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Ganchev, Alexander

Dimitar A. Tsenov Academy of Economics

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THE BEHAVIOUR OF CHINESE GOVERNMENT BOND YIELD CURVE BEFORE AND DURING THE COVID-19 PANDEMIC

Alexander GANCHEV *

Department of Finance and Credit, Dimitar A. Tsenov Academy of Economics, 2 Emanuil Chakarov Str., Svishtov, Bulgaria

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Abstract. The aim of the study is to investigate the behaviour of the Chinese government bond yield curve before and during the COVID-19 pandemic. Its methodology comprises the techniques of time series analysis, correlation analysis and dimensionality reduction. The main empirical results show that in the pandemic period, the behaviour of the Chinese government bond yield curve differs significantly from that before the outbreak of COVID-19. This is evidenced by the weaker correlations among the analysed yields, the presence of anomalies, heterogeneous behaviour and probable arbitrage opportunities at the long-term end of the studied yield curve, as well as the significant changes in the main factors of its dynamics. The research also reveals that prior to the COVID-19 pandemic, portfolios composed of Chinese government bonds could be well protected against interest rate risk even by using traditional parallel shift immunization techniques. However, after the outbreak of the COVID-19 pandemic the use of such techniques would be relatively effective for portfolios of Chinese government bonds with maturities between 1 and 5 years, while portfolios that include Chinese government bonds with maturities greater than 7 years should be either hedged against all the three factors of the yield curve dynamics or be used only for arbitrage strategies.

Keywords: Chinese government bond market, government bonds, yield curve, COVID-19.

JEL Classification: G11, G12, G15, H63.

Introduction

The COVID-19 pandemic has severely affected the global economy and disrupted the functioning of many of its industries. It particularly strongly influenced the activity of the pharmaceutical industry (Zaharieva et al., 2022), the tourism sector (Ilieva et al., 2021), the insurance industry (Erusalimov & Iliev, 2022), also affected the economic processes and planning in small and medium enterprises (Bogdanova et al., 2022) and even had an impact on the regional and cohesion policies of large supranational structures such as the European Union (Pavlova-Banova et al., 2022). Almost immediately, the COVID-19 crisis and the policies implemented to combat it caused turbulences in financial markets and, in particular, bond markets in many leading world economies (Kapalu & Kodongo, 2022). All of this has led to a slowdown in world economic growth, stagnation in international trade, and a global decline in employment (Khan et al., 2021). In this situation, the only world leading economy that managed to pass through the COVID-19 crisis without serious economic shocks is that of China. Moreover, as Zhao & Lin demonstrate in 2022, despite the fluctuations and volatility in economic development in the largest Asian economy observed over the past three years, the prospects for its growth and its characteristics until 2025 remain very good (Zhao & Lin, 2022). For this, the specific way the COVID-19 crisis has been addressed in China has sparked the interest of the scientific community to reveal the impact of the pandemic on the Chinese economy and Chinese financial markets. For example, a study by Liu from 2021 shows that despite the lack of visible economic problems the health crisis related to the novel coronavirus had an impact on the fiscal and monetary policy in China (Liu, 2021). In another study COVID-19 was found to lead to a negative shock on the Chinese stock market and have a positive impact on the entire bond market in China (Chen et al., 2021). On the other hand, the results from applying the methodology of Xu, Li & Wei, published in 2022 suggest that the pandemic situation does not have a significant impact on the yield of Chinese stocks and bonds (Xu et al., 2022). An event

* Corresponding author. E-mail: *a.ganchev@uni-svishtov.bg*

study analysis performed by Yi, Bai, Lyu, & Dai indicates that the COVID-19 crisis has increased the cumulative abnormal return of China's green bond market (Yi et al., 2021). However, the cited studies do not examine how the COVID-19 pandemic affects the behaviour of one of the most important indicators of the Chinese financial markets – the Chinese government bond yield curve, especially from the investment point of view. This is what motivates conducting scientific research on the topic and makes it relevant. Its scientific value could be further enhanced by the fact that enough time has elapsed since the outbreak of the novel coronavirus pandemic. This allows the current characteristics of the Chinese government bond yield curve to be effectively compared with those before the emergence of COVID-19. Such a comparative analysis will make the investigation of the behaviour of the Chinese government bond yield curve during the current pandemic more complete, and the conclusions from it – more robust. That is why, the aim of the present study is to investigate the behaviour of the Chinese government bond yield curve during the COVID-19 pandemic and to compare its characteristics with those before the outbreak of the coronavirus disease. This will allow making findings and conclusions useful to investors in Chinese government bonds.

