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Research on Interest Rate Transmission Mechanism of China's Bond Market: Empirical Analysis Based on Granger Causality Complex Network

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Abstract The bond market is an important market for investment and financing in China's economic sectors, and also an important part of the monetary policy framework. The internal transmission of bond market is an important part of market interest rate transmission, which iscritical to the effectiveness of monetary policy. However, few scholars have studied the characteristics of interest rate transmission in China. An in-depth study of the interest rate transmission mechanism and its dynamic evolution between different bond markets is conducive to clarify the pulse of transmission within Chinese bond market and to further unblock the transmission mechanism of monetary policy. From the perspective of system theory and based on the analysis method of Granger causality complex network, this paper finds that the interest rate transmission among various varieties in China's bond market is relatively significant. Treasury bonds and CDB bonds are the two core bond varieties of interest rate transmission in the bond market. Simultaneously, this study concludes that the medium and long-term interest rate played a dominant role in the transmission of market interest rate during the easing phase of monetary policy, while the short-term interest rate played a dominant role in the

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transmission of market interest rate during the tightening phase of monetary policy. This paper also gives enlightenment and suggestions.

Keywords bond market; interest rate; transmission mechanism; Granger causality; complex network

1 Introduction

Interest rate is the price paying for capital and is an important macroeconomic variable. Since entering the era of paper money and electronic money, the currency issuing authority has had the ability to generate inflation and obtain a seigniorage tax. As the nominal price of capital, nominal interest rate is not only affected by capital supply and demand, but also deeply affected by inflation and inflationary expectations[1]. Capital is an important factor of production, and its price not only has a huge impact on the investment and financing decisions of market participants, but also affects the allocation of social resources and welfare. Obviously, interest rate fluctuations in different markets affect the allocation of social resources.

Since the 1990s, China has carried out a series of reforms in the money market, bond market, and deposit and loan market. The market-oriented reform of interest rate has been gradually implemented. The institutional reform of the bond market and the policy of opening to the outside world have been deepened. Meanwhile, China's financial infrastructure construction is accelerating. In addition, under the modern financial system, the formation and transmission mechanism of interest rates in the bond market has become more complex due to the extensive participation of various types of unincorporated financial products, non-bank financial institutions and overseas institutions in the market. Currently, various types of participating institutions have different risk-return preferences and face different regulatory, tax, accounting and other policy environment constraints. Portfolio changes and investment transaction decisions are significantly differentiated, which directly affect the prices of major bond varieties such as treasury bonds, policy financial bonds, credit bonds and other bonds.

In 2013, the Third Plenary Session of the 18th CPC Central Committee explicitly proposed 'improving the yield curve of treasury bond to reflect the relationship between market supply and demand' for the first time. In 2020, the state again stressed 'deepening the market-oriented reform of interest rate, improving the benchmark interest rate and market-oriented interest rate system, making better use of the benchmark role of treasury bond yield curve for pricing and enhancing the independent pricing ability of financial institutions'. The benchmark role of treasury bond interest rate and the impact of treasury bond interest rate on other bonds have become a topic of general concern in the academic community and the market. However, as the treasury market is the first bond market to develop in China, many studies have focused on the transmission efficiency and effect of policy interest rate on treasury rate, and then analyzed the impact of treasury rate on other bond market interest rates and financial market pricing[2]. In fact, from the perspective of market transaction, the issuance and trading of treasury bonds, policy financial bonds and corporate credit bonds are facing the same external environment. The impact of external environment changes on each bond market segment has no time sequence, and there is no upstream and downstream relationship. From the perspective of investment portfolio, investors' trading decisions are also carried out in a variety of bond varieties at the same time, which synchronously affects the prices of a variety of bond varieties and forms the

interest rates of various bonds. In terms of trading volume, the total trading volume of policy financial bonds in 2020 was 88.6 trillion Yuan, which was 46.5 trillion Yuan higher than that of treasury bonds in the same period. Therefore, it is important to carry out an in-depth research of the price discovery and transmission mechanism characteristics of the major bond market segments. Such research is fundamental to the study of China's monetary policy transmission mechanism and has strong implications for the analysis of the transmission from policy interest rate to bond interest rate. Therefore, this paper will make an in-depth study on the interest rate transmission mechanism of China's bond market from the perspective of system theory. Based on the Granger causality complex network analysis method, this paper discusses whether the treasury bond plays a fundamental role in the bond market pricing, and the asymmetric changes of the interaction between various bonds in different periods.

The rest of the paper is organized as follows. Section 2 highlights the previous work about the formation and transmission of interest rate in different market. Section 3 introduces the methods we have employed in this paper. In section 4, this paper presents the empirical results of different periods and different stages, and makes a comparative discussion. Section 5 summarizes the whole research, and puts forward suggestions and prospects.

2 Literature Review

The formation and transmission of interest rate has always been a hot research topic. From a macro perspective, Keynes[3] believed that the interest rate was determined by the supply and demand of money, and the interest rate was a compensation for foregone liquidity. With the construction of the modern central bank system and the development of financial markets and financial institutions, whether monetary policy interest rate can be effectively transmitted to the interest rates of different markets and assets such as deposits, loans and financial assets has been the focus of academic research. Like other asset prices, some studies have found that interest rate changes randomly[4, 5]. Estrella and Mishkin[6] studied the yield curve and monetary policy instruments in Europe and the United States, which finds that monetary policy was not the only determinant of the interest rate changes even though it could effectively explain the changes of interest rate curve. Karagiannis, et al.[7] compared the interaction between money markets, policy interest rates and bank interest rates in different countries and found that in the Euro Area, short-term market interest rates appeared to have a more significant impact on loan and deposit interest rates, while in the United States, policy interest rates were more influential. Albagli, et al.[8] traced the effects of FOMC on international bond yields using panel regressions. He found that US monetary policy spillovers to long-term yields have increased substantially after the global financial crisis. Meanwhile, spillovers work through different channels, concentrated in risk neutral rates for developed countries, but predominantly on term premium in emerging markets.

