

Market uncertainty and interest rate risk of commercial banks based on duration, modified duration, convexity and F-W model: Evidence from COVID-19 epidemic

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Abstract. COVID-19 affects the supply and demand of funds in the financial market, leads to great uncertainty in the capital market, and causes the concern of interest rate risk of commercial banks. Therefore, it is necessary to figure out how to eliminate loss and negative effects on the capital market. In this paper, we will study the interest rate risk of China's commercial banks through theoretical analysis and empirical analysis. We will use the F-W duration model and the commercial bank's 2019 and 2020 annual report data to make some empirical analysis. Our analysis reflects the degree of interest rate risk affected by COVID-19 in China's commercial banks. We find that ICBC had interest rate risk both before and after the epidemic, but interest rate risk was rather less after being affected by the epidemic. Finally, we also explored the detailed mechanism for the decrease of interest risk.

Keywords: interest rate; duration; covid-19.

1. Introduction

Interest rate risk refers to the possibility that commercial banks' profits will decrease or their losses will increase due to the fluctuation of market interest rate under the circumstance that the principal and interest of loan can be paid off normally. The emergence of interest rate risk depends on two conditions: one is when the fluctuation of the market interest rate is inconsistent with the duration of assets and liability of commercial banks. Another is when liabilities are longer than asset maturity, or asset maturity is longer than debt maturity. As long as these two conditions are satisfied simultaneously, commercial banks will have interest rate risk. The scale of interest rate risk depends on the fluctuation of interest rate and the extent of inconsistency between the maturity of assets and liabilities of commercial banks. Due to the interaction of capital supply and capital demand in the market economy, the market interest rate is always fluctuating. Meanwhile, to pursue higher profits, commercial banks will borrow short-term funds and issue long-term loans in the process of operation. There will be inconsistency between the maturity of assets and liabilities, which shows that in the market economy, commercial banks will inevitably have interest rate risk during their operation process.

The research on interest rate risk management began in the 1970s. With the advent of interest rate marketization, J.P. Morgan company first proposed the method to measure the interest rate sensitivity gap in 1983. In the 1980s, Macaulay put forward the concept of convexity. The combination of duration and convexity can measure interest rate risk much accurately. After the 1990s, the G30 group put forward the VAR model in the report of *practice and derivatives rules*, which can accurately predict the risks commercial banks are facing. Generally, banks usually use measurement methods,

including interest rate sensitivity gap model, duration analysis, value at risk (VaR) analysis, scenario analysis, and stress test to measure the risk.

Besides these theoretical achievements, researchers have studied more risk aversion strategies for specific problems based on them. Flannery [1] studied American commercial banks' profitability and interest rate risk in the late period of interest rate liberalization in the United States. He structured a model to estimate the duration of bank assets and liabilities, which showed that banks adjust the duration of assets and liabilities on the balance sheet to make them consistent with coping with the risk of market interest rate fluctuations. Brewer [2] also proposed using duration analysis and duration gap model to measure interest rate risk. He suggested that banks use interest rate futures to avoid interest rate risk, fix the expected return, and realize the dual management of on and off the balance sheet. In more specific cases, Ahmed, Beatty, and Bettinghaus [3] studied the data disclosure of the U.S. banking industry in 1990 and 1997. The results show that the banks with more exposure information, such as the duration gap, have higher efficiency of net interest income. Therefore, duration gap and net interest income are closely related, and disclosure information is helpful for banks to manage their interest rate risk. The interest rate risk gap model is the most simple and convenient method for banks to measure their own interest rate risk.

Wetmore and Brick [4] discussed how to estimate the bank's gap according to the Price Optimization Models and found that the gap estimated according to the bank's interest rate sensitive assets and liabilities is always positive. The average value of the bank's gap also tends to be greater than zero, which indicates that the bank risk is not managed according to the traditional minimum optimal gap. Ballester, Ferrer, and González [5] conducted a comprehensive analysis of Spanish commercial banks' linear and nonlinear interest rate risk by using parametric and nonparametric estimations. The results show that interest rate changes have a great impact on Spanish banks. Banks have a large interest rate risk exposure. Moreover, the estimation results of the nonlinear model show that the traditional linear model will exaggerate the bank's interest rate risk.

