Working Paper No. 1044

Empirical Models of Chinese Government Bond Yields

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February 2024

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Acknowledgements: The authors thank participants at various workshops for their comments.
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Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.
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ISSN 1547-366X

ABSTRACT

This paper econometrically models the dynamics of long-term Chinese government bond (CGB) yields based on key macroeconomic and financial variables. It deploys autoregressive distributive lag (ARDL) models to examine whether the short-term interest rate has a decisive influence on the long-term CGB yield, after controlling for various macroeconomic and financial variables, such as inflation or core inflation, the growth of industrial production, the percentage change in the stock price index, the exchange rate of the Chinese yuan, and the balance sheet of the People's Bank of China (PBOC). The findings show that the short-term interest rate has an economically and statistically significant effect on the long-term CGB yield of various maturity tenors. John Maynard Keynes claimed that the central bank's policy rate exerts an important influence over long-term government bond yields through the short-term interest rate. The paper's findings evince that Keynes's claim holds for China, implying that the PBOC's actions are a driver of the long-term CGB yield. This means that policymakers in China have considerable leeway in fiscal and monetary operations, government deficit finance, and central government debt management.

KEYWORDS: Chinese Government Bonds; Long-term Interest Rates; Short-term Interest Rates; People's Bank of China; John Maynard Keynes

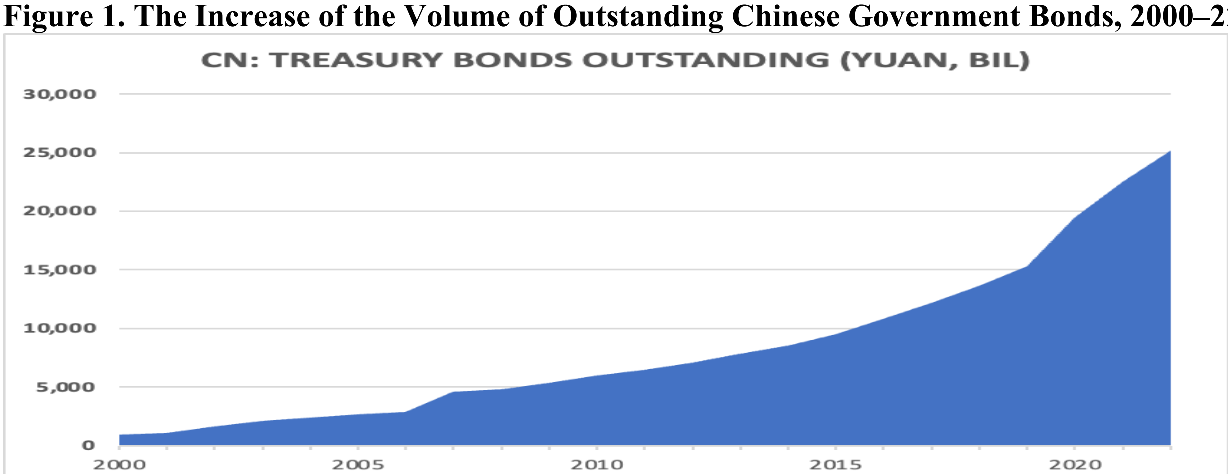
JEL CLASSIFICATIONS: E43; E50; E58; E60; G10; G12

SECTION 1: INTRODUCTION

This paper econometrically models the dynamics of long-term Chinese government bond (CGB) yields based on key macroeconomic and financial variables. It deploys autoregressive distributive lag (ARDL) models to examine whether the short-term interest rate has a decisive influence on the long-term CGB yield, after controlling for various macroeconomic and financial variables.

With the rapid growth of the Chinese economy over the past several decades, China's capital markets have expanded notably. While investors and analysts have often focused on equities, the rise of capital markets has also resulted in the development of China's bond market. In particular, the volume of outstanding CGBs has risen dramatically, from merely 915 billion yuan in 2000 to 25,194 billion yuan in 2022, as shown in Figure 1. (The sources of the data in the figures are listed in Table 1.) During the same period, the claims on the central government have risen from nearly 6 percent of nominal GDP in 2000 to 37 percent of nominal GDP in 2022. This sharp increase in outstanding CGBs, the growing importance of the bond market, and the ongoing financialization of the Chinese economy warrant a detailed empirical study of the dynamics of government bond yields in China.

Figure 1. The Increase of the Volume of Outstanding Chinese Government Bonds, 2000–22



This paper models CGB yields from a Keynesian perspective. It shows that the short-term interest rate has an important influence on long-term government bond yields of various maturity tenors, after controlling for relevant macroeconomic and financial variables. The findings of the study lend credence to John Maynard Keynes's (1930, 352–63) claim that the central bank's policy rate has an influential role in setting the long-term interest rate on government bonds, mainly through its effect on the short-term interest rate, which generally moves in lockstep with the central bank's policy rate.