In the aspect of market interest rate transmission, scholars mostly conduct research along the general equilibrium theory[9] and the non arbitrage equilibrium pricing theory[10]. Compared with cross variety transmission, many studies mostly focus on term transmission. Hall, et al.[11] conducted cointegration modeling on the interest rate of US treasury bonds in different periods and found that the short-term interest rate has a conduction relationship with the long-term

interest rate. Albagli, et al.[8] believed that the change of yield curve includes the change of expected yield (risk neutral part) and the change of risk premium, according to the term structure model of non arbitrage interest rate. In terms of risk premium, economic prosperity or economic growth expectation[12] and the uncertainty of inflation can be important factors affecting the term premium[13]. Tang and Zhang[14] used the AFNS model to model the treasury yield curve, and believed that different monetary policy instruments had an impact on the term structure of interest rate, which is also the flatness and steepness of yield. Li[15] believed that the term premium of long-term treasury bonds would be affected by the volatility of short-term interest rates, and the high volatility of short-term interest rates will restrict the transmission of price intermediary targets to long-term yields through portfolio rebalancing channels. Yuan, et al.[16] analyzed the transmission process of short-term interest rate as well as medium and long-term interest rate from the two aspects of theoretical model and empirical test. She believed that the interest rate transmission of China's current interest rate corridor mechanism was effective, and that the transmission efficiency of long-term policy interest rate was better than that of short-term policy interest rate.

The research on cross variety transmission mainly focuses on the transmission between the bond market and other markets, or the influence between individual bond varieties. Bondt[17] empirically examined the interest rate pass-through at the Euro Area level. Empirical results, on the basis of an error-correction and vector autoregressive model, suggest that the pass-through of official interest to market interest rates is complete for money market interest rates up to three months, but not for market interest rates with longer maturities. Karagiannis, et al.[18] compared the interest rate transmission mechanism of the BRICs countries. He found that the transmission from the money market interest rate to the deposit and loan interest rate is slow and incomplete, and the upward adjustment of interest rate and the downward adjustment of interest rate are asymmetric in the deposit market and the loan market. Zhang and Liu[19] studied the relationship between the yield to maturity of the 3-year AAA notes and the 10-year treasury bonds and the influencing factors of interest rate spread, and found that the interest rate spread between the two elements was mainly affected by credit interest rate spread, term risk, macro fundamentals, capital cost, stock market fluctuation with credit interest rate spread playing a major role in explaining the spread. Yan and Zhang[20] studied the movement mechanism of China's interest rate curve by using NARX neural network model, and thought that the pricing efficiency of China's treasury bonds was insufficient. He thinks that the trading price significantly deviated from the theoretical price, and excess returns could be obtained through the treasury bond portfolio management strategy. Xu[21] used the VEC model and Granger causality test to study the interest rate transmission between China's money market and bond market from 2007 to 2014. He found that the overnight interest rate has an impact on the lending rate and bond interest rate of other terms, and the interest rate of one-year treasury bonds has a greater impact on the interest rate of one-year policy financial bonds. Lu and Xu[22] analyzed the transmission relationship between China's money market interest rate and bond market interest rate with VARX model. He found that the interest rate of issuing short-term treasury bonds has insufficient conductivity to the interest rate of medium and long-term treasury bonds, and the medium-term interest rate of the money market has

more effective transmission to the medium and short-term interest rate.

Different from developed countries, the institutional differences and frictions in China's bond market are obvious. Wei[23] believed that the immature development of China's financial market restricts the efficiency of interest rate transmission. For example, the trading volume of treasury bonds has been lower than that of policy financial bonds for a long time, and the treasury bond yield curve lacks sufficient liquidity support. At present, an important contradiction in deepening the market-oriented reform of interest rates lies in the obstacles in the formation and transmission of interest rates. The reasons include market segmentation caused by regulatory arbitrage and immature financial market, as well as institutional problems such as soft budget constraints of local platforms and disorderly competition in deposits[24].

The Granger causality complex network used in this paper is a method that can measure the interaction between time series and has been gradually applied in the field of empirical research. Applying a modified conditional Granger causality network, Wang and Zhang[25] found that the LPR reform could effectively open up the interest rate transmission path of monetary policy by analyzing the structural characteristics of interest rate transmission network, and that monetary policy could be transmitted to the loan market mainly through quotation path, cost path and targeted monetary policy instrument path. Tang, et al.[26] constructed a Granger causality network for the freight fluctuation of 13 routes of Shanghai Export Container Freight Index by using the complex network theory and Granger causality test method, and found that how freight of different routes impact other routes. Moreover, using a Granger causality test of the spectrum, Li, et al.[27] found that the market price of lamb was mainly transmitted from product exporting regions to net inflow regions.

In general, interest rate transmission includes several transmission steps, such as the transmission from monetary policy to market interest rates, the transmission within and among various financial submarkets, and the transmission from market interest rates to the real economy. In developed countries, because the financial markets are more mature and there are fewer frictions, academic research has mostly focused on the transmission of monetary policy to market interest rates and the transmission of market interest rates to the macro economy. However, the price transmission within financial submarkets has been scarcely studied. Therefore, it is of practical significance to analyze the law of price linkage within the bond market and study the evolution characteristics of interest rate transmission mechanism. From the perspective of complex system, this paper makes an empirical study on the internal transmission of China's bond market.

