Analysis and Prediction of the Causes of Non-Performing Loans: A Case Study of China

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Abstract. This paper conducts a case study of China to analyze and predict the causes of non-performing loans. Firstly, by defining and classifying non-performing loans, the paper analyzes the causes of non-performing loans, including the macroeconomic environment, internal bank management, and market competition. Secondly, using the time series analysis method, the paper predicts the non-performing loan ratio of China from 2020 to 2021. The results show that the time series regression model can predict the non-performing loan ratio well. Finally, based on the causes of non-performing loans and the prediction results, the paper proposes corresponding suggestions, including strengthening macroeconomic regulation and improving internal bank management. The paper also analyzes the shortcomings and limitations of the prediction method and provides prospects for the future. This paper has particular reference value for the causes and prediction of non-performing loans and can provide some reference for relevant departments and financial institutions.

Keywords: non-performing loan; market factors; time series regression model; prediction.

1. Introduction

Non-performing loans are when banks or other financial institutions fail to repay or cannot repay loans on time. Non-performing loans will severely impact financial institutions and the entire economic system. Therefore, it is essential to predict and respond to them. Predicting non-performing loans can help financial institutions identify risks promptly and take corresponding measures for risk management. From the public policy perspective, this analysis is also crucial because banks bearing risks will affect the economy's fragility, fluctuations in the business cycle, and economic growth. It is important to consider risk factors and market conditions when making loan investments and to understand how these factors change over time when making loan decisions [1]. The background and significance of studying the causes, prediction, and response measures of non-performing loans are to improve the ability of financial institutions to identify and manage risks, reduce the occurrence of non-performing loans, and maintain the stability of the financial market.

Non-performing loans cannot be repaid or defaulted by banks or other financial institutions. They usually refer to loans not repaid according to the contract for a certain period. These loans may be caused by insufficient repayment ability of borrowers, changes in the economic environment, policy adjustments, and other reasons. Non-performing loans will significantly impact the asset quality and solvency of banks or financial institutions. They may lead to losses and increased risks for banks or financial institutions.

Before 1998, China classified loans into four categories: normal, overdue, idle, and bad debt, with the latter three categories referred to as non-performing loans, based primarily on the loan term, by the regulations of the Financial and Insurance Enterprise Financial System. This loan classification method, mainly based on the term, is simple and easy to implement. However, it has many limitations, especially in identifying credit asset risks, and it is no longer suitable for the development needs of credit management. According to the degree of risk, loans are classified into five categories: normal, watch, substandard, doubtful, and loss, and banks are required to implement the five-level classification method gradually.

During the late 1980s and early 1990s, numerous nations embarked on financial liberalization policies, leading to increased competition among banks and a relaxation of loan scrutiny. As a

consequence, the problem of non-performing loans witnessed a significant rise [9]. In response to the global financial crisis in 2008, many countries implemented measures to mitigate the non-performing loan issue, such as reinforcing supervision and establishing asset management firms. However, the uncertain global economic climate and the adverse effects of the COVID-19 pandemic have caused economic growth to stagnate in certain countries, once again bringing attention to the problem of non-performing loans. The increase in bank competition has led to an increase in credit risk, namely the relaxation of bank borrowing standards and screening procedures, leading to a decline in the quality of bank lending activities, namely an increase in non-performing loan ratios. Before the financial crisis in the first decade of this century, the quality of loan portfolios was relatively stable. Afterward, the quality of loan portfolios deteriorated sharply, leading to an increase in non-performing loan levels. Therefore, non-performing loans are almost equally apparent in developed and emerging countries [2]. In the future, the level of non-performing loans will only show extreme growth, which will negatively impact global macroeconomic stability. China's problem of non-performing loans gradually emerged after financial reform, especially in the late 1990s and early 2000s, when the ratio of loans with poor performance of China's banking industry soared. The Chinese government has implemented various measures to tackle the issue of non-performing loans, including creating asset management firms and bolstering supervision. As a result, the non-performing loan problem has been partially alleviated. The chart below illustrates the non-performing loan balance and ratio over the last decade.