Keynes argued that "the influence of the [current] short-term rate of interest on the long-term rate is much greater than anyone [...] would have expected" (353) and that "there is no reason to doubt the ability of a central bank to make its short-term rate of interest effective in the [government bond] market" (363). He maintained that investors rely on current conditions and trends to formulate their outlook because of ontological uncertainty about the future. He wrote: "By 'uncertain' knowledge […] I do not mean merely to distinguish between what is known for certain from what is only probable. […] About these matters there is no scientific basis on which to form any calculable probability whatever. We simply do not know. Nevertheless, the necessity for action and for decision compels us practical men to do our best to overlook this awkward fact …." (Keynes 1937, 213–14).

While the standard view is that the long-term interest rate depends not just on the current short-term interest rate, but also on the path of future short-term interest rates and perhaps some term premium, Keynes (1937) emphasized the exorbitant influence of the current short-term interest rate on the long-term interest rate. He recognized that, even for well-informed investors, their outlook tends to be "oversensitive […] to the near future" (359). He held that investors "know almost nothing about the more remote future" and that their "ignorance about […] the remote future is much greater than knowledge" (360) about the current economic and market conditions. This leads investors to give much greater prominence to current data and current economic conditions than anything else. Moreover, Keynes (1930, 2007 [1936]) realized that there is herding in financial markets and that investors are motivated by the ebb and flow of animal spirits. He shrewdly noted that "as long as a crowd can be relied on to act in a certain way, even if it is misguided, it will be to the advantage of the better-informed professional [investors] to act in the same way—a short period ahead" (1930, 357–61).

Keynes's (1930, 352–62) claims about interest rate dynamics had empirical foundations. He relied on Riefler's (1930) statistical analysis of interest rate behavior in the United States in the 1920s, as well as his own analysis of interest rates in the United Kingdom's bond market around the same period. Riefler (1930, 123; cited in Keynes 1930, 354–55) summarized his own findings thusly: "the surprising fact is not that [long-term] bond yields are relatively stable in comparison to short-term [interest] rates, but they have reflected fluctuations in short-term [interest] rates so strikingly and to a such a considerable extent." In concordance with Keynes's astute insights, Akram (2022a, b) has presented some simple models that formalize the ties between the long-term interest rate on government bonds and the central bank's policy rate through its effect on the short-term interest rate.

In recent years, empirical studies of government bond yields have provided ample evidence that Keynes's claim of the close connection between the short-term interest rate and the long-term interest rate holds in advanced countries, such as the US, the UK, the member countries of the eurozone, Japan, Canada, Australia, and several selected emerging markets, such as India, Brazil, and Mexico. Lavoie (2014, 186–88, 232–34) provides a selected overview of the Keynesian literature on interest rate dynamics. The relationship between the short-term and long-term interest rate has been examined in advanced countries, such as the US (Akram and Li 2020a) and Japan (Akram and Li 2020b, 2020c), and emerging markets, such as Brazil (Akram and Uddin 2021) and Mexico (Akram and Uddin 2022). Vinod, Chakraborty, and Karun (2014) examine government bond yields in India. They uncover that monetary policy, inflation expectations, and the volatility of capital flows affect the long-term interest rate, while the fiscal deficit has no discernable effect. Simoski (2019) corroborates that the short-term interest rate is the key determinant of the long-term interest rate in several Latin American countries, including Brazil, Mexico, and Colombia. Gabrisch (2022) has modeled interest rate dynamics in six financial markets, finding that the long-term interest rate is related to the short-term interest rate in these markets. Kim's (2020, 2021) two separate panel-data studies of nine eurozone countries and seventeen advanced countries clarifies that, in countries with monetary sovereignty, the central bank's policy rate influences the long-term interest rate, usually irrespective of the government debt ratio and market sentiment. While no similar studies have been conducted for CGBs, Akram and Mamun (2023) have demonstrated that the short-term interest rate has a statistically significant and economically relevant effect on market interest rates, such as long-term swap yields, in China.