3 Research Methods

In recent years, Granger causality complex network has been widely used in the empirical research of transmission relationship in the field of economy and finance. To elaborate it, Granger causality network is to analyze the interaction relationship between interest rates by using the method of Granger causality test. The network has been established as a complex network model with various types of interest rates as nodes and Granger causality between interest rates as edges. On the basis of network itself, the network topology can be further analyzed to study the transmission paths between the interest rates of major bond varieties.

Moreover, the method has overcome some shortcomings of traditional quantitative modeling methods, for example the situation that a large number of variables often make the parameters difficult to estimate. Compared with the traditional two-way Granger test, the combination of Granger causality and complex network can better analyze the indirect transmission channels between variables, especially when there are many research objects.

3.1 Construction of Granger Causality Complex Network

Granger causality test was pioneered by Clive W.J. Granger to analyze the causality between economic variables. It has defined causality as 'the variance that depends on the best least squares prediction using all the information at some time point in the past'.

In the time-series case, the Granger causality between two economic variables X and Y is defined as follows — The prediction of variable Y when the past information of variables X and Y is both included, is better than the prediction of Y by past information of Y alone, which means that variable X helps to explain the future change of variable Y, and thus variable X can be regarded as the Granger cause of variable Y. What's more, a prerequisite for Granger causality test is that the time series must be stable, otherwise false regression problems may occur. Therefore, the data is often differenced after taking the logarithm to make the data more stable.

Granger causality test assumes that the information about the predictions of both variables Y and X is totally contained in the time series of these variables. The test requires estimating the following regressions.

White noise u_{1t} and u_{2t} are assumed to be uncorrelated. Equation (1) assumes that the current Y is related to both the past value of Y itself and that of X, while Equation (2) assumes a similar behavior for X.

$$y_t = \sum_{i-1}^{q} a_t x_{t-i} + \sum_{j-1}^{q} \beta_j y_{t-j} + u_{1t}, \tag{1}$$

$$x_t = \sum_{i-1}^{s} \lambda_t x_{t-i} + \sum_{j-1}^{s} \delta_j y_{t-j} + u_{2t}. \tag{2}$$

For Equation (1), its null hypothesis $H_0 : a_1 = a_2 = a_3 = \cdots = a_s = 0$. For Equation (2), its null hypothesis is $H_0 : \delta_1 = \delta_2 = \delta_3 = \cdots = \delta_s = 0$. The discussion can be divided into four cases. First, X is the reason for the change of Y, that is, there exists a one-way causal relationship from X to Y. If the overall statistical significance of the coefficient estimate of the lagging X in Equation (1) is not zero, and the overall statistical significance of the coefficient estimate of the lagging Y in Equation (2) is zero, then X can be regarded as the cause of the change of Y.

Second, Y is the reason for the change of X, that is, there exists a one-way causal relationship from Y to X. If the overall statistical significance of the coefficient estimate of the lagging Y in Equation (2) is not zero, and the overall statistical significance of the coefficient estimate of the lagging X in Equation (1) is zero, then Y can be regarded as the cause of the change of X.

Third, X and y are mutually causal, that is, there exists a one-way causality from X to Y, and also a one-way causality from Y to X at the same time. If the overall statistical significance of the coefficient estimate of the lagging X in Equation (1) is not zero, and the overall statistical

significance of the coefficient estimate of the lagging Y in Equation (2) is not zero, it can be said that there is a feedback relationship or two-way causality between X and Y.

Fourth, X and Y are independent with no causal relationship between them. If the overall statistical significance of the coefficient estimate of lagging X in Equation (1) is zero, and the overall statistical significance of the coefficient estimate of lagging y in Equation (2) is also zero, then X and Y have no causal relationship.

In this paper, different interest rates were defined as nodes of the complex network, and the Granger causality between different interest rates was defined as edge. GC_{ij} represented the Granger causality between interest rate i and interest rate j. There exist three possible conditions.

1. If there is a one-way causal relationship between i and $j, GC_{ij} = 1, GC_{ji} = 0$.
2. If there is a two-way causal relationship between i and $j, GC_{ij} = 1, GC_{ji} = 1$.
3. If there is no causal relationship between iand $j, GC_{ij} = 0, GC_{ji} = 0$.

After constructing the Granger causality complex network, the centrality of each node and the density of the whole network could be calculated to evaluate the importance degree of different interest rates and to estimate the dynamic evolution of interest rate transmission characteristics at different stages. Therefore, the centrality was the number of all connected edges of a single type of bond. The greater the centrality was, the greater the influence of this bond on other bonds could be. On the other hand, the degree of the network referred to the total number of all connected edges. Similarly, the greater the degree of the network was, the stronger the interconnectedness of the whole network and the higher the efficiency of the network transmission could be.

3.2 Network Topology Analysis

In order to further explore the network topology of the major subdivided bond markets, the relational density values between major types of interest rates were further calculated based on the Granger causality complex network. The four categories of bonds were divided into five matrix rows (A, B, C, D, E) and five matrix columns (a, b, c, d, e), and the density value D was the proportion of the nodes in block A and the nodes in block b of the network matrix showing how they were associated. N_A and N_b were the maximum possible number of lines that module A and module b could have respectively, while E_{A-b} was the actual number of connected lines between module A and module b.