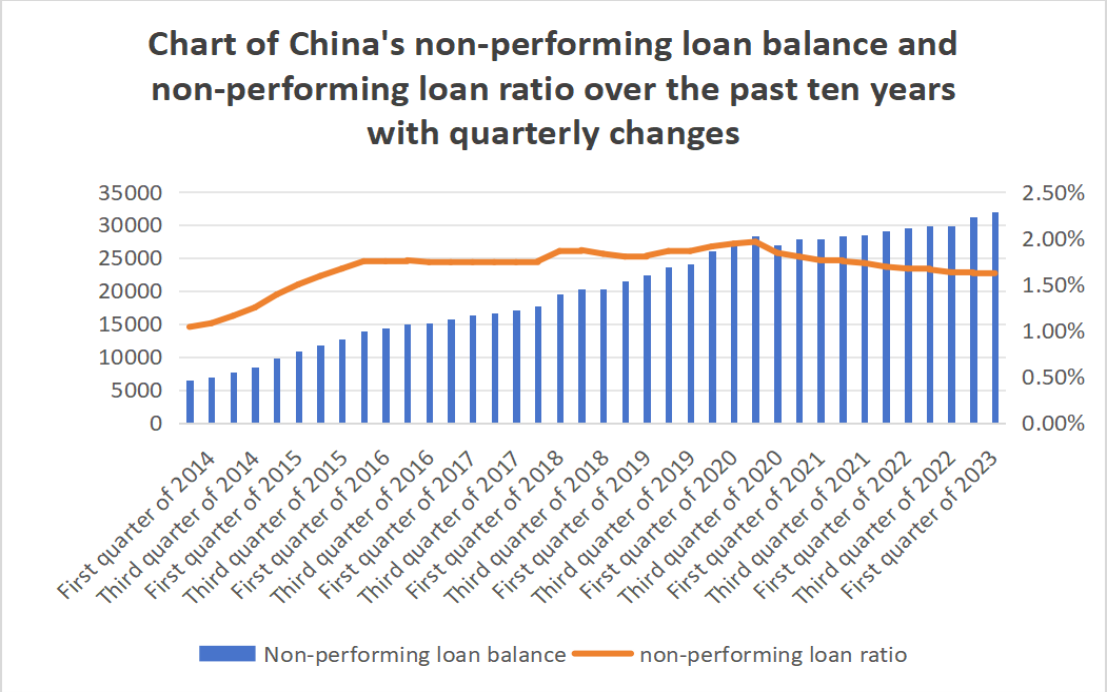


Figure 1. Chart of China's non-performing loan balance and non-performing loan ratio over the past ten years with quarterly changes

According to the table, China's non-performing loan ratio has witnessed a continuous rise from 2014 to 2023. Nevertheless, there was a slight improvement in the ratio of non-performing loans in 2019 following the China Banking and Insurance Regulatory Commission's emphasis on enhanced management of such loans [8]. The period between 2014 and 2018 experienced a slowdown in China's economic growth, accompanied by increased downward pressure on the economy. Consequently, state-owned commercial banks faced significant challenges, leading to a notable deterioration in credit quality and heightened operational risks.

From the information perspective, the formation of non-performing loans can also be explained [6,10]. The nature of bank operations can be understood as "information production" to some extent. The need for this information in the economy comes from the widely existing phenomenon of "information asymmetry" in credit transactions, which means that the information about the quality

of the transaction object held by both buyers and sellers is unequal. Information asymmetry can lead to adverse selection and moral hazard. Economist Akerloff's research on the "lemon problem" in the second-hand car market caused by information asymmetry between buyers and sellers pioneered the study of adverse selection problems. In the second-hand car market, owners of high-quality old cars will gradually withdraw from the transaction, leaving only low-quality old car transactions in the market, ultimately leading to the "market closure phenomenon" where transactions do not occur at all. Moral hazard refers to the risks that various hidden actions after the transaction may bring to the transaction counterpart, and it occurs after the parties sign the contract.

This paper first introduces the characteristics of non-performing loans and then conducts a qualitative analysis of the macroeconomic, internal, and external economic factors that affect non-performing loans. The empirical analysis section will use various macroeconomic factors to predict the ratio of loans with poor performance, warn of possible non-performing loans, optimize credit risk management, and improve the accuracy and efficiency of loan approval. Ultimately, this paper aims to reduce the impact of non-performing loans on banks and the economy.