What's more, researchers are constantly exploring new ways to avoid interest rate risk. Scannella and Bennardo [6] proposed a new systematic method to analyze bank interest rate risk, namely the asset-liability management method. They used three displacement methods of interest rate curve for simulation analysis and gave the simulation results of bank interest rate risk exposure. Therefore, banks can choose appropriate hedging strategies to manage interest rate risk.

Covid-19 has been a major threat to the financial market since 2020. However, we still have insufficient research on the potential impact of the new crown epidemic on commercial banks. Therefore, in this paper, we will study the interest rate risk of China's commercial banks through theoretical analysis and specific data. We will use the F-W duration model and the commercial bank's 2019 and 2020 annual report data to make some empirical analysis. Our analysis reflects the degree of interest rate risk affected by COVID-19 in China's commercial banks.

2. Literature review

2.1 The causes of interest rate risk

From the perspective of the causes of interest rate risk, we can attribute interest rate risk to three factors: policy factor, market factor, and internal factor.

2.2 Interest rate risk caused by policy factors

First, the central bank makes strict interest rate control policy. For countries that have not yet completed the marketization of interest rates, the central bank still regulates interest rate adjustment, so it is difficult for commercial banks to control interest rate risk according to their own assets and liabilities. Banks are still limited in the right of independent pricing and cannot achieve the purpose of controlling interest rate risk.

Second, the central bank's monetary policy changes frequently. Interest rate is an important tool for financial authorities to carry out macroeconomic regulation and control. Since the economic

environment is complex, the central bank, as the direct maker of interest rate policy, must formulate interest rate policy to serve the economic development from time to time. As a result, the systematic risk of bank interest rates increases greatly.

2.3 Interest rate risk caused by market factors

The income of banks mainly comes from the gap of interest between deposits and loans. However, suppose the interest rate is not fully marketized. In that case, there is not much difference in the income of business and credit assets of commercial banks, which leads to fierce competition in the bank industry and increased operational risk. It will also lead some banks to take illegal means to raise deposit interest rates, which will bring more serious interest rate risk.

2.4 Interest rate risk caused by internal factors of banks

In the business structure of commercial banks, deposit and loan business takes the main part, so the change of interest rate greatly impacts the operation of commercial banks. Some enterprises have not established a standardized system and the bank's internal management system still has some deficiencies. Some credit funds turned into non-performing assets, resulting in a low-interest recovery rate, seriously affecting the bank's net interest income. Most banks have a large gap between deposit and loan, and the ratio of deposit and loan does not match. Once the interest rate is adjusted, banks will bear greater interest rate risk.

2.5 The impact of COVID-19 on macro-financial markets

At the end of 2019, covid-19 erupted and spread worldwide immediately.

Although it is a public health event, the capital market showed a quick response. Behavioral finance illustrates that investors can be irrational and further result in capital market fluctuation. Basing on signal transmission theory, the coronavirus pandemic may deliver negative information to investors, particularly during the period in which covid-19 broke out in early 2020. The government requires citizens to quarantine at home, in which case, social productivity was declined. Moreover, the government funds capital in health care, some countries such as China even provide free treatment to its citizens, which reduces investors' expectation of future bond yield. The stock price would suffer from it. According to the Chinese stock exchange data, on the first trading day after the spring festival, stock prices were reduced by 8 percent [8].

However, it was back on track on February 5th owing to the adjustments by the government. In addition, the COVID-19 pandemic increased government, firms, and individuals' demand for capital gain and debts. It also drove cuts of interest rates, which had a great influence in banking and capital markets due to the volatility in liquidity, rates, and fees [9].

The degree of pandemic impact depends on how long it would last. If the pandemic tends to be less severe, we will suffer at most half a year of negative GDP growth. Then capital markets would be under control afterward. While the worst scenario is the long-term economic recessions, central banks would implement monetary policy and fiscal policy as the response [10].

To conclude, COVID-19 affects the supply and demand of funds in the financial market, leads to great uncertainty in the capital market, and causes the concern of interest rate risk of commercial banks. Therefore, it is necessary to figure out how to eliminate loss and negative effects on the capital market.