The criterion of α density index was used to determine the values of the matrix table and to obtain the adjacency matrix[28], with α being the number of possible connected edges in the whole network. Supposing that there were N nodes in the network, and E edges were actually connected and directed, then the network density could be:

$$WD = \frac{E}{\alpha}, \text{ where } \alpha = N(N-1).$$

The value of WD was equal to the density of the whole network, which meant the ratio of the total number of all connected edges and α. The value in the density table was compared

with WD. When the density value D was greater than or equal to WD, the value of the adjacency matrix table was 1, and when the density value D was less than or equal to WD, the value of the adjacency matrix table was 0. In this way, the bond density table was obtained, according to which the transmission relationship between categories of interest rates could be further obtained, and the network topology analysis diagram could be drawn on the foundation of the density table.

4 Research on the Transmission Network of Various Bond Interest Rates

4.1 Variable Selection

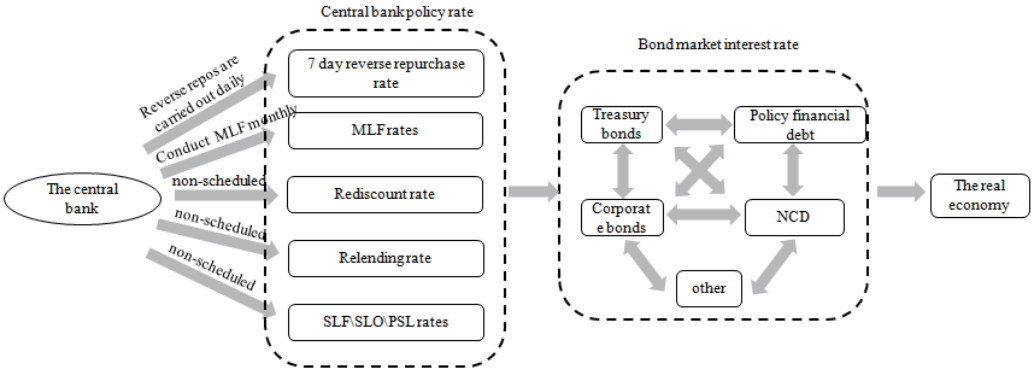

Figure 1 Bond market transmission path of China's monetary policy

At present, monetary policy is in the stage of price-based regulation, as shown in Figure 1. To achieve the purpose of macro-control, the central bank adjusts the policy interest rate, which affects the bond market interest rate and finally transmits it to the real economy. The bond market can be divided into multiple market segments based on the issuers, regulators, and circulation places. Through literature study, considering the representativeness and availability of indicators, this paper divides the market according to the issuers, and selects representative bonds according to the issuance and trading volume. Treasury bonds are selected as the representative of government bonds. National debt and local debt are the two main varieties of government credit bonds in China. Since the issuing body of national debt is the central government, the rate is usually considered as risk-free interest rate, which is the pricing basis of a large number of sustainable bonds and floating rate bonds in the market. For instance, local bonds are mostly issued in the form of 'interest rate of government bonds + fixed interest margin' due to historical reasons. The transaction volume of government bonds in 2020 is 46.5 trillion Yuan. Second, CDB bonds are selected as the representative of policy financial bonds. National development bonds, agricultural development bonds and export bank bonds are the bond varieties issued by China's three major development and policy financial institutions. They are issued to the society with quasi government credit to raise funds for investment in the important fields of China's economy and society. The main reason for choosing CDB bonds is that both the issuing market and trading market of CDB bonds was extremely active. In 2020, the transaction volume of CDB bonds was 56.8 trillion Yuan, far exceeding the 14.9

trillion Yuan and 14.8 trillion Yuan of export bank bonds and agricultural development bonds during the same period. Third, AAA and AA+ credit bonds are selected as the representative of general corporate bonds. In recent years, China's general enterprise credit bond market has developed rapidly. The rating of issuers ranges from AAA to AA−. However, due to the rating system and issuance system, China's stock of credit bonds is mostly concentrated in AAA and AA+, with the stock scale of 32.5 trillion Yuan and 6.9 trillion Yuan respectively in the end of 2020. Fourth, AAA interbank certificate of deposit (NCD) is selected as the representative of ordinary commercial bank bonds. NCD is an important tool for commercial banks to manage their active liabilities. The term of NCD mainly includes 1 month, 3 months, 6 months, 9 months and 1 year. For the market, the issuing interest rate of one-year certificates of deposit often reflects the bank's expectation of future funds. To sum up, this paper selects treasury bonds, CDB bonds, AAA and AA+ credit bonds and NCD as the research object. The key term interest rate of various types of bonds is determined as the research sample for modeling. The sample data mainly includes the daily data of 4 major varieties and 15 subcategories, which are respectively: The 1-year, 3-year, 5-year and 10-year maturities of treasury bonds, which are referred to as TR1, TR3, TR5 and TR10 respectively. The 1-year, 3-year, 5-year and 10-year maturities of CDB bonds are referred to as CDBR1, CDBR3, CDBR5 and CDBR10 respectively. The 1-year, 3-year and 5-year maturities of AAA grade medium and short-term notes and AA+ grade medium and short-term notes are referred to as CBAAA1, CBAAA3, CBAAA5, CBAA+ 1, CBAA+ 3 and CBAA+ 5 respectively. The one-year term of the interbank certificate of deposit of commercial banks, referred to as NCD1. The data source is Wind database, and the data range is from December 12, 2013 to October 21, 2021. The internal transmission mechanism of bond market is affected by many factors, such as economic development, market construction, system construction and monetary policy. Among them, monetary policy is an important external variable of bond market. In order to overcome the impact of the pandemic, we first divided the samples by taking the pandemic outbreak as the node, corresponding to the period of conventional monetary policy (December 12, 2013 to January 23, 2020) and the period of monetary policy in response to the pandemic (January 24, 2020 to October 21, 2021). In the period of conventional monetary policy, it is further divided into the easing stage and the tightening stage of monetary policy, i.e., the monetary policy easing stage (December 12, 2013 to November 3, 2016, January 19, 2018 to January 23, 2020) and the monetary policy tightening stage (November 4, 2016 to January 18, 2018).