1. Methodology and assumptions

The study on the behaviour of Chinese government bond yield curve before and during the COVID-19 pandemic will be conducted in several separate stages. Firstly, a comparative analysis of the studied bond yields and their volatility against the return and volatility of index that represents the state of the Chinese stock market will be performed. Secondly, a review of the volatility profile of the studied yield curve will be made. The research will then concentrate on the characteristics of the individual behaviour of the analysed yields. In particular, it will focus on investigating the presence of autocorrelation, checking for stationarity in their absolute changes, and revealing the characteristics of their probability distribution. The correlation in the behaviour of Chinese government bond yields and the main factors of their joint dynamics over time will also be investigated. Against this methodological framework, the study adopts the SSE Composite Index of the Shanghai Stock Exchange as a benchmark that represents the equity market of China. Its average continuously compounded daily return and its standard deviation are annualized on a basis of 250 business days in a calendar year. In turn, the influence of past observations of the studied yields on their current values is analyzed by using the autocorrelation function and partial autocorrelation function. Further, the Augmented Dickey-Fuller test is engaged in checking whether the absolute changes in the yields of Chinese government bonds follow a stationary process. In the probe for the characteristics of their probability distribution for the two considered periods a traditional analysis based on the coefficients of skewness, kurtosis as well as the Jarque-Bera coefficient for revealing the presence of a normal probability distribution is applied. In turn, standard correlation coefficients in combination with their t-tests are used to analyse the nature of the joint behaviour in the yields of considered maturity spectrum and to examine their statistical significance. Finally, the main factors of the yield curve dynamics are revealed through the econometric technique principal component analysis (PCA), which is applied to the values of the studied yields, i.e., the analysis is not using their absolute changes. Due to its higher methodological precision as the basis of the conducted principal component analysis, the correlation matrix among the yields of Chinese government bonds is chosen. For all calculations of the above-mentioned variables, coefficients and models, the statistical and econometric tools of EViews 13 software package are used.

2. Study period and used data

According to its purpose, the study covers two main periods in the functioning of the government bond market in the People's Republic of China – before the emergence of the COVID-19 and after the outbreak of the new coronavirus pandemic. For this reason, it becomes imperative to define their beginning and end. The beginning of the pre-pandemic period is associated with the growing fears about the possible financial crisis in the biggest Asian economy in mid-2015. These fears led to the collapse of the Chinese equity market that year. This made the People's Bank of China (PBOC) continue and intensify its loose monetary policy by lowering its Loan Prime Rate to 4.35% on 1 October 2015 (Wang et al., 2022). Combined with other measures taken by PBOC, this gradually calmed the financial markets in China. Thus, on 28 January, 2016, the SSE Composite Index of the Shanghai Stock Exchange reached its lowest value since the beginning of the stock market crash in 2015 and began to gradually rise. Therefore, the study assumes that after this date the financial markets in China begin to function in new financial conditions. For this reason, January 28, 2016 was chosen as the start of the pre-pandemic period. Its end is fixed on the date of December 31, 2019, on which the Chinese authorities officially admitted the presence of a new coronavirus infection (Reuters, 2019). All this means that the first period considered in the study includes 1433 calendar days. In turn, the date January 2, 2020 is chosen as the start of the pandemic period, which is also the first trading day for financial markets in China after the official start of the COVID-19 pandemic. The end of the pandemic period is fixed on November 11, 2022. The reason is that on that date, the official authorities in China announced the first major easing of the COVID-19 related travel restrictions (Reuters, 2022a). Moreover, as of November 2022, China has begun the process of further easing of its zero-COVID policy (Reuters, 2022b). That is why, the date November 11, 2022 marks a major shift in China's philosophy in the fight against the novel coronavirus. Therefore, this date could be chosen as the end of the pandemic period in the present study. Thus, the second period spans 1 044 calendar days, making it relatively equal in length to the pre-pandemic period.

Specifically, the analysis is focused on the yield to maturity yield curve of the bonds issued by the government of the People's Republic of China. The data on the analysed yields to maturity for the two studied periods are obtained from the database of the investment portal Investing.com and its World Government Bonds section (Investing.com, 2023a). This database contains information on yields with residual maturity between 1 and 30 years. For the same period, data on the value of the SSE Composite Index were also collected. Its source is again the Investing.com portal in its World and Sector Indices section (Investing.com, 2023b). Both used databases contain bond yields and index quotes on a daily basis.

3. Empirical results

The empirical investigation in the study begins with a comparative analysis of the return and risk of the Chinese equity market and the Chinese government bond yields and their volatility. It is clear from the data in Table 1 and Table 2, that for the pre-pandemic period, the Chinese equity market offered an average annual return that was comparable in size to the average annual return on Chinese government bonds. However, this occurred at over 43 times higher volatility. In the pandemic period, the average annual return of the Chinese equity market was very low. This is due to the decline of the SSE Composite Index that started at the end of 2021 and continued throughout the whole 2022. During this second period, the Chinese government bonds provided average annual yields in the range of 2.195–3.514% at the cost of over 65 times lower volatility than the volatility of SSE Composite Index. This is why, in general, the Chinese government bonds could be classified as a very good investment during the COVID-19 pandemic. More important for the present analysis, is the detailed comparison of the specifics in the behaviour of yields from the defined maturity spectrum before and after the outbreak of COVID-19. It is made on the basis of the examination of the average yield curves for the periods January 28, 2016 – December 31, 2019 and January 2, 2020 – November 11, 2022, respectively. They are derived using the information in Table 2 and presented graphically in Figure 1 and Figure 2.