3. Data and Methodology

3.1 The operation of industrial and Commercial Bank of China

The performance of the Industrial and Commercial Bank of China is showing steady progress. They actively adapt to the needs of the real economy and provide service more efficient. First of all, integrated investment and financing services were promoted in a coordinated way. They use credit

debts, bonds, equities, agency, and rent to give full support to real business. Secondly, new breakthroughs were made in FinTech innovation through introducing a smart bank ecosystem (ECOS 1.0) to support the combination of finance and technology. Thirdly, the revenue structure continued to improve. While continue to reduce fees and profits for customs, they still innovate business and optimize revenue structure depending on customers' demands. Fourthly, the layout of international service has been further improved. The number of overseas institutions had reached 428, covering 48 countries or regions by 2019. As it comes to risk management, ICBC also kept improving the quality of assets. During 2019, the defect rate has fallen for 12 consecutive quarters. More than 2 trillion yuan of outstanding loans have been transferred and relent. The recovered relent funds have continued to migrate to high-quality industries, key areas, and high-quality customers. Nearly 190 billion yuan of non-performing loans were cleared and disposed of through various means.

3.2 Source of data

The data of this experiment, such as assets and liabilities, are all from the official websites of China Construction Bank and Industrial and Commercial Bank of China. Some data, such as spot interest rate, are obtained by the formula:

Spot rates r_t , $t = 1, \dots, T$: current annualized interest rate for a maturity date t ("average" between now and t). The data in the formula came from the Global Economic Data Network (<http://www.qqjjsj.com>).

3.3 Measurement

The traditional Macaulay duration formula is:

$$D = \frac{\sum_{i=1}^n \frac{C_i}{(1+r)^i} \times i}{P} \quad (1)$$

The following formula can measure the relationship between the yield change and the price change:

$$\frac{\Delta P}{P} = -D^* \times \Delta r \quad (2)$$

In the formula, $D^* = \frac{D}{1+r}$ is the corrected duration.

In this way, we can calculate the corresponding maturity of each phase of cash flow of commercial banks and whether it meets the condition of zero gaps.

We can manage interest rate risk through the duration gap of bank assets and liabilities in the formula, and the formula of duration gap can be obtained as follows:

$$G_D = D_A - \frac{P_L}{P_A} D_L \quad (3)$$

Duration of assets and liabilities is represented by D_A and D_L ;

P_L , L , and P_A represent the market value of liabilities and assets, respectively.

With the rise and fall of the interest rate, the duration gap will also change. The main task of interest rate risk management is to make the duration gap zero and make the duration gap of assets and liabilities match each other.

For the duration of the derivative again, you can get a more accurate measure, which is convexity. The formula for convexity is

$$C = \frac{1}{P} \cdot \frac{d^2 P}{dr^2} \quad (4)$$

When we measure non-interest bearing bonds, this formula can be further simplified to

$$C = \frac{n(n+1)}{(1+r)^2} \quad (5)$$

If the advantage of convexity is combined with the calculation of duration, the accuracy of measuring yield rate risk will be greatly improved by using this combination.

As an important reference index, the net market value of the bank is expressed as

$$P_N = P_A - P_L \quad (6)$$

If market interest rates fluctuate, the value of the assets and liabilities of commercial banks will change accordingly:

$$\Delta P_N = \Delta P_A - \Delta P_L \quad (7)$$

When measuring the impact of interest rate risk on the assets and liabilities of commercial banks, interest rate changes will have a certain impact on the net worth of banks. To measure the sensitivity between the two, the following formula is used

$$\Delta P_A = \frac{dP_A}{dr} \cdot \Delta r + \frac{1}{2} \frac{d^2 P_A}{dr^2} \cdot (\Delta r)^2 \quad (8)$$

$$\Delta P_L = \frac{dP_L}{dr} \cdot \Delta r + \frac{1}{2} \frac{d^2 P_L}{dr^2} \cdot (\Delta r)^2 \quad (9)$$

Rearrange this, we can get

$$\begin{aligned} \Delta P_N &= \left(\frac{dP_A}{dr} - \frac{dP_L}{dr} \right) \cdot \Delta r + \frac{1}{2} \frac{d^2 P_A}{dr^2} \cdot (\Delta r)^2 - \frac{1}{2} \frac{d^2 P_L}{dr^2} \cdot (\Delta r)^2 \\ &= -\left(D_A^* \cdot P_A - \frac{P_L}{P_A} \cdot D_L^* \cdot P_A \right) \Delta r + \frac{1}{2} \left(C_A \cdot P_A - \frac{P_L}{P_A} \cdot C_L \cdot P_A \right) \cdot (\Delta r)^2 \\ &= -\left(D_A^* - \frac{P_L}{P_A} \cdot D_L^* \right) P_A \cdot \Delta r + \frac{1}{2} \left(C_A - \frac{P_L}{P_A} \cdot C_L \right) P_A \cdot (\Delta r)^2 \end{aligned}$$

Inside this formula, $D_A^* - \frac{P_L}{P_A} \cdot D_L^*$ is the duration gap, $C_A - \frac{P_L}{P_A} \cdot C_L$ is the convex gap.