4.2 Statistical Analysis

As shown in Figure 2, since December 2013, the interest rate trend of China's main bond varieties has strong directionality and consistency. In terms of the absolute value, the two relative highs of interest rate appeared in early 2014 and early 2018, while two relative lows of interest rate appeared in late 2016 and April 2020 respectively.

As shown in Table 1, the average interest rate of treasury bond is low. The average interest rate of one-year treasury bond is 2.75%, which is the lowest among the 15 sub varieties. The interest rate of AA+ credit debt is higher, and the average interest rate of five-year AA+ credit debt is 4.60%, which is the highest among the 15 sub varieties. In terms of fluctuation level, the standard deviation of 10-year Treasury bonds is lowest of 47 bps, while the standard deviation

of 1-year AA+ credit bonds is highest of 96bps. In terms of varieties, the interest rates from lowest to highest are treasury bonds, CDB bonds, interbank certificates of deposit, AAA credit bonds and AA+ credit bonds.

As shown in Table 2, in terms of term spread, the interest rates of medium and long-term bonds are generally higher than those of short-term bonds of the same type. Take CDB bonds as an example, the average interest margin levels in 10-year to 1-year, 5-year to 1-year and 3-year to 1-year are 77bps, 62bps and 42bps respectively. The 10-year to 1-year interest margin reached the highest value of 169bps in May 2020 and the lowest value of -15bps in December 2014.

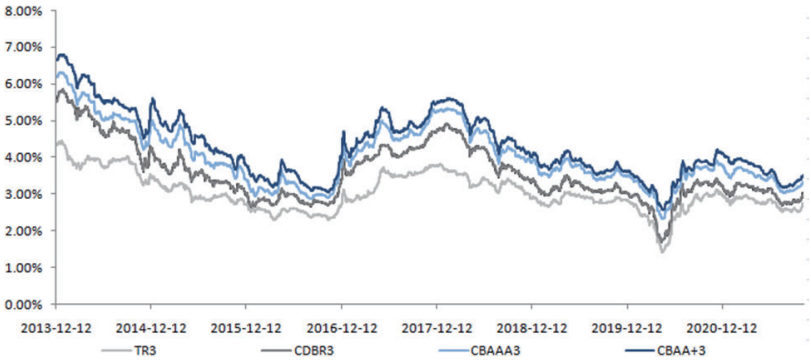

Figure 2 Interest rate trend of 3-year treasury bonds, CDB bonds, AAA credit bonds and AA+ credit bonds

Table 1 Interest rate statistics of main bond varieties with different-maturities since 2013 (Unit: %)

Name	Average	Standard Deviation	Median	Maximum	Minimum
TR: 1 year	2.75	0.57	2.64	4.25	1.12
TR: 3 years	3.02	0.51	2.92	4.45	1.41
TR: 5 years	3.18	0.49	3.08	4.53	1.79
TR: 10 years	3.36	0.46	3.28	4.66	2.48
CDBR: 1 year	3.15	0.83	2.81	5.55	1.19
CDBR: 3 years	3.57	0.78	3.32	5.85	1.69
CDBR: 5 years	3.77	0.72	3.58	5.89	2.13
CDBR: 10 years	3.92	0.68	3.74	5.92	2.79
CBAAA: 1 year	3.68	0.89	3.31	6.33	1.76
CBAAA: 3 years	4.01	0.81	3.81	6.30	2.33
CBAAA: 5 years	4.23	0.75	4.05	6.36	2.88
CBAA+: 1 year	3.93	0.94	3.57	6.79	1.96
CBAA+: 3 years	4.29	0.88	4.09	6.81	2.58
CBAA+: 5 years	4.59	0.82	4.39	6.91	3.21
NCD(AAA): 1 year	3.59	0.87	3.22	5.98	1.57

Table 2 Interest rate spread of main bond varieties of different maturities since 2013 (Unit: %)

Type	Name	Average	Standard Deviation	Median	Maximum	Minimum
Term Spread	Spreads of TR10-TR1	0.62	0.29	0.58	2.02	−0.07
	Spreads of TR5-TR1	0.43	0.23	0.4	1.64	−0.1
	Spreads of TR3-TR1	0.28	0.18	0.26	1.29	−0.09
	Spreads of CDBR10-CDBR1	0.77	0.31	0.8	1.69	−0.15
	Spreads ofCDBR5-CDBR1	0.62	0.23	0.64	1.19	−0.16
	Spreads of CDBR3-CDBR1	0.42	0.16	0.42	0.91	−0.19
	Spreads of CBAAA5-CBAAA1	0.55	0.27	0.56	1.3	−0.09
	Spreads ofCBAAA3-CBAAA1	0.32	0.18	0.32	0.83	−0.1
Variety Spread	Spreads of CDBR3-TR3	0.54	0.32	0.41	1.63	0.1
	Spreads of CBAAA3-TR3	0.99	0.35	0.89	2.1	0.38
	Spreads of CBAA+3-TR3	1.27	0.43	1.15	2.65	0.59

4.3 Dynamic Evolution Analysis of Interest Rate Transmission

4.3.1 Overall Analysis of Conventional Monetary Policy Period

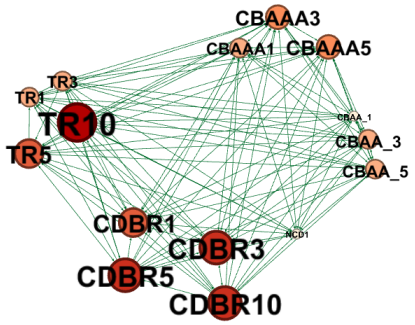

Figure 3 Analysis diagram based on Granger causality complex network in the period of conventional monetary policy