The direction of Granger causality between the short-term interest rate and the long-term interest rate is an active topic of contention among Keynesian economists. Pollin (1991; 2008) has argued that market forces, rather than a central bank's actions, determine market interest rates. Li and Su (2021) have proclaimed that the relationship between the short-term and long-term interest rates is asymmetric. They contend that the direction of temporal precedence varies in different financial markets. The findings from Rahimi, Lavoie, and Chu (2016) and Rahimi, Chu, and Lavoie (2017) regarding the US and Canada are mixed. They report evidence of bidirectional causality, but they also note that in recent US business cycles, the short-term interest rate Granger causes the fed funds target rate. In contrast, besides the studies mentioned earlier, Atesogulu (2003–4; 2005), Cook (2008), Deleidi and Levrero (2020), and Payne (2006–7) evince that the short-term interest rate rules the roost and has an important role in setting the long-term interest rate, whether it is the long-term government bond yield or some other benchmark market interest rate. Recently there has been a spate of studies revealing that the Keynesian conjecture about the tight connection between the short-term interest rate and long-term interest rate holds for long-term interest rate swap yields denominated in different currencies.

This brief survey of the literature reveals that there are vigorous debates regarding the determinants of interest rate dynamics. This suggests that the econometric modeling of the long-term interest rate on CGBs is worthwhile because it can further illuminate the interest rate dynamics in emerging markets, and provide useful insights for policymakers regarding monetary transmission mechanisms, fiscal and monetary operations, and central government debt management. It can be useful for both domestic and foreign investors for asset allocation and risk management.

The paper is organized as follows. Section 2 presents the macroeconomic backdrop to the evolution of CGB yields during the study period. Section 3 describes and summarizes the time series data used in the study, undertaking tests to divulge the time series properties of these variables. Section 4 covers the econometric models used to analyze the interest rate dynamics and reports the findings of the estimated models. Section 5 concludes with a summary of the findings and their implications for economic policy in China.

SECTION 2: THE MACROECONOMIC BACKDROP TO THE EVOLUTION OF CGB YIELDS

It is apposite to begin with a review of the macroeconomic backdrop to the evolution of the CGB yields during the study period (2007–23).

Figure 2 displays the evolution of government bond yields in China during the study period. It shows that CGB yields varied substantially, ranging from 1.3 to 4.7 percent.

Figure 2. The Evolution of Government Bond Yields in China, 2007M01–2023M08

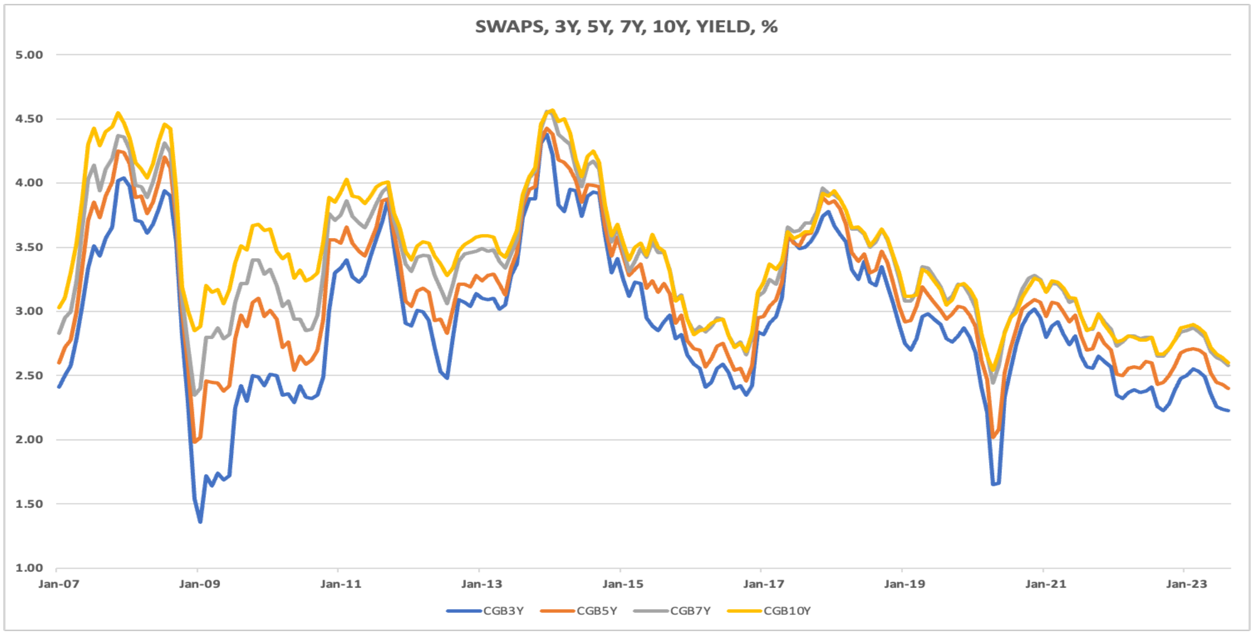