In the Macaulay hypothesis, if the assumption that the discount rate is the same for each period is not established, the actual situation will be different from the duration result.

In the F-W long term proposed in 1971, the present value of creditor's rights is regarded as the spot interest rate, and the relationship between the two is

$$P = \sum_{i=1}^n \frac{C_i}{(1+r_i)^i} \quad (10)$$

Then the duration of F-W is

$$D_{FW} = -\frac{1}{P} \cdot \frac{dP}{dr_i} = -\frac{\sum_{i=1}^n \frac{C_i}{(1+r_i)^{i+1}} \times i}{p} \quad (11)$$

We can solve the problem through the F-W duration that the assumption of the same discount rate for each period proposed by the traditional Macaulay duration is not valid and leads to the inaccurate result. However, we still assume that the rate of return occurs parallel shift, which still has some limitations on the results of the F-W duration calculation.

4. Empirical results analysis

4.1 Empirical illustrations

Duration is the actual maturity of a bond, calculated considering the present value of the bond's cash flows. Its gap theory has long been proven in financial markets and is commonly used to measure interest rate risk. As commercial banks have a large share of assets and liabilities, it is important to study their interest rate risk. In this paper, ICBC is studied for its interest rate risk using duration and convexity gap theory. ICBC is a large, centrally managed state-owned bank. ICBC is a large centrally managed state-owned bank with strong financial services expertise, a high degree of information technology, and, for many years, the highest profitability of any bank in China.

The empirical thinking of this paper focuses on China's government bond yields constructed from previous years' data, calculating the discount rate for each maturity, and then discounting each of ICBC's balance sheet items for the two years 2019 and 2020, calculating its market value and performing a gap analysis of duration and convexity to derive the change in its net assets for comparative analysis. The following is the relevant data to be used in the course of the empirical analysis.

Table 1. Average interest rates on ICBC's assets and liabilities in 2019

Assets	Average interest rate	Liability	Average interest rate
Customer loans	4.50%	Customer deposits	1.59%
Investment	3.60%	Interbank deposits and liabilities to the central bank	2.38%
Deposit with the central bank	1.55%	Bond issuance	3.56%
Deposit and lending	3.12%		

a. Data source: ICBC Annual Report 2019

Table 2. Average interest rates on ICBC's assets and liabilities in 2020

Assets	Average interest rate	Liability	Average interest rate
Customer loans	4.26%	Customer deposits	1.61%
Investment	3.37%	Interbank deposits and liabilities to the central bank	1.75%
Deposit with the central bank	1.48%	Bond issuance	2.93%
Deposit and lending	2.02%		

a. Data source: ICBC Annual Report 2020

Table 3. 2019 ICBC Balance Sheet (Unit: million yuan)

Assets	Within 3 months	3 months to 1 year	1 to 5 years	More than 5 years
Cash and deposits with the central bank	2,970,858	-	-	-
Deposit with banks and other financial institutions				
Funds and borrowed funds	1,317,721	491,964	52,363	842
Derivative financial assets	-	-	-	-
Customer loans and advances	10,849,253	4,966,835	320,940	135,154
Financial investment				
—Measured at fair value and its changes				
The financial investment included in current profit and loss	124,802	128,720	45,262	102,776
—Measured at fair value and its changes				
The financial investment included in other comprehensive income	232,121	233,683	677,791	278,014
—Financial investment measured at amortized cost	289,260	700,577	2,405,542	1,812,788
Long-term equity investment	-	-	-	-
Fixed assets and construction in progress	-	-	-	-
Other	3,395	76	-	-
Total assets	15,787,410	6,521,855	3,501,898	2,329,574
Liability	Within 3 months	3 months to 1 year	1 to 5 years	More than 5 years
Borrowing from the central bank	141	-	876	-
Deposits with banks and other financial institutions				
Funds and borrowed funds	2,212,773	236,160	38,775	38,624
Measured at fair value and its changes included				
Financial liabilities for current profit and loss	834	19762	12,068	-
Derivative financial liabilities	-	-	-	-
Certificate of deposit	245,817	102,708	6,903	-
Customer deposit	14,687,406	4,670,307	3,084,830	24,008
Debt securities issued	231,676	39,201	122,446	349,552
Other	2,549	5,087	15,970	7,211
Total Liabilities	17,381,196	5,073,225	3,281,868	419,395