In this subsection, we apply the Granger causality complex network to model and analyze the sample data. The results are shown in Figure 3. The size of the node is the centrality of the node, which indicates the influence of the node on other nodes in the complex network. The larger the node, the more important the variety plays in the conduction network. The empirical results show that the node of 10-year treasury bonds is the largest among the 15 nodes, indicating that 10-year treasury bonds are the most critical node in the network. In terms of categories, the node accumulation of CDB bonds is the largest among all categories, followed by treasury bonds, which means that in the whole complex network, the importance of CBD bonds and treasury bonds ranks in the top two. In terms of different durations, among the 1-year varieties, CDB bonds have the largest node, and AAA credit bonds and treasury

bonds rank second and third. Among the 3-year varieties, CDB bonds have the largest node, and AAA credit bonds and treasury bonds rank second and third. Among the 5-year varieties, CDB bonds have the largest node, and national debt and AAA credit bonds rank second and third. Among the 10-year varieties, the nodes of treasury bonds are larger than those of CDB bonds.

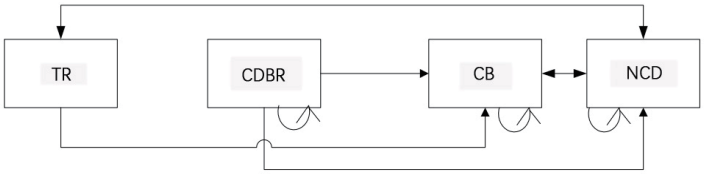

Figure 4 Transmission relationships of major interest rates in the period of conventional monetary policy

On the basis of the above network analysis, we further calculate the transmission relationship between the interest rates of major categories of bonds, as shown in Figure 4. First, the interest rate of CDB bonds and the interest rate of treasury bonds play an important role in the whole transmission network of bond interest rates. The interest rate of CDB bonds has an obvious transmission relationship with the interest rate of treasury bonds, credit bonds and NCD. The interest rate of treasury bonds has an obvious transmission relationship with the interest of credit bonds and NCD. There is an obvious transmission relationship between the credit bond and NCD. But the interest rate of treasury bonds has no conduction force to the interest rate of CDB bonds. Second, the interest of treasury bonds, CDB bonds, credit bonds and NCD have a significant self transmission relationship, showing obvious historical correlation and cross term correlation of the same variety.

In general, the conduction of CDB bonds to the bond market is stronger than that of treasury bonds. Statistics show that the total transaction volume of CDB bonds was 187.4 trillion Yuan from December 12, 2013 to January 23, 2020, which is much higher than 114.2 trillion Yuan of treasury bonds in the same period.

4.3.2 Tightening Stage of Conventional Monetary Policy Period

In the stage of tightening monetary policy, the samples from November 4, 2016 to January 18, 2018 are used for modeling research. The empirical results show that, as shown in Figure 5, the 1-year treasury bond and 1-year CDB bond have the greatest influence. The 10-year treasury bond and 10-year CDB bond also have a strong influence. On the basis of this network, we can further obtain the transmission relationship of major types of interest rates, as shown in Figure 6.

It can be found that CDB bonds have the greatest influence among the main bond varieties at this stage, and have strong price transmission power on the other three types of bond markets. Treasury bond market has strong price transmission power to the credit bond market and NCD market.

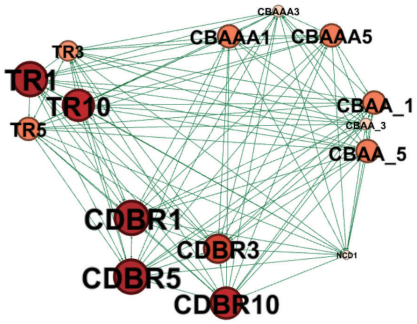

Figure 5 Granger causality complex networks from November 4, 2016 to January 18, 2018

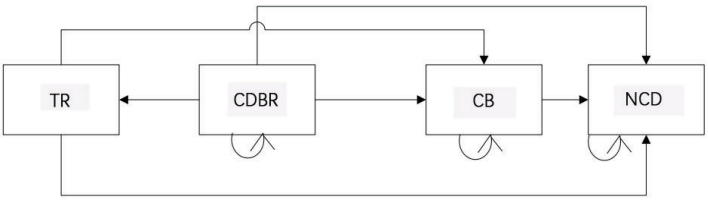

Figure 6 Transmission relationships of major interest rates from November 4, 2016 to January 18, 2018

4.3.3 Easing Stage of Conventional Monetary Policy Period

In the monetary policy easing stage, the samples from December 12, 2013 to November 3, 2016 and the samples from January 19, 2018 to January 23, 2020 are used separately in this analysis. The Granger causality complex network diagram is shown in Figures 7 and 9. Overall, 10-year and 5-year treasury bonds and CDB bonds have strong influence, while credit bonds and NCD have weak influence. Based on the complex network analysis, we further get the interest rate transmission relationship between major categories, as shown in Figures 8 and 10. CDB bonds and treasury bonds play a significant role in the price transmission of the bond market. The credit bond market and NCD market have a strong interaction, but have little impact on the price of CDB bonds and treasury bonds. The main bond varieties have significant self conduction relationship.