2. Analysis of Factors Affecting Non-Performing Loans

2.1. Macro-economic factors

2.1.1 Gross Domestic Product Growth Rate

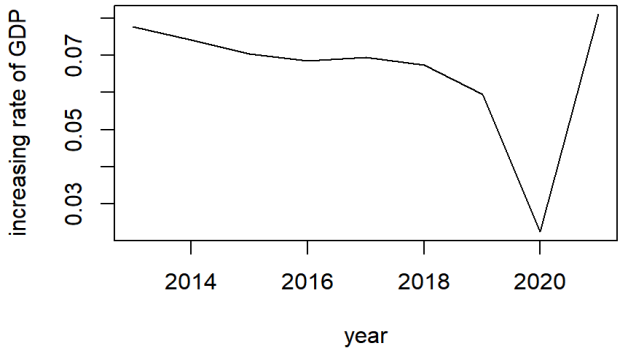


Figure 2. GDP growth rate over years

The information shows that China's economic growth rate has been falling annually since 2013, from 0.0776 to 0.0244 in 2020, and that it will likely increase to 0.0811 in 2021. Non-performing loans have been impacted in a specific way by the slowdown in economic growth. The risk of default and bad loans rises as a result of the slowdown in economic growth since it lowers company profitability and, in turn, their capacity to pay back loans. Additionally, economic downturns raise the risk of bad loans for banks, which will have some impact on both their profitability and asset quality.

2.1.2 The Consumer Price Index

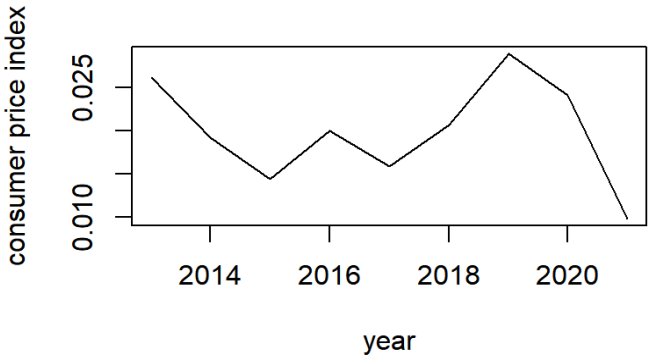


Figure 3. CPI growth rate over years

As China's economy reached a certain level of development, it entered a new phase of growth. In 2014, President Xi Jinping recognized this strategic shift, leading to a slowdown in GDP growth. However, CPI has become a more accurate indicator of the nation's economic state, as China shifts towards an internally-driven economy. From 2015 to 2021, the table demonstrates a consistent increase in China's inflation rate, despite the country's overall slowing economic growth.

2.1.3 Growth rate of broad money supply

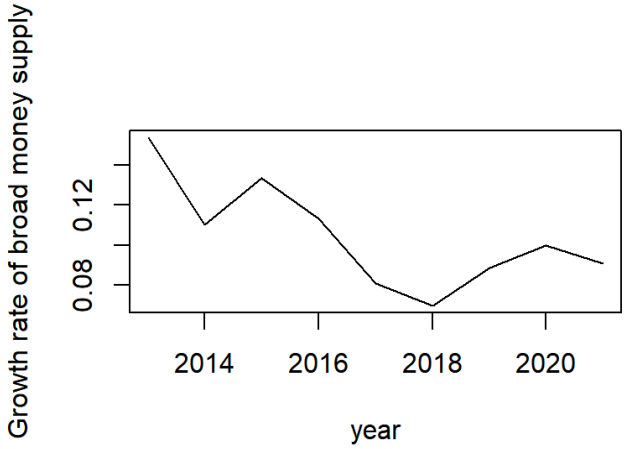


Figure 4. The growth rate of broad money quantity varies with the year

China's broad money supply growth rate has declined in recent years, with the People's Bank of China taking measures to control it in response to challenges such as inflation and financial risks. These measures include adjusting monetary policy and strengthening financial regulation. However, an increase in the broad money supply may lead to an increase in the non-performing loan ratio, as it can cause inflation and reduce repayment ability. When the economy is in a downturn, loose monetary policies may be adopted to support economic development, but this may also lead to an increase in the ratio of defaulted loans.

2.2. Financial Market Factors

2.2.1 Interest Rate Levels (Taking the five-year and above loan interest rates of Industrial and Commercial Bank of China as an example)

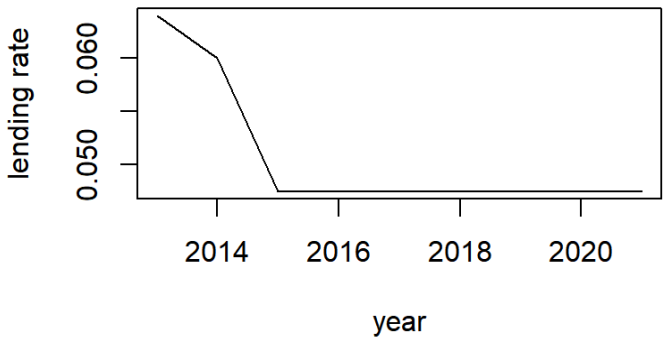


Figure 5. Five-year loan rate growth over years

The reason for choosing the interest rates of loans with a maturity of five years or more is that it is more in line with the borrowing behavior of individuals and companies. At the same time, due to the longer repayment period, there is greater repayment pressure, which is more likely to lead to the formation of non-performing loans, and thus there is a greater correlation with the non-performing loan ratio. From the chart, it can be seen that the interest rate for loans with a maturity of five years or more at the Industrial and Commercial Bank of China decreased from 6.4% in 2013 to 4.75% in 2015 and has remained at this level since then.