Table 1. Total return, mean annual return and annual volatility of SSE Composite Index for the pre-pandemic and pandemic period (source: calculations of the author)

Indicator	Pre-pandemic period	Pandemic period
Total return	14.854%	0.068%
Mean annual return	3.629%	0.024%
Annual standard deviation	16.632%	17.999%

Figure 1 clearly shows that for the period before COVID-19 pandemic, the Chinese government bond yield curve had a relatively constant positive slope and it changed mainly parallel to itself in the upward and downward direction. This proves that before the emergence of the novel coronavirus, the debt markets in China had no serious doubts about the positive direction for development of the Chinese economy. In the context of COVID-19 pandemic, however, the situation with the studied yield curve is different. First of all, Figure 2 shows that it has maintained its positive slope, but has shifted downward on average by about 0.5% for all analysed maturities. This suggests that despite the restrictions imposed by the Chinese official authorities to prevent the spread of the SARS-CoV-2 virus, the debt market in China retains its expectations for economic growth in the country, albeit possibly at lower general price levels or lower/decreasing inflation. Furthermore, the range of variation of the yield curve shows that its dynamics for the pandemic period were more inhomogeneous than in the pre-pandemic period. This is supported by two

Table 2. Mean annual yield and annual volatility of the yield to maturity of Chinese government bonds for the pre-pandemic and pandemic period (source: calculations of the author)

Pre-pandemic period									
Indicator	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
Mean yield	2.84%	3.00%	3.05%	3.18%	3.36%	3.36%	3.69%	3.73%	3.88%
Standard deviation	0.48%	0.43%	0.42%	0.41%	0.37%	0.35%	0.35%	0.33%	0.32%
Pandemic period									
Indicator	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
Mean yield	2.20%	2.42%	2.52%	2.69%	2.91%	2.93%	3.29%	3.51%	3.51%
Standard deviation	0.39%	0.35%	0.33%	0.28%	0.23%	0.20%	0.25%	0.21%	0.23%

pieces of evidence. Firstly, the minimum yields between 1 and 5 years to maturity were relatively low. Secondly, the average yield curve at the 10-year residual maturity exhibited concave shape and emphasized convex shape at the 20-year residual maturity.

The raw data indicates that the low minimum yield of the considered short-term bonds is primarily due to market dynamics that occurred in the first pandemic year. It is produced mainly by the observed strong investors' interest in buying short-term Chinese government bonds with maturities between 1 and 5 years in the first half of 2020. This led to a sharp decline in their yields especially between the beginning of April and the end of May 2020. Later in that year, the slope of the yield curve of Chinese government bonds began to normalize, and between mid-November and the end of December, the difference between the 30-year and 1-year yields even fell below 1%. From the beginning of 2021 to the end of the second study period, the Chinese government bond yield curve became more stable, and its shape was closer to the average yield curve from Figure 2 with a spread between the longest and the shortest yields of around 1.261%. Nevertheless, during the entire pandemic period, the yields of 20-year bonds remained slightly higher than 30-year yields, and yields on China's 10-year government bonds remain relatively low. This suggests the presence of incorrectly priced bonds in the segment between 10 and 30 years to maturity which may indicate the presence of arbitrage opportunities. Such opportunities were not as clearly evident in the pre-pandemic period.

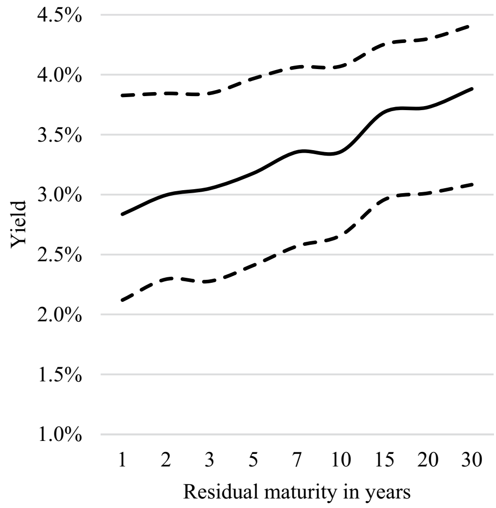

Figure 1. Average yield curve of the Chinese government bonds and its range of variation for the pre-pandemic period (source: calculations of the author)