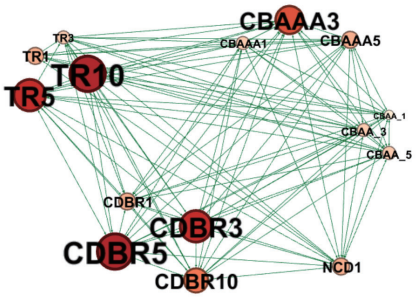

Figure 7 Granger causality complex networks from December 12, 2013 to November 3, 2016

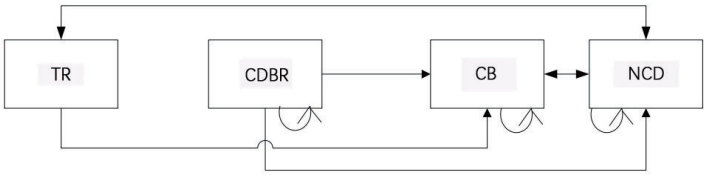

Figure 8 Transmission relationships of major interest rates from December 12, 2013 to November 3, 2016

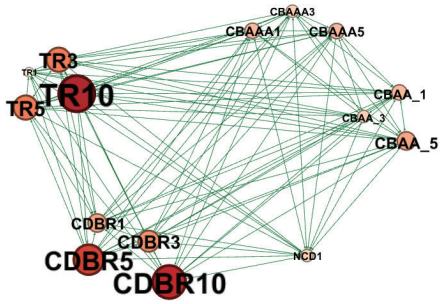

Figure 9 Granger causality complex networks from January 19, 2018 to January 23, 2020

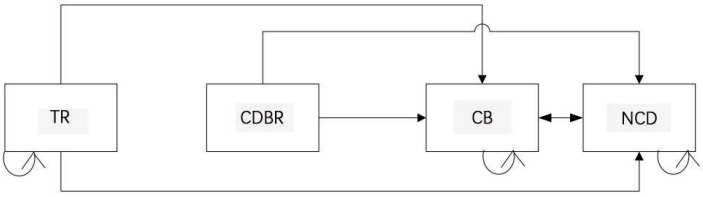

Figure 10 Transmission relationships of major interest rates from January 19, 2018 to January 23, 2020

4.3.4 Research on Interest Rate Transmission During the Period of Pandemic

Since the outbreak of the pandemic in early 2020, central banks around the world have implemented unconventional easing policies. China has strengthened the countercyclical and cross cyclical regulation of macro policies and issued a series of fiscal, monetary and industrial policies. For instance, the people's Bank of China's reduction on open market operating interest rates. The Ministry of Finance issued 1 trillion Yuan of special treasury bonds. Under the impact of the epidemic and a large number of policies, the interest rate transmission in the bond market during this period has new characteristics.

Using the samples from January 24, 2020 to October 21, 2021, the empirical results show that the influence of 3-year treasury bonds, CDB bonds and credit bonds has increased significantly, while the influence of 10-year CDB bonds and treasury bonds has decreased significantly. 3-year treasury bonds and 3-year CDB bonds have the strongest influence. The transmission relationship between the interest rates of major types of bonds is shown in Figure 11. It can be found that the transmission force of treasury bonds is the strongest in the complex network,

and the impact between credit bonds and NCD is no longer significant. It can be found that in the period of pandemic, the transmission characteristics of the bond market are significantly different from those before the pandemic, which is mainly reflected in the significant increase in the influence of 3-year bond varieties during this period. The main reasons may be the following two aspects. Firstly, due to the impact of the pandemic and the care of policies, both the short-term 1-year interest rate and the long-term 10-year interest rate have been at historic lows. Due to the loose monetary policy, the short-term interest rate fluctuation is not flexible. The fluctuation standard deviation of 1-year treasury bonds is 41 bps, which is lower than the historical average. The long-term interest rate also has low amplitude due to multiple shocks of the pandemic. The 3-year interest rate is greatly affected by market trading sentiment. Secondly, during this period, the willingness to issue 3-year bonds decreased compared with that before the pandemic. According to the statistical data of the primary issuance market, in 2020 and 2021, the issuance scale of 3-year treasury bonds, CDB bonds and credit bonds accounted for 9.1% and 10.3% of the total issuance scale in the same period respectively, significantly lower than 17.4% in 2018 and 13.2% in 2019. There was a relative shortage in the supply of 3-year bonds, which may cause the price elasticity increased.

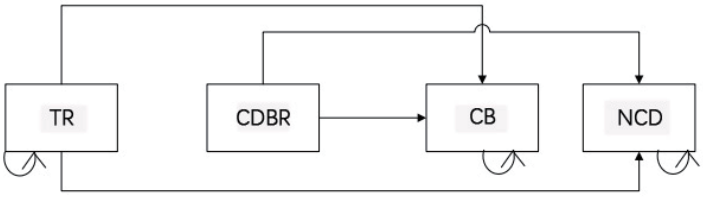

Figure 11 Transmissionrelationships of major interest rates during the period of monetary policy in response to the pandemic

4.3.5 Comparative Analysis of Bond Centrality and Network Centrality in Different Periods

The connectivity of a single type of bonds is defined as the centrality, which is used to assist in observing the impact of a single bond on other bonds in different periods. As shown in Figures 12 and 13, in different stages, the value of the centrality of each bond fluctuates greatly, and some bonds are strongly related to the stage. For example, the centrality of 1-year treasury bonds reaches the maximum value of 14 in the period of monetary policy tightening from November 4, 2016 to January 18, 2018, and the minimum value of 5 in the period of monetary easing from January 19, 2018 to January 23, 2020. The fluctuation range is as high as 9. The centrality of some bonds is relatively stable, and the stage characteristics are not significant. For example, the fluctuation range of the centrality of 10-year treasury bonds is only 2. Compared with the main bond market segments, the centrality of treasury bonds and CDB bonds has been maintained at a high level. Especially the centrality of 3-year, 5-year and 10-year CDB bonds is more stable, all above 10. In general, the impact of long-term treasury bonds and CDB bonds on the whole bond market is obvious at all stages, while other bonds are relatively less influential than treasury bonds and CDB bonds. Influence of other bonds are relatively poor stability, and vulnerable to fluctuations caused by changes in monetary policy.