2.2.2 stock market volatility and foreign exchange market fluctuations

Stock market fluctuations can impact banks' non-performing loan ratio and asset quality, negatively affecting the economy. Fluctuations can weaken the repayment ability of enterprises and individuals due to decreased profitability and personal wealth, leading to a rise in the non-performing loan ratio. Additionally, stock market fluctuations may affect banks' asset quality, decreasing investment returns and potentially leading to asset devaluation.

Exchange rate fluctuations can contribute to non-performing loans. For example, the depreciation of the US dollar in 2018 increased the overseas debt burden for some enterprises, resulting in difficulty repaying debts on time. Similarly, the appreciation of the euro in 2019 affected the profitability and cash flow of German automakers, making it difficult to repay debts on time. These fluctuations can increase costs and affect cash flow, leading to a rise in the ratio of loans with poor performance.

2.3. Internal Factors of Banks

2.3.1 Risk Management Capability (Credit Risk)

Credit risk is the possibility of a creditor suffering losses due to a borrower's violations or credit rating downgrade caused by information asymmetry. Non-performing loans, a major risk for financial institutions, result from borrowers' poor financial conditions, deteriorating operating conditions, macroeconomic instability, or market fluctuations. This can negatively impact asset quality, profitability, and credit ratings. Commercial banks' main risk control mechanism is the three-loan investigation system, which includes pre-loan investigation, mid-loan review, and post-loan examination. However, state-owned commercial banks need to improve in implementing this system, often only superficially executing it.

Regarding the pre-loan investigation, banks need more understanding of borrowers or borrowing enterprises and have yet to conduct in-depth investigations into the value and ownership of collateral. This may result in loans being granted to higher-risk borrowers, resulting in non-performing loans.

Regarding mid-loan review, state-owned commercial banks often prefer to expand loan size and overlook the importance of mid-loan review. This may lead to some deeply hidden enterprises or borrowers obtaining loans, even though they do not have the relevant repayment ability. In terms of post-loan examination, banks have not continuously supervised borrowers or borrowing units nor established a sensitive and accurate set of quantitative indicators to avoid non-performing loans caused by external factors.

2.3.2 Loan approval process and loan management system (moral and compliance risks)

Loan transactions are contractual agreements between lenders and borrowers. Because a balance must be sought between profitability and safety, the loan process generally includes basic steps such as loan application, loan investigation, loan approval, loan contract signing and loan disbursement, loan inspection, and loan recovery. Loan approval is the credit decision-making process of the bank, and the key is to set reasonable approval authority. Usually, banks generally implement the system of separating credit review from approval, and hierarchical approval. The so-called separation of credit review and approval aims to form a mechanism of division of labor and cooperation, and mutual constraints between the credit expansion department and the risk management department. The risk management department is responsible for reviewing loan projects and approving loans within its authority, while large loans and risky difficult loans require collective discussion and final opinions from the loan review committee. The so-called hierarchical approval refers to the head office of the bank determining the approval authority of its loan amount based on the business volume, management level, and credit asset quality of each branch institution. Loans exceeding the approval authority should be reported to the higher-level bank for approval. Therefore, it can be seen that the loan approval process is crucial for banks and financial institutions. If the loan approval process is not strict or there is improper interest transmission or misconduct within the bank, it may lead to the issuance of non-performing loans by the bank or financial institution, which in turn may cause an

increase in the non-performing loan ratio. Therefore, banks or financial institutions need to continuously improve the loan approval process, strengthen internal management, improve the ethical level and professional quality of managers, prevent internal control and internal trading phenomena, and reduce the risk of non-performing loans. In addition, banks should strengthen internal management, improve the ethical level and professional quality of managers, and prevent internal control and internal trading phenomena. Only in this way can banks effectively reduce the risk of non-performing loans, improve customer satisfaction, and ensure their own profitability and safety. The issue of the owner's vacancy caused by the state as the only property rights subject of state-owned commercial banks has led to relatively serious "internal control" and "internal trading" behaviors. The fact shows that under the formalization and weakening conditions of supervision of managers at all levels of state-owned commercial banks, managers generally lack awareness of loan risk prevention, while having a strong impulse to use problem loans to obtain their own interests. As a result, a large number of enterprises and individuals with serious moral risks can easily obtain loans from state-owned commercial banks, and these loans constitute an important part of the non-performing loans of state-owned commercial banks.