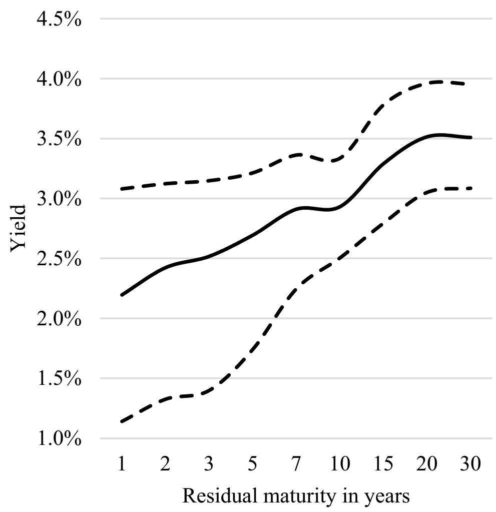

Figure 2. Average yield curve of the Chinese government bonds and its range of variation for the pandemic period (source: calculations of the author)

The observed characteristics of the variation of the yield curve for the two periods under study require a more detailed volatility analysis of the analysed yields. To this end, Figure 3 presents the term structure of volatility in the studied yields for the pre-pandemic and pandemic periods. The information in it shows that prior to the emergence of the COVID-19 crisis and after the start of 2020, the volatility of Chinese government bonds yields decreases as the residual term to maturity increase. However, some specifics for the two studied periods could be observed in the presented graphic information. First of all, Figure 3 shows that the volatility in the investigated yields is much higher in the pre-pandemic period compared to the pandemic period. The observed average excess volatility during the pre-pandemic period stands at approximately 43.24% for all considered maturities, and for some medium and long-term maturities it reaches or exceeds 60%.

What is more interesting, however, is that during the COVID-19 pandemic, the standard deviation profile of Chinese government bond yields has anomalies that are observable at 10, 15, and 30 term to maturity. These anomalies are expressed in the presence of a possibly lower than normal volatility of the 10- and 20-year bond yields, or in the relatively higher standard deviation of the

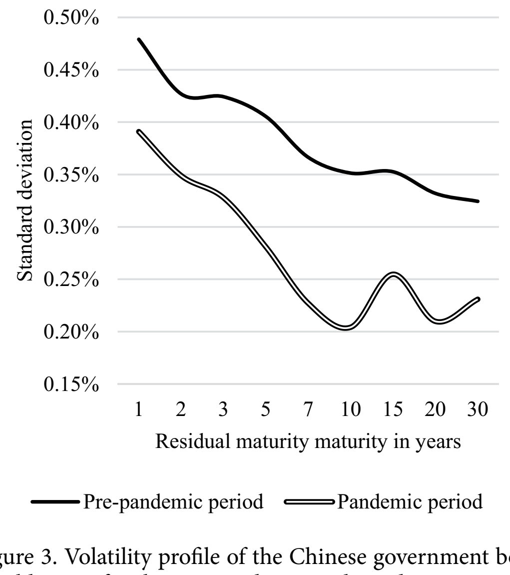

Figure 3. Volatility profile of the Chinese government bond yield curve for the pre-pandemic and pandemic periods (source: calculations of the author)

30-year and especially the 15-year bond yields. This suggests that under the COVID-19 conditions, the studied yield curve probably has distortions related to the incorrect valuation of long-term Chinese government bonds. However, these conclusions should not be considered absolute, due to the fact that the indicated anomalies in the yield volatility of long-termed bonds issued by the Government of People's Republic of China have a magnitude of around 0.5%, which is negligibly small.

Tables 3 and 4 present data for the values of the autocorrelation and partial autocorrelation coefficients for the analysed yields in the two periods under study. It can

Table 3. Value of the autocorrelation function for the yield to maturity of Chinese government bonds during the pre-pandemic and pandemic period (source: calculations of the author)

Pre-pandemic period									
Lag	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
1	0.997	0.997	0.998	0.998	0.998	0.998	0.997	0.996	0.998
2	0.994	0.994	0.995	0.995	0.995	0.994	0.994	0.993	0.995
3	0.990	0.991	0.991	0.991	0.992	0.991	0.990	0.990	0.991
4	0.987	0.987	0.987	0.987	0.988	0.987	0.987	0.987	0.988
5	0.983	0.983	0.983	0.983	0.985	0.984	0.983	0.984	0.984
6	0.979	0.979	0.979	0.979	0.981	0.980	0.980	0.981	0.981
Pandemic period									
Lag	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
1	0.994	0.996	0.995	0.994	0.993	0.992	0.988	0.985	0.994
2	0.989	0.990	0.989	0.987	0.986	0.984	0.980	0.975	0.987
3	0.982	0.984	0.983	0.980	0.978	0.975	0.974	0.968	0.980
4	0.975	0.978	0.976	0.973	0.970	0.965	0.968	0.962	0.973
5	0.967	0.971	0.968	0.965	0.962	0.956	0.960	0.955	0.966
6	0.958	0.964	0.960	0.955	0.953	0.945	0.953	0.949	0.959