a. Data source: ICBC financial statements 2019

Table 4. 2020 ICBC Balance Sheet (Unit: million yuan)

Assets	Within 3 months	3 months to 1 year	1 to 5 years	More than 5 years
Cash and deposits with the central bank	3,190,119	-	-	-
Deposit with banks and other financial institutions				
Funds and borrowed funds	1,405,431	345,048	35,806	5,289
Derivative financial assets	-	-	-	-
Customer loans and advances	6,912,607	10,463,879	406,172	336,693
Financial investment				
—Measured at fair value and its changes				
The financial investment included in current profit and loss	117,682	130,810	71,188	147,550
—Measured at fair value and its changes				
The financial investment included in other comprehensive income	272,625	258,282	614,011	314,100
—Financial investment measured at amortized cost	384,141	638,819	2,688,862	2,553,846
Long-term equity investment	-	-	-	-
Fixed assets and construction in progress	-	-	-	-
Other	3,121	70	-	-
Total assets	12,285,726	11,836,908	3,816,039	3,357,478
Liability	Within 3 months	3 months to 1 year	1 to 5 years	More than 5 years
Borrowing from the central bank	574	52,373	1,992	-
Deposits with banks and other financial institutions				
Funds and borrowed funds	2,715,947	268,836	52,264	27,239
Measured at fair value and its changes included				
Financial liabilities for current profit and loss	4,972	63	11,618	14
Derivative financial liabilities	-	-	-	-
Certificate of deposit	174,300	154,366	7,010	-
Customer deposit	15,597,045	3,808,680	5,137,289	20,242
Debt securities issued	169,119	60,501	149,678	418,829
Other	2,625	5,987	16,703	6,426
Total Liabilities	18,664,582	4,350,806	5,376,554	472,750

a. Data source: ICBC financial statements 2020

4.2 Empirical assumptions

The theoretical foundations for the empirical evidence in this paper are the McCauley duration model and its fundamental properties, the modified duration and its fundamental properties, the F-W duration model, convexity and the term structure of interest rates, and other related theories. With the exception of demand deposits, all items of assets and liabilities are free from default risk and do not have the characteristics of implied options, and have fixed cash flows.

Interest payments are made annually, and cash on hand does not generate interest income in its initial state.

For ease of calculation, the remaining maturity is limited to two months for maturities of three months, six months for maturities of three months to one year, three years for maturities of one to five years, and seven years for maturities of five years or more.

The term structure of interest rate yields has not changed significantly in the last five years, and there is no impact from the new crown epidemic.

When market interest rates fluctuate, there is a parallel shift in the yield curve and the same magnitude of change in each item of commercial banks' assets and liabilities for different maturities.

4.3 The empirical analysis

Firstly, as the process of calculating duration requires matching the spot rate of each period, the spot rate can only be obtained by first determining the term structure of the interest rate. China generally uses treasury rates as benchmark rates for three reasons.

It has a fairly high degree of marketability.

It is fundamental and has a strong correlation with other financial market interest rates or financial product prices

It can reflect market signals and effectively transmits the central bank's regulatory signals to other financial markets and financial product prices.

Therefore, the interest rate term structure, i.e., the spot yield curve, is chosen to be constructed from Treasury market data and can effectively reflect the fluctuations in market interest rates.

China's treasury bond trading market is currently divided into three main sub-markets: the interbank market, the exchange market, and the over-the-counter market. As only the exchange market has the characteristics of the wide variety of treasury bonds, strong liquidity, and diversified hierarchy, and these characteristics make the treasury bond interest rates in the exchange market have a certain degree of continuity, this paper, therefore, chooses to use the exchange treasury bond data to fit the interest rate curve and construct the interest rate curve function.