3. Empirical Analysis

3.1. Data Description and Statistical Analysis

The main objective of this chapter is to predict the future value of non-performing loan ratios through the trends of various correlation factors. Here, four common economic indicators are selected to reflect basic economic factors: non-performing loan ratio (y), GDP growth rate (X1), money supply growth rate (X2), five-year and above loan interest rate (X3), and consumer price index (X4). Non-performing loans have always been considered as commercial secrets and have only been disclosed to the public in recent years.

The data used in this article comes from three websites: the China Banking and Insurance Regulatory Commission (http://www.cbirc.gov.cn/), the National Bureau of Statistics (http://www.stats.gov.cn/), and the CSMAR database (http://www.csmar.com/channels/31.html).

The statistical analysis software used in this study is R studio.

Table 1. Various economic variables over the year

year	Non-performing loan ratio	GDP growth rate	Consumer Price Index	Growth rate of broad money supply	Interest rate (five-year deposit interest rate)
2013	1	0.0777	0.0262	0.1539	0.066
2014	1	0.0743	0.0192	0.1101	0.066
2015	1.39	0.0704	0.0144	0.1334	0.045675
2016	1.74	0.0685	0.02	0.1133	0.0435
2017	1.74	0.0695	0.0159	0.0811	0.0435
2018	1.89	0.0675	0.0207	0.0699	0.04355
2019	2.04	0.0595	0.029	0.0888	0.0435
2020	1.89	0.0224	0.0242	0.1001	0.0405
2021	1.75	0.0811	0.0098	0.0908	0.0405

In this section, we mainly describe the correlation between explanatory variables and the explained variable, as the size and trend of various data have been analyzed in the previous section. Using R language for calculation, we obtain the following results:

Based on the values of the correlation coefficients, the following conclusions can be drawn:

(1) The correlation coefficient between the growth rate of broad money supply and the non-performing loan ratio is -0.7110561, indicating a negative correlation between the two, i.e., the higher the growth rate of broad money supply, the lower the non-performing loan ratio.

(2) The correlation coefficient between GDP growth rate and non-performing loan ratio is -0.8641864, indicating a strong negative correlation between the two, i.e., the higher the GDP growth rate, the lower the ratio of loans with poor performance.

(3) The correlation coefficient between loan interest rate and non-performing loan ratio is -0.9739922, indicating a very strong negative correlation between the two, i.e., the higher the loan interest rate, the lower the ratio of loans with poor performance.

(4) The correlation coefficient between consumer price index and non-performing loan ratio is -0.1424094, indicating a certain negative correlation between the two, but the correlation is not very strong.

The strong negative correlation between loan interest rate and non-performing loan ratio may seem unusual, but it has a certain historical background. China implemented a series of measures to lower loan interest rates from 2013 to 2019, mainly to ease downward pressure on the economy, promote investment and consumption, etc. China gradually promoted economic structural adjustment during this period, strengthened rectification and disposal of "zombie enterprises," "excess capacity" and other areas, which led to some enterprises experiencing tight funding situations and unable to repay loans on time, resulting in an increase in non-performing loan ratio. Although loan interest rates were lowered, the Chinese banking industry also strengthened risk control during the adjustment process, and adopted restrictive measures for high-risk borrowers and industries, which led to some borrowers being unable to obtain loans, thereby affecting their repayment ability and causing an increase in non-performing loan ratio. As loan interest rate is an important factor affecting non-performing loan ratio, it is still considered in the regression model. Therefore, the impact of the growth rate of broad money supply, GDP growth rate, and loan interest rate on the ratio of loans with poor performance is relatively significant, with loan interest rate having the most obvious impact. The impact of consumer price index on non-performing loan ratio is not very obvious, possibly because consumer price index only reflects a part of the economic environment and cannot fully reflect the impact of the entire economic environment on non-performing loan ratio.