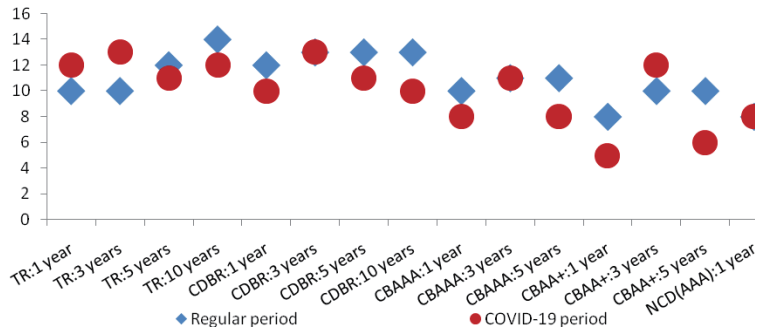

Figure 12 Comparison of bond centrality at different periods

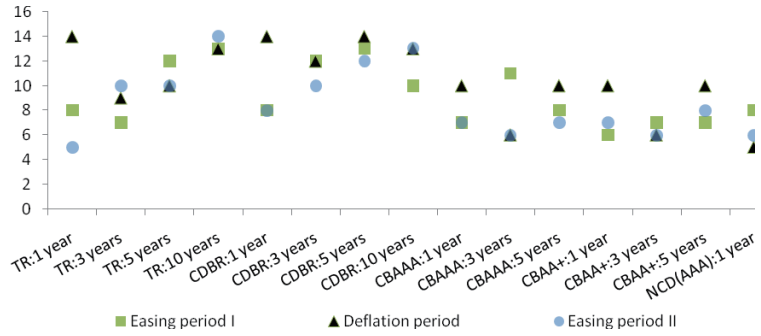

Figure 13 Comparison of bond centrality at different stages

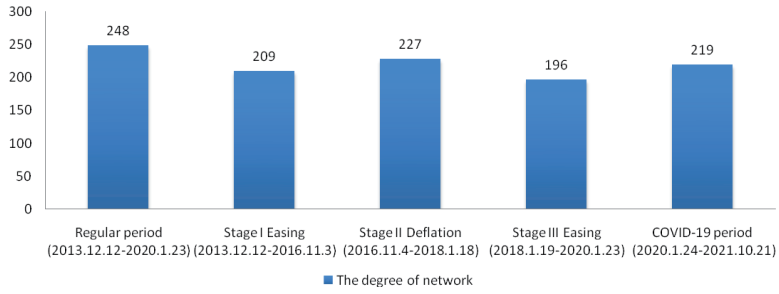

Figure 14 Degree comparison of bond networks at different stages

The number of all connected edges in the network is defined as the degree of the network. As shown in Figure 14, the degree of the whole network reflects that the transmission efficiency is also different in different stages. The degree of the network reaches 227 in the stage of monetary policy tightening. The degree of the network reaches 209 and 196 in the stage of monetary easing respectively. Compared with period of monetary policy tightening, the transmission efficiency decreases. Although the transmission efficiency of monetary policy in the pandemic period is not as good as that in the monetary tightening period, its transmission efficiency has also been significantly improved compared with the monetary easing stage.

5 Conclusions

Using the method of Granger causality complex network, this paper studies the price transmission mechanism in China's bond market. The empirical results show that the interest rate transmission mechanism among the main bond varieties in China is relatively significant and smooth, and the interest rates of CDB bonds and treasury bonds are at the core of the interest rate transmission network. In different periods of monetary policy, there are obvious differences in the overall transmission efficiency and internal transmission network of the bond market. First, in the stage of monetary policy easing, the transmission influence of medium - and long-term interest rates is significantly stronger than that of short-term interest rates. On the contrary, in the tightening stage of monetary policy, the short-term interest rate has a stronger transmission effect on interest rates in other markets and other terms. Second, national debt and national development bond are two important varieties of price discovery and price transmission in China's bond market. Especially in the tightening stage of monetary policy, the impact of national development bond on the bond market is significantly stronger than that of national debt. First, treasury bonds and CDB bonds are sovereign and quasi sovereign credit bonds, with low credit risk and the advantages of low occupation of venture capital and strong pledge ability. The two varieties have many investors in the bond market and have good liquidity; Second, due to different tax conditions and capital constraints faced by various types of investment institutions, for example, investment in treasury bonds and CDB bonds by public funds is exempt from income tax, and only investment in treasury bonds by commercial banks is exempt from income tax, transactional financial institutions prefer CDB bonds.

The highly market-oriented bond market cannot be separated from the efficient transmission relationship within the market. First, we should improve the liquidity of credit bonds and treasury bonds, eliminate market friction caused by tax, regulatory and other systems, and create a fair investment environment. Second, we should speed up the construction of treasury bond forward, credit default and other related financial derivatives markets. The third is to subdivide the credit rating system, build a multi-level credit bond market and improve the pricing ability of credit bonds. Bonds of different varieties and maturities in China show different characteristics in different periods. Due to space limitations, this paper does not conduct a more in-depth analysis on the reasons for the current situation of bond market transmission in China. Especially, the influence of institutional arrangements and market micro mechanisms on interest rate transmission is also a problem worthy of subsequent exploration.

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