What people remember most about the banking environment of the 1990s was deterioration in credit quality of the financial institutions in Taiwan. This led to deteriorated lending decisions and many financial institutions having no credit measuring function. Therefore, bank regulators had to develop an effective credit review process which was used to measure the credit risk for their loans.

This paper focused on providing an appropriate model, the Markov chain model, to measure the default probability for bank loans in Taiwan. We analyzed the default probability of banks in Taiwan as to whether there were appropriate checks and balances and whether credit was given appropriately. We also provide an effective method to screen credit quality and to focus credit analysis where
it can add the most value. On the other hand, the Financial Holding Company Act was signed into law on June 2001 in Taiwan. The Act permit banks, insurance companies, securities firms, and other financial institutions to affiliate under common ownership and offer their customers a complete range of financial services. Affiliation offers some advantages for financial institutions. As a result, we compare the differences in the default probability of banks belonging to financial and non-financial holding companies. The empirical result indicates that banks have different default probability whether participate in financial holding companies or not.

In addition, in using the model in this paper, it is important to note that the thoroughness of our analysis will depend largely on the borrower’s credit rating class and the risk-free term structure of the interest rate, which are forward looking and reflect the current position. They are a timely and reliable measure of credit quality. Accurate and timely information from the borrower’s credit rating data provides a continuous credit monitoring process by the Markov chain model in this paper. On the whole, we hope that the Markov chain model helps banks estimate their credit risk more carefully and is also an effective tool for any financial institutions’ credit review process. The model is not only an effective early warning protection against deteriorating credit quality but also a help in focusing the efforts of the traditional credit process. Consequently, we expect that the model proposed will be helpful for Taiwan’s financial institutions in facing the Basel Capital Accord.

Acknowledgments

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References


**Appendix**

Listed below are the sample banks which belong to financial holding companies in Taiwan.

(1) First Commercial Bank belongs to the First financial holding company.

(2) Fubon Commercial Bank and Taipei Bank belong to the Fubon financial holding company.

(3) United World Chinese Commercial Bank belong to the Cathay financial holding company.

(4) Hua Nan Commercial Bank belongs to the Hua Nan financial holding company.

(5) Jih Sun International Bank belongs to the Jih Sun financial holding company.

(6) E. Sun Commercial Bank belongs to the Esun financial holding company.

(7) Chiao Tung Bank and The International Commercial Bank of China belong to the Mega financial holding company.

(8) Fuhwa Commercial Bank belongs to the Fuhwa financial holding company.

(9) Taishin International Bank belongs to the Taishin financial holding company.

(10) Chinatrust Commercial Bank belongs to the China-trust financial holding company.