3.2. Analysis of empirical results

To better formulate loan policies, we can use a three-variable linear regression model to make a brief prediction of non-performing loan ratio [5]. The basic form of the model is $Y = \beta 0 + \beta 1x1 + \beta 2x2 + \beta 3x3 + \varepsilon$, where we assume that non-performing loan ratio Y is jointly influenced by three independent variables: GDP growth rate x1, growth rate of broad money supply x2, and loan interest rate x3. $\beta 0$, $\beta 1$, $\beta 2$, and $\beta 3$ are regression coefficients, and ε is an error term. Our goal is to find the best regression coefficients by fitting this model to predict non-performing loan ratio Y. We can use the least squares method to solve the regression coefficients. Specifically, we can first substitute the sample data into the model to obtain a system of equations about $\beta 0$, $\beta 1$, $\beta 2$, and $\beta 3$. Then, by solving this system of equations, we can obtain the best regression coefficients. The training set consists of data for the above four indicators from 2013 to 2019, and the test set consists of data for the same four indicators from 2020 to 2021. We will compare the predicted non-performing loan ratio with the actual non-performing loan ratio to evaluate the feasibility of the regression results and assess the predictive ability of the model.

The algebraic expression is shown in the following table:

$$Y=\begin{pmatrix} Y_{2013} \\ Y_{2014} \\ \vdots \\ Y_{2019} \end{pmatrix}_{7*1}, X=\begin{pmatrix} 1 & X_{2013,1} & X_{2013,2} & X_{2013,3} \\ 1 & X_{2014,1} & X_{2013,3} & X_{2013,3} \\ \vdots & \vdots & \vdots & \vdots \\ 1 & X_{2019,1} & X_{2019,2} & X_{2019,3} \end{pmatrix}_{7*4}, \beta=\begin{pmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_3 \end{pmatrix}_{4*1}, \varepsilon=\begin{pmatrix} \varepsilon_{2013} \\ \varepsilon_{2014} \\ \vdots \\ \varepsilon_{2019} \end{pmatrix}$$

The formula for solving the equation is as follows:

$$Y = X\beta + \varepsilon$$
$$\hat{\beta} = (X^T X)^{-1} X^T Y$$

3.3. Results validation and goodness-of-fit evaluation

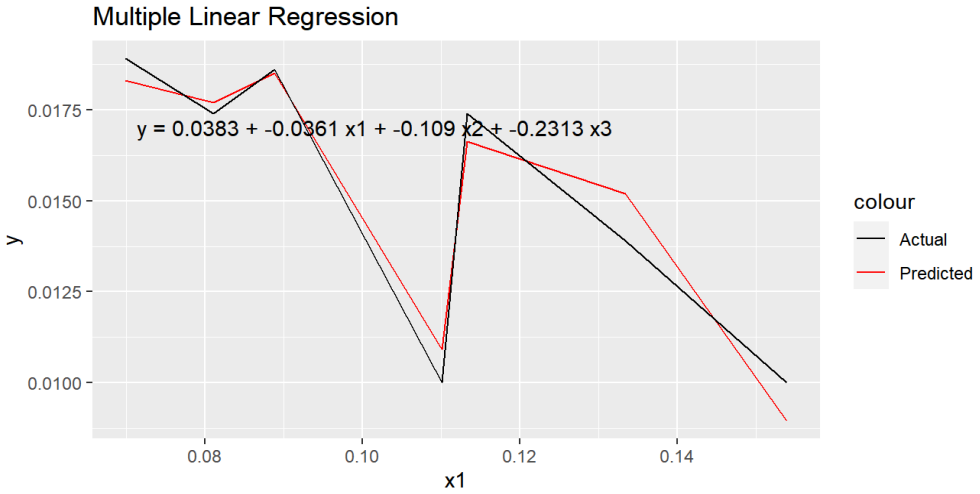


Figure 6. Linear regression simulation diagram

The predicted values are in good agreement with the actual values, and the fitted function is shown in the figure below:

$$Y=0.0383-0.0361X_1-0.109X_2-0.23123X_3$$

The regression equation for the ratio of loans with poor performance and economic development indicators in this study shows that the coefficients for each variable are negative, indicating that each independent variable has a positive promoting effect on reducing the ratio of loans with poor performance. The intercept value is 0.0383, which means that when the GDP growth rate, the growth rate of broad money supply, and the five-year deposit interest rate are all 0, the average value of the ratio of loans with poor performance is 0.0383. β 1 = -0.0361, indicating that for every 1 percentage point increase in GDP growth rate, the average non-performing loan ratio decreases by 0.0361 percentage points. β 2 = -0.109, indicating that for every 1 percentage point increase in the growth rate of broad money supply, the average non-performing loan ratio decreases by 0.109 percentage points. β 3 = -0.23123, indicating that for every 1 percentage point increase in the five-year deposit interest rate, the average non-performing loan ratio decreases by 0.23123 percentage points.