Previously, the discount function for 2016 had been fitted using exchange-traded Treasury bond data as of 31 December 2016 as

$$D_{(t)} = 1 - 0.040019t + 0.010527t^2 - 0.003148t^3 [7] [2]$$

$$\text{And because } D_{(t)} = \frac{1}{(1+r_t)^t} [3]$$

$$\text{So the spot interest rate is } r_t = D_{(t)}^{-\frac{1}{t}} [4]$$

Combining formula (1) and formula (3) can get the spot interest rate under different maturities.

After calculating the spot interest rates for each period, use the data in Table II and Table IV to calculate the market value of each bank's assets in 2020. According to the market value, the F-W duration and convexity of assets and liabilities are further calculated. Analyze the interest rate risk during the epidemic by calculating its duration gap and convexity gap.

To compare the impact of the epidemic on the interest rate risk, based on the data in Table I and Table III, repeat the above operations and conduct a comparative analysis.

4.4 Empirical results

4.4.1 Operation of ICBC

The analysis of ICBC's operations is based on Tables III and IV. In terms of overall transaction size, ICBC, as the most profitable bank in China, has considerable total assets and liabilities. Total assets of RMB 28,140,737 million and total liabilities of RMB 26,155,684 million in 2019 and total assets of RMB 31,293,125 million in 2020, an increase of approximately 11.20%, and total liabilities of RMB 28,864 million in 2020, an increase of approximately 10.36% to \$31,293,125 million and \$28,864,692 million in 2020. Total assets and total liabilities grew at relatively consistent rates.

When comparing the different maturities of assets, it can be seen that the increase in total assets was mainly due to the significant increase in assets between 3 months and 1 year, on the contrary, assets of all other maturities decreased rather than increased, in particular, total assets decreased the most within 3 months, by approximately 22.18%. The decrease in total assets within 3 months was mainly due to the decrease in loans and advances to customers, while all other accounts were increasing. Interestingly, the significant increase in assets between 3 months and 1 year also stems mainly from the loans and advances to the customers' account. Still, at this time, this account is significantly higher.

Again, comparing the different maturities of liabilities, all maturities increased except for the 3 months to 1-year liabilities, with the largest increase of approximately 63.83% in the 1 to 5-year liabilities. The decrease or increase in the 3 months to 1 year and 1 year to 5-year liabilities both came from the customer deposits account.

Comparing the two-year aggregate changes in the customer loans and advances and customer deposits accounts separately, both increased in 2020.

4.4.2. Interest rate risk during the epidemic

Since duration and convexity are both additives, the duration and convexity of the overall assets and liabilities can be calculated by weighting the duration and convexity of each asset and liability:

$$D = \sum_{i=1}^n \frac{P_i}{P} \cdot D_i \quad (12)$$

$$C = \sum_{i=1}^n \frac{P_i}{P} \cdot C_i \quad (13)$$

The F-W duration and convexity of each asset and liability were calculated as follows:

Table 5. F-W duration and convexity of various assets and liabilities in 2020

Assets	Within 3 months		3 months to 1 year		1 to 5 years		More than 5 years		Total	
	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity
Cash and deposits with the central bank	0.17	0.19							0.17	0.19
Funds and borrowed funds	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	0.28	0.51
Customer loans and advances	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	0.44	0.85
Financial investment included in current profit and loss	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	1.25	5.11
Financial investment included in other comprehensive income	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	1.83	7.24
Financial investment measured at amortized cost	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	2.50	10.65
Other	0.17	0.19	0.49	0.71					0.17	0.20
Total assets	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	0.77	2.52
Liability	Within 3 months		3 months to 1 year		1 to 5 years		More than 5 years		Total	
	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity
Borrowing from the central bank	0.17	0.19	0.49	0.71	2.84	10.88			0.57	1.06
Funds and borrowed funds	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	0.25	0.47
Financial liabilities for current profit and loss	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	2.01	7.57
Certificate of deposit	0.17	0.19	0.49	0.71	2.84	10.88			0.37	0.64
Customer deposit	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	0.76	2.45
Debt securities issued	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	1.96	9.11
Other	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	2.14	8.41
Total Liabilities	0.17	0.19	0.49	0.71	2.84	10.88	4.62	26.94	0.72	2.33

From the data in the above table, the duration gap of the net assets of each period can be obtained:

$$G_D = D_A - \frac{P_L}{P_A} \cdot D_L \quad (14)$$

According to the meaning of the duration gap, if the duration gap is negative, the market interest rate will decrease, and the net worth of commercial banks will decrease. If the result is positive, the market interest rate will decrease, and the net worth will increase.