Table 4. Value of the partial autocorrelation function for the yield to maturity of Chinese government bonds during the pre-pandemic and pandemic period (source: calculations of the author)

Pre-pandemic period									
Lag	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
1	0.997*	0.997*	0.998*	0.998*	0.998*	0.998*	0.997*	0.996*	0.998*
2	–0.065	–0.036	–0.125*	–0.122*	–0.121*	–0.188*	0.001	0.070	–0.094*
3	–0.031	–0.062	–0.074*	–0.076*	–0.055	–0.045	–0.034	0.003	–0.074*
4	–0.034	–0.071*	–0.046	–0.072*	–0.056	0.016	–0.002	0.006	–0.057
5	–0.032	–0.012	–0.016	0.045	0.047	0.038	–0.024	–0.022	0.046
6	–0.033	–0.011	–0.052	–0.037	–0.017	–0.040	0.017	–0.007	–0.027
Pandemic period									
Lag	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
1	0.994*	0.996*	0.995*	0.994*	0.993*	0.992*	0.988*	0.985*	0.994*
2	–0.024	–0.159*	–0.164*	–0.136*	–0.061	–0.063	0.155*	0.195*	–0.034
3	–0.074*	–0.046	–0.003	0.004	–0.008	–0.008	0.105*	0.094*	0.022
4	–0.063	–0.030	–0.031	–0.017	0.013	–0.052	0.026	0.100*	–0.047
5	–0.063	–0.028	–0.083*	–0.070*	–0.034	–0.006	–0.045	–0.010	–0.025
6	–0.096*	–0.099*	–0.114*	–0.103*	–0.098*	–0.051	–0.016	0.039	0.005

Note: * statistical significance at 95% confidence interval.

be seen from them that the values of the autocorrelation function are very high, both in the pre-pandemic and in the pandemic period. For example, during the pre-pandemic period, the values of the calculated autocorrelation coefficients exceed 0.97 for all considered lags, and during the pandemic they exceed a value of 0.94. Despite these facts the truly significant autocorrelation coefficients are indicated by the values of the partial autocorrelation function.

According to them, in both the pre-pandemic and pandemic periods, all autocorrelation coefficients with lag of 1 period are statistically significant. It is noteworthy that during the two analysed periods at some maturities there are significant autocorrelation coefficients with lags of up to 4 or even 6 periods. This indicates that certain parts of the considered maturity range tend to accumulate past macroeconomic and market information much more strongly than others. This is especially valid for medium-termed Chinese government bonds in the first period of the study, as well as for short-termed and some long-termed bonds in the second analysed period.

Table 5 contains information on the values of the Dickey-Fuller test statistic for the studied yields in the two predefined periods of the study. The results show that the value of the Dickey-Fuller criterion exceeds the threshold value for the two studied periods at a 99% confidence interval for all analyzed maturities. Moreover, during the pre-pandemic period the values of the analyzed criterion were on average 7.98 times lower than the threshold value, and during the pandemic period the values of the Dickey-Fuller test statistic are 7.1 times lower than −3.44.

This clearly suggests that the absolute changes in Chinese government bond yields follow a stationary process in both the pre-pandemic and pandemic periods. Therefore, it can be concluded that for the two analysed periods, the Chinese government bond yield curve is relatively stable on a daily basis and its short-term changes are relatively weak and, most importantly, there is no significant trend in their dynamics. These findings, coupled with the already revealed strong autocorrelation in the analyzed yields, indirectly confirm the conclusion drawn by Hong, Lin, & Wu from 2012, regarding the corporate bond market, that debt markets are predictable based on their past observations (Hong et al., 2012). This conclusion is particularly interesting from the perspective of the pandemic period because it indicates that Chinese government bonds have been stable and safe investment.

Table 6 provides additional insights into the study of the yield dynamics of Chinese government bonds for the pre-pandemic and pandemic periods. It presents the characteristics of the probability distribution of their absolute changes. As noted by some authors the probability distribution is an important measure of the uncertainty associated with the yield curve (Hackworth, 2008). The estimated Jarque-Berra coefficients from the pre-pandemic period show that then the probability distribution of the absolute changes in Chinese government bond yields deviates significantly from normal. The stronger factor for this is their very high kurtosis, which significantly exceeds the value indicating the presence of a normal probability distribution. Against this background, their positive skewness for all analysed maturities except the 10-year one means that, the probability distribution of the changes in the Chinese government bond yields generally approaches the lognormal distribution. This means that the absolute changes in the analysed yields were mostly small in the pre-pandemic period. This is not the case during the pandemic period. Through it, the absolute changes in Chinese government bond yields again exhibit a probability distribution that is not normal. Here, however, it shows an emphasized left skewness for the bonds with maturities between 5 and 30 years, indicating that the change in these yields was mostly large during the second period under study.

Table 7 shows the correlation coefficients among the studied yields for the pre–pandemic and pandemic periods.

Table 5. Values of augmented Dickey-Fuller test statistic for the absolute changes in the yield of Chinese government bonds for the pre-pandemic and pandemic period (source: calculations of the author)

Pre-pandemic period									
Indicator	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
T-Stat.	−29.87	−31.61	−19.09	−15.04	−28.55	−24.79	−33.10	−35.58	−29.44
Test critical values for 1% level	−3.44	−3.44	−3.44	−3.44	−3.44	−3.44	−3.44	−3.44	−3.44
Pandemic period									
Indicator	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
T-Stat.	−27.17	−22.91	−23.01	−23.81	−25.79	−25.75	−24.41	−20.13	−26.82
Test critical values for 1% level	−3.44	−3.44	−3.44	−3.44	−3.44	−3.44	−3.44	−3.44	−3.44

Table 6. Probability distribution characteristics of the absolute changes in the yield of Chinese government bonds for the pre-pandemic and pandemic period (source: calculations of the author)

Pre-pandemic period									
Indicator	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
Skewness	2.21	0.59	0.93	0.52	0.23	–0.23	0.41	0.00	0.68
Kurtosis	31.67	12.68	17.28	10.72	7.16	6.10	12.43	9.89	12.06
Jarque-Bera	37627*	4248*	9268*	2711*	783*	439*	4007*	2124*	3754*
Pandemic period									
Indicator	Residual maturity in years								
	1	2	3	5	7	10	15	20	30
Skewness	1.39	0.13	0.31	–0.05	–0.46	–0.91	–0.28	–0.54	–1.19
Kurtosis	20.09	10.15	12.09	5.86	8.72	11.81	8.78	26.73	11.72
Jarque-Bera	9253*	1579*	2560*	253*	1035*	2500*	1043*	17429*	2523*

Note: * significance at 99% confidence interval.

Table 7. Correlation dependencies among the yields on Chinese government bonds for the pre-pandemic and pandemic period (source: calculations of the author)

Pre-pandemic period									
Residual maturity in years	1	2	3	5	7	10	15	20	30
1	1								
2	0.982*	1							
3	0.969*	0.989*	1						
5	0.951*	0.978*	0.986*	1					
7	0.932*	0.965*	0.978*	0.984*	1				
10	0.924*	0.952*	0.962*	0.969*	0.990*	1			
15	0.938*	0.957*	0.965*	0.963*	0.977*	0.984*	1		
20	0.938*	0.958*	0.964*	0.962*	0.976*	0.980*	0.991*	1	
30	0.878*	0.915*	0.938*	0.950*	0.972*	0.969*	0.966*	0.967*	1
Pandemic period									
Residual maturity in years	1	2	3	5	7	10	15	20	30
1	1								
2	0.963*	1							
3	0.950*	0.988*	1						
5	0.946*	0.985*	0.990*	1					
7	0.942*	0.955*	0.957*	0.975*	1				
10	0.920*	0.924*	0.910*	0.943*	0.979*	1			
15	0.826*	0.801*	0.780*	0.814*	0.902*	0.927*	1		
20	0.864*	0.860*	0.854*	0.872*	0.921*	0.903*	0.886*	1	
30	0.797*	0.765*	0.748*	0.779*	0.882*	0.908*	0.979*	0.882*	1

Note: * significance at 99% confidence interval.

It is obvious that in both periods the correlations among all yields from the studied maturity range are very strong. Moreover, all correlation coefficients are statistically significant at 99% confidence interval. What is notable is that, with few exceptions, the relationship among the different yields weakens slightly during the pandemic period. The largest decline is observed in the correlation coefficients between long-term and short-term, long-term and medium-term yields, and among the different long-term yields. In practice, this suggests that the Chinese government bond yield curve exhibits more inhomogeneous dynamics during the pandemic period, especially at its long-term end. This conclusion is confirmed by the principal component analysis of the dynamics of the yield curve under study, which is presented in Table 8 and Figures 4 and 5. The data show that for the period from January 28, 2016 to December 31, 2019, more than 99.17% of the dynamics of the Chinese government bond yield curve can be explained by its first three principal components.

As Figure 4 shows, they can be associated with the three main factors of the yield curve dynamics – level, slope and curvature, first discovered by Litterman and Scheinkman (Litterman & Scheinkman, 1991). Moreover, the level factor in the pre-pandemic period, which is associated with the influence of inflation in the scientific studies (Kaya, 2014), has an extremely high contribution to the overall dynamics of the analysed yield curve, with a share of over 96.6%. On the other hand, the second principal component, which is primarily associated with economic growth (Abdymomunov, 2013), causes the slope of the analysed yield curve in the pre-pandemic period. However, its contribution is only 1.96%. As Abdymomunov's 2013 study shows, the third principal component could also be attributed to the influence of economic growth, but according to an earlier study by Rudebusch & Wu, it can also be associated with the type of central bank's monetary policy (Rudebusch & Wu, 2008). The data in Table 8 and Figure 4 show that it contributes to the joint dynamics of the studied yields only by 0.61%, but makes the studied yield curve concave in the region around 5 years residual maturity and causes its convexity in the region around 20 years term to maturity. The above conclusions differ significantly from the findings of previous studies, according to which the first three principal components of the Chinese government bond yield curve explain only 90% of its dynamics (Hu & Lin, 2007). Moreover, the conclusions from the Hu & Lin's study that traditional portfolio immunization techniques are not applicable to Chinese government bonds are also incorrect as the estimated impact of level factor during the pandemic period is almost 97%.

Table 8. Principal component analysis of the dynamics in the Chinese government bond yield curve for the pre-pandemic and pandemic period (source: calculations of the author)

Pre-pandemic period			
Component	Eigenvalue	Share	Cumulative share
1	8.694	96.60%	96.60%
2	0.177	1.96%	98.56%
3	0.055	0.61%	99.17%
4	0.027	0.30%	99.47%
5	0.015	0.17%	99.64%
6	0.012	0.13%	99.77%
7	0.010	0.11%	99.88%
8	0.007	0.08%	99.96%
9	0.004	0.04%	100%
Pandemic period			
Component	Eigenvalue	Share	Cumulative share
1	8.179	90.88%	90.88%
2	0.547	6.08%	96.97%
3	0.123	1.36%	98.33%
4	0.072	0.81%	99.13%
5	0.035	0.38%	99.52%
6	0.020	0.23%	99.74%
7	0.015	0.16%	99.91%
8	0.005	0.06%	99.96%
9	0.003	0.04%	100.00%

The data from the second part of Table 8 and the information in Figure 5 show that there is a significant change in the dynamics of Chinese government bond yield curve for the period from January 2, 2020 to November 11, 2022. First of all, the combined impact of the first three principal components of its dynamics decreases, albeit slightly, by 0.84% to a level of 98.33%. More interestingly, however, the influence of the parallel shift in the yield curve drops dramatically to 90.88%, which is accompanied by an increase in the influence of the second and third principal components to 6.08% and

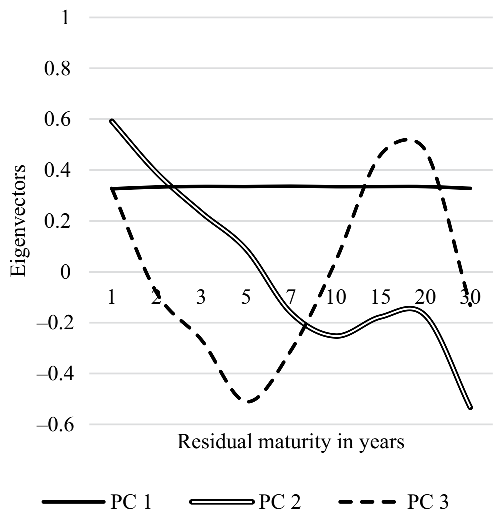

Figure 4. Eigenvectors of the three main components of the dynamics of Chinese government bond yield curve for the pre-pandemic period (source: calculations of the author)

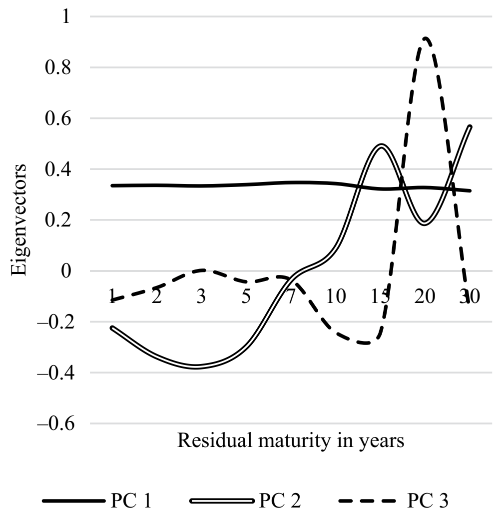

Figure 5. Eigenvectors of the three main components of the dynamics of Chinese government bond yield curve for the pandemic period (source: calculations of the author)

1.36%, respectively. Therefore, China's economic growth prospects and its character have become a much more significant factor for the dynamics of the analysed yield curve during the pandemic period.

Another significant difference can be seen in the nature of the influence of the second and the third principal components. While in the pre-pandemic period the second main component (the economic growth) pushed the short-term yields up and long-term yields down, in the pandemic period it caused a significant decrease in short-term yields and an increase in long-term yields. On the other hand, in the pandemic period, the third principal component causes a clearly observed positive convexity in the analysed yield curve, but only for maturities around 20 years. All this shows that the behaviour of Chinese government bond yield curve in the pandemic period is noticeably different from that before the outbreak of the pandemic. This certainly requires a serious change in the way portfolios of Chinese government bonds are managed.

Conclusions

The study conducted presents an empirical analysis of the behaviour of the Chinese bond yield curve before and after the outbreak of the COVID-19 disease. The findings indicate that even after the inception of the COVID-19 pandemic, Chinese government bonds were a stable, relatively safe and profitable investment that offered a much better risk-return ratio than the Chinese equity market during the same period. The latter conclusion is also valid for the pre-pandemic period. The remaining important conclusions of the research could be formulated as follows:

First. The behaviour of the Chinese government bond yield curve during the COVID-19 pandemic is different from that before the pandemic. Although the observed difference is not very large, it indicates the practically different conditions in which the Chinese government bond market has operated since the beginning of 2020.

Second. During the pandemic period, a distinctive anomaly was observed in the Chinese government bond yield curve, which consisted in the lower yield of the 30-year Chinese government bonds compared to the 20-year bonds. Moreover, this anomaly persisted after mid-2021, which may have been driven by the increased interest of investors in the longest-term Chinese government bonds. On the other hand, the anomaly itself indicates the potential for 30-year Chinese government bond prices to decline, or the prices of 20-year Chinese government bonds to rise in the future. It is important to note, however, that given the persistence of the observed anomaly, these possibilities are currently only theoretical.

Third. The entire Chinese government bond yield curve could be effectively predicted based on its past observations. The stated conclusion is strongly valid for both the pre-pandemic and the pandemic period at a lag of one period.

Fourth. The probability distribution of the absolute changes in the analysed yields revels a serious shift in the risk profile of medium and long-term Chinese government bonds during the pandemic period. In the COVID-19 environment, their yields tend to change by a larger magnitude compared to the yields of the shorter-term bonds. In contrast, during the pre-pandemic period, the observed yields mostly changed only slightly, except for the 10-year bond yields, the absolute changes of which could be defined as predominantly large.

Fifth. The dynamics of the Chinese government bond yield curve in the pandemic period differ significantly from those before the outbreak of the COVID-19 pandemic. This is due to the weaker correlations among the analysed yields and the significant changes in the explanatory power in the three main components of the yield curve dynamics. A particularly significant change is observed in the influence of the slope and curvature components at the long-term end of the analysed yield curve.

Sixth. Despite the decline in its explanatory power, the most important factor in the dynamics of the Chinese government bond yield curve during the COVID-19 pandemic is the level factor, i.e. the inflation. The influence of the slope factor during the pandemic period suggests that in the COVID-19 environment, China's debt markets did not expect the country's economic growth to deteriorate.

Seventh. During the COVID-19 pandemic, investment portfolios of Chinese government bonds that are immunized only to the level change in the yield curve would be again effective, especially if they include only bonds with residual maturities between 1 and 5 years. However, portfolios that include Chinese government bonds with maturities greater than 7 years should be hedged against all three components of the yield curve dynamics. This represents a significant difference from the pre-pandemic period, where portfolios composed of all possible Chinese bonds would have been protected against interest rate risk only through traditional parallel shift immunization.

Eighth. The heterogeneous characteristics observed in the behaviour of the long-term end of the analysed yield curve and the anomalies in its volatility during the pandemic period suggest the potential for arbitrage opportunities and increased interest rate risk in the Chinese government bonds with maturities between 10 and 30 years. These arbitrage opportunities or higher interest rate risk were either absent or present to a much lesser extent before the COVID-19 pandemic. However, the lower correlation between short-term and long-term yields and the significant difference in the skewness coefficients for yield changes in bonds with maturities between 1 and 3 years compared to those with maturities between 5 and 30 years indicate that arbitrage opportunities may exist between short-term and medium/long-term Chinese government bonds.

The key findings of the empirical research provide a solid picture of the dynamics in the Chinese government bond yield curve in both the pre-pandemic and pandemic periods. However, the study has two general limitations stemming mainly from its purpose. Firstly, it does not reveal the causes of the anomalies in the long-term end of the analysed yield curve during the current pandemic, and secondly, it does not investigate the possible application of various investments strategies that include Chinese government bonds. That is why these two areas can be identified as directions for future research regarding the behaviour of Chinese government bond yield curve.

Disclosure statement

The study is solely intended for scientific purposes. It is not funded by scientific and governmental organizations or financial institutions with any financial interest in Chinese government bonds. The author has no investments in Chinese government bonds and his findings reflect only the empirical results of the methodology used in the study. Furthermore, none of the conclusions drawn from the conducted research should be considered as a recommendation for making investment decisions.

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