The ratio of loans with poor performance is negatively impacted by the GDP growth rate, the growth rate of the total money supply, and the interest rate on five-year deposits. This suggests that as these three independent variables rise, the ratio of loans with poor performance would fall. This makes sense considering that economic growth and a rise in the money supply typically encourage the growth of the banking sector. Additionally, lowering loan interest rates encourages borrowing, which lowers the proportion of loans with poor performance. With a regression coefficient of -0.23123, the five-year deposit interest rate has the largest influence on the ratio of loans with poor performance, showing that the loan interest rate has the biggest influence on the ratio of loans with poor performance. This is in line with our experience as well because loan interest rates are the main source of revenue for the banking sector and are essential in reducing the potential danger of non-performing loans.

Given the explanatory variables for 2020 and 2021, we can predict the non-performing loan ratio. It is found that the predicted non-performing loan ratio for 2020 is 0.02283007, while the actual value is 0.0189. The predicted non-performing loan ratio for 2021 is 0.01676551, while the actual value is 0.0175.

```
      x1      x2      x3   predicted_y
1 0.1001 0.0224 0.0405  0.02283007
2 0.0908 0.0811 0.0405  0.01676551
```

The goodness of fit was validated and tested using the testing set, as shown in the figure below. Based on the three indicators of mean squared error, root mean squared error, and mean absolute error, the model had relatively small prediction errors for the testing data, indicating a good fit. Additionally, the goodness of fit is an important indicator for evaluating the model's fitting effect on the testing data. In this example, the goodness of fit was 0.8612, indicating that the model can explain 86.12% of the variance in the testing data, demonstrating a good level of fitting for the model.

```
> predicted_y=c(0.02283007,0.01676551
)> test_y=c(0.0189,0.0175)>
mse <- mean((test_y - predicted_y)^2
> mse <- mean((test_y - predicted_y)^2)
> mse
[1] 2.290086e-06
> rmse <- sqrt(mse)
> rmse
[1] 0.001513303
> mae <- mean(abs(test_y - predicted_y))
> mae
[1] 0.001073227
> r_squared <- cor(test_y, predicted_y)^2
> r_squared
[1]0.86122
> r_squared <- cor(test_y, predicted_y)^2
> cat("R-squared: ", round(r_squared, 4))
R-squared:  0.8612
```

4. Conclusion and Recommendations

4.1. Conclusion of the Study

According to empirical analysis, it has been shown that the non-performing loan ratio of commercial banks in China is influenced by economic factors [4]. Therefore, in order to reduce the non-performing loan balance of commercial banks, it is necessary for the government to carry out macroeconomic regulation. Firstly, it is important to expand domestic demand and stimulate economic growth through consumption, which can help reduce non-performing loans. Secondly, improving the external environment of state-owned commercial banks and playing a guiding role in dealing with non-performing loans by providing policy and financial support can help alleviate non-performing loans. Thirdly, a favorable credit environment for commercial banks can be created by enhancing the legal system and actively assisting the banking industry to protect assets, control the market economy, and enhance the social credit system. To accomplish socialized enterprise credit supervision and management, the government should gradually construct and improve the enterprise credit system, assist business operators in developing strong credit awareness, and promote organizational coordination. The impact of the external macroeconomic policy environment is important, but so is the internal risk management of banks. Since the second half of 2008, China's economy has been severely tested by various factors, including shrinking demand, slowing export growth, and economic decline. Therefore, expanding domestic demand and stimulating economic

growth can have a certain effect on reducing non-performing loans of state-owned commercial banks. At the same time, it requires joint efforts from the government, banks, and enterprises to gradually establish a new system in which the government takes the lead and the enterprises and banks coordinate their operations to actively and effectively promote the continuous reduction of the ratio of defaulted loans of commercial banks.

4.2. Limitations and Prospects of the Study

Conducting this study, relying mainly on publicly available data and literature, which could lead to issues of inaccurate data and incomplete information. Secondly, the quantitative study only focused on the non-performing loan situation in China, and expanding the research scope to other countries and regions may result in different conclusions. Additionally, our regression analysis only focused on basic variables such as GDP growth rate, loan interest rate, which may limit the accuracy of our research results. In fact, there are many other factors that can affect the occurrence and development of non-performing loans, such as enterprise operating conditions, industry risks, and policy environments, which were not fully considered in our study. Therefore, future research can strengthen the study of other factors and explore how to comprehensively consider the impact of multiple factors on non-performing loans. For example, financial indicators of enterprises and industry development conditions can be added to construct a more comprehensive model to improve the accuracy and reliability of research.