In the same way, if convexity is considered, the convexity gap can be calculated as:

$$G_C = C_A - \frac{P_L}{P_A} \cdot C_L \quad (15)$$

Calculate changes in bank net worth based on duration gap and convexity gap:

$$\Delta P = -G_D \cdot P_A \cdot \Delta r + \frac{1}{2} G_C \cdot P_A \cdot (\Delta r)^2 \quad (16)$$

All calculation results are as follows:

Table 6. Net Asset Duration Gap, Convexity Gap and Net Value Movement in 2020

	Duration gap	Convexity gap	Net value movement
Within 3 months	-0.085981656	-0.097713285	-10247.73401
3 months to 1 year	0.310599044	0.449486505	35991.23672
1 to 5 years	-1.162085425	-4.447965795	-42077.72512
More than 5 years	3.97113965	23.15009905	31316.52289
Total	0.053062216	0.21496602	14982.30047

It can be seen that the gaps within 3 months and between 1 and 5 years are negative, while the gaps between 3 months and 1 year and over 5 years are positive. The overall net assets have a duration gap of 0.05306 and a convexity gap of 0.21497. Therefore, when market interest rates fall by 1%, the Bank's net worth rises by \$14,982.3 million, and conversely, when market interest rates rise by 1%, the Bank's net worth falls by \$14,982.3 million, and there is some interest rate risk.

4.4.3. Comparative analysis before and after the epidemic

Based on the data in Table I and Table III, repeat the above operations to obtain the results for 2019, as shown in the following table:

Table 6. F-W duration and convexity of various assets and liabilities in 2020

Assets	Within 3 months		3 months to 1 year		1 to 5 years		More than 5 years		Total	
	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity
Cash and deposits with the central bank	0.17	0.19							0.17	0.19
Funds and borrowed funds	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	0.33	0.62
Customer loans and advances	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	0.33	0.61
Financial investment included in current profit and loss	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	1.00	3.87
Financial investment included in other comprehensive income	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	1.95	7.66
Financial investment measured at amortized cost	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	2.40	9.98
Other	0.17	0.19	0.49	0.71					0.17	0.20
Total assets	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	0.69	2.26
Liability	Within 3 months		3 months to 1 year		1 to 5 years		More than 5 years		Total	
	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity	F-W Duration	Convexity
Borrowing from the central bank	0.17	0.19	0.49	0.71	2.84	10.87			2.46	9.34
Funds and borrowed funds	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	0.25	0.49
Financial liabilities for current profit and loss	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	1.33	4.35
Certificate of deposit	0.17	0.19	0.49	0.71	2.84	10.87			0.31	0.54
Customer deposit	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	0.59	1.73
Debt securities issued	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	1.65	7.61
Other	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	2.20	8.78
Total Liabilities	0.17	0.19	0.49	0.71	2.84	10.87	4.60	26.75	0.58	1.71

Table 7. Net Asset Duration Gap, Convexity Gap and Net Value Movement in 2019

	Duration gap	Convexity gap	Net value movement
Within 3 months	-0.01672	-0.01877	-2560.56
3 months to 1 year	0.109086	0.157865	6967.057
1 to 5 years	0.178427	0.682782	5941.208
More than 5 years	3.770369	21.93693	20938.26
Total	0.120365	0.582539	31285.96

Comparing the results for overall net assets for both years, the results are positive for both years, and the results for 2020 have decreased. From the perspective of the existence of interest rate risk, both years' gap results are non-zero, and the size of the market value of the bank's net assets is affected by interest rates. Therefore ICBC is exposed to interest rate risk both before and after the epidemic. However, in terms of the magnitude of interest rate risk, the 2020 result is smaller in absolute terms and less affected by interest rate fluctuations, so the year of the epidemic has less interest rate risk instead.