Future research can be carried out from the following aspects: Firstly, case studies of non-performing loans can be strengthened to gain a deeper understanding of the specific reasons and influencing factors of enterprise defaults and non-performing loans. Secondly, research on bank risk management and supervision can be strengthened to explore how to improve the bank's risk management capabilities and regulatory effectiveness. This is because the new regulatory system requires banks to provide more timely and forward-looking information to better manage credit risk. Banks should update loan loss provisions based on the credit cycle to better manage operational risk and avoid underestimating or overestimating credit risk [7]. Thirdly, research on early warning and risk assessment of non-performing loans can be strengthened to explore how to identify and respond to non-performing loan risks early. Finally, research on the governance and disposal of non-performing loans can be strengthened to explore how to effectively solve non-performing loan problems and ensure the stable operation of the banking system.

4.3. The R code for the above program

```
1.  ```{r setup, include=FALSE}
2.  knitr::opts_chunk$set(echo = TRUE)
3.  installed.packages("ggplot2")
4.  library(ggplot2)
5.  x1=c(2013:2021)
6.
7.  y10=c(0.1539,0.1101,0.1334,0.1133,0.0811,0.0699,0.0888,0.1001,0.0908)
8.  plot(x1,y10,type = "l",xlab="year",ylab="Growth rate of broad money supply")
9.  y20=c(0.0777,0.0743,0.0704,0.0685,0.0695,0.0675,0.0595,0.0224,0.0811)
10. plot(x1,y20,type = "p",xlab="year",ylab="increasing rate of GDP")
11. y30=c(0.064,0.06,0.0475,0.0475,0.0475, 0.0475,0.0475, 0.0475,0.0475)
12. plot(x1,y30,type = "l",xlab="year",ylab="lending rate")
13. y40=c(0.0262,0.0192,0.0144,0.02,0.0159,0.0207,0.029,0.0242,0.0098)
14. plot(x1,y40,type = "l",xlab="year",ylab="consumer price index")
15.
```

```
y=c(0.01,0.01,0.0139,0.0174,0.0174,0.0189,0.0186)

x11=c(0.1539,0.1101,0.1334,0.1133,0.0811,0.0699,0.0888)
cor(x, y11, method="pearson")
x21=c(0.0777,0.0743,0.0704,0.0685,0.0695,0.0675,0.0595)
cor(x, y21, method="pearson")
x31=c(0.066,0.066,0.045675,0.0435,0.0435,0.0435,0.0435)
cor(x, y31, method="pearson")
library(ggplot2)
df <- data.frame(y = c(0.01,0.01,0.0139,0.0174,0.0174,0.0189,0.0186),
                 x1 = c(0.1539,0.1101,0.1334,0.1133,0.0811,0.0699,0.0888),
                 x2 = c(0.0777,0.0743,0.0704,0.0685,0.0695,0.0675,0.0595),
                 x3 = c(0.066,0.066,0.045675,0.0435,0.0435,0.0435,0.0435))

model <- lm(y ~ x1 + x2 + x3, data = df)

df$predicted_y <- predict(model)

ggplot(df, aes(x = x1)) +
  geom_line(aes(y = predicted_y, color = "Predicted")) +
  geom_line(aes(y = y, color = "Actual")) +
  labs(x = "x1", y = "y") +
  ggtitle("Multiple Linear Regression") +
  annotate("text", x = 0.1, y = 0.017, label = paste("y =", round(coef(model)[1], 4), "+", r
ound(coef(model)[2], 4), "x1 +", round(coef(model)[3], 4), "x2 +", round(coef(model)[4], 4), "x3
")) +
  scale_color_manual(values = c("Actual" = "black", "Predicted" = "red"))
model <- lm(y ~ x1 + x2 + x3, data = df)
predicted_y <- predict(model, df)
print(predicted_y)
test_df <- data.frame(x1 = c(0.1001,0.0908),
                      x2 = c(0.0224,0.0811),
                      x3 = c(0.0405,0.0405))
test_df$predicted_y <- predict(model, newdata = test_df)
test_df
predicted_y=c(0.008962061,0.010912397,0.015198711,0.016633871,0.017686131,0.01
8308114,0.018498714,0.02283007,0.01676551)
test_y=c(0.01,0.01,0.0139,0.0174,0.0174,0.0189,0.0186,0.0189,0.0175)
mse <- mean((test_y - predicted_y)^2)
mse
rmse <- sqrt(mse)
rmse
mae <- mean(abs(test_y - predicted_y))
```

```
mae
r_squared <- cor(test_y, predicted_y)^2
r_squared
r_squared <- cor(test_y, predicted_y)^2
cat("R-squared: ", round(r_squared, 4))
x41=c(0.0262,0.0192,0.0144,0.02,0.0159,0.0207,0.029)
cor(x, y41, method="pearson")
```

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