Comparing the results by maturity again, it can be seen that both the 3 months and 1 to 5-year results are lower, with the latter even dropping from positive to negative values so that when interest rates fall, both markets incur losses on a net basis. Based on the balance sheet changes, it can be seen that the immediate cause is a significant decrease in assets or a significant increase in liabilities. The results for 3 months to 1 year and more than 5 years increase, and the increase is greater for 3 months to 1 year. Therefore when interest rates fall, both market net values increase.

As the duration gaps on net assets within 3 months are both small, there is essentially no interest rate risk, and therefore no analysis is undertaken. In turn, the duration gap on net assets over 5 years for the epidemic is not significant and therefore is also not analyzed, focusing on comparing the change in duration gap for net assets from 3 months to 1 year and from 1 year to 5 years. The assets are represented by loans and advances to customers, which are more representative of the changes. Therefore the assets are studied using this account as a proxy, and similarly, the liabilities are studied using customer deposits as a proxy.

As can be seen from the changes in the balance sheet, the change in net assets between 1 and 5 years is mainly due to a significant increase in customer deposits. This is because, as a result of the epidemic, the overall investment and financing environment has been hit hard, and there are fewer good projects or even money to invest in. At this time, people are more likely to choose long-term deposits to hedge against the risks associated with the epidemic than investment financing. At the same time, more than 5 years is too long and risky, so more deposits of 1 to 5 years are chosen.

The balance sheet also shows that bank loans have increased, except for loans within 3 months, with the largest increase in 3 months to 1 year, and that overall total loans have also increased compared to the pre-epidemic period. The reason for this is twofold; on the one hand, banks received a large number of long-term deposits after the epidemic, and their liabilities increased, so they would want to lend out more money to make a profit, thus introducing a series of incentives to stimulate lending. This will reduce the losses incurred due to the impact of the epidemic and thus the dampening of loan demand. On the other hand, the state has always had loan-related support policies for MSMEs, like granting short-term loans to sustain operations. However, the epidemic's impact has led to a reduction in business, loss of profitability, and a break in the capital chain of the MSMEs. The short-term loans previously granted are not sufficient to tide the MSMEs over, so the State has issued a number of preferential policies for business loans. The first and foremost was to increase credit support, reduce lending rates appropriately and increase credit loans and medium to long-term loans. However, due to China's relatively excellent epidemic prevention measures, work gradually resumed in March. The economy slowly started to recover, so the shift from short-term to longer-term loans was mostly from 3 months to 3 months to 1-year loans.

After the epidemic, the structure of liabilities increased significantly due to changes in customer deposits, shifting from deposits within 3 months to 1 to 5 years and a significant increase in the

combined duration of liabilities. The asset mix is skewed towards 3 months to 1-year loans due to changes in customer loans. The duration of combined assets clearly increases less than liabilities, resulting in a reduction in the overall duration gap and a reduction in interest rate risk.

5. Conclusion

According to the definition of the Basel Committee on banking supervision, the main factors of interest rate risk include repricing risk, yield curve risk, benchmark risk, and risk of the option. Recently, the VAR model is one of the most used tools to measure interest risk. Comparing to previous studies, our study's innovation is that we selected two years' data, such as assets and liabilities of commercial banks from 2019 to 2020, and then calculate duration and convexity to do analysis. That is, we can research time analysis, which can make it more intuitive for readers to get to know how much change of commercial interest rate risk in terms of time.

Economists introduced two scenarios of the coronavirus pandemic in terms of the severity to do the anticipation of the impact of COVID-19 to the capital market. They delve deeper into three steps: to respond and deal with practical issue, reset specific capabilities as the effects of the pandemic begin to dissipate and ultimately renew the finance function for a path forward in the post-pandemic era. Others discuss the impact of covid-19 on the capital market through industry heterogeneity analysis, inflection point analysis, and scenario study to show that the short-term impact of covid-19 on the capital market is severe, and this impact has obvious characteristics of industry heterogeneity. However, we study the impact of COVID-19 on commercial interest rate risk, which supports how pandemic changes the financial market.

In previous researches, people learned how to prevent the financial market from risk under different extreme situations. Our study is concerned with risk management in terms of market uncertainty. After public events appeared, the central bank would change monetary policy to carry a stable financial market, while the interest rate is always the appropriate tool to regulate macroeconomically. Our research is straightforward to get to know how the government takes actions to manage risk due to market emergency break out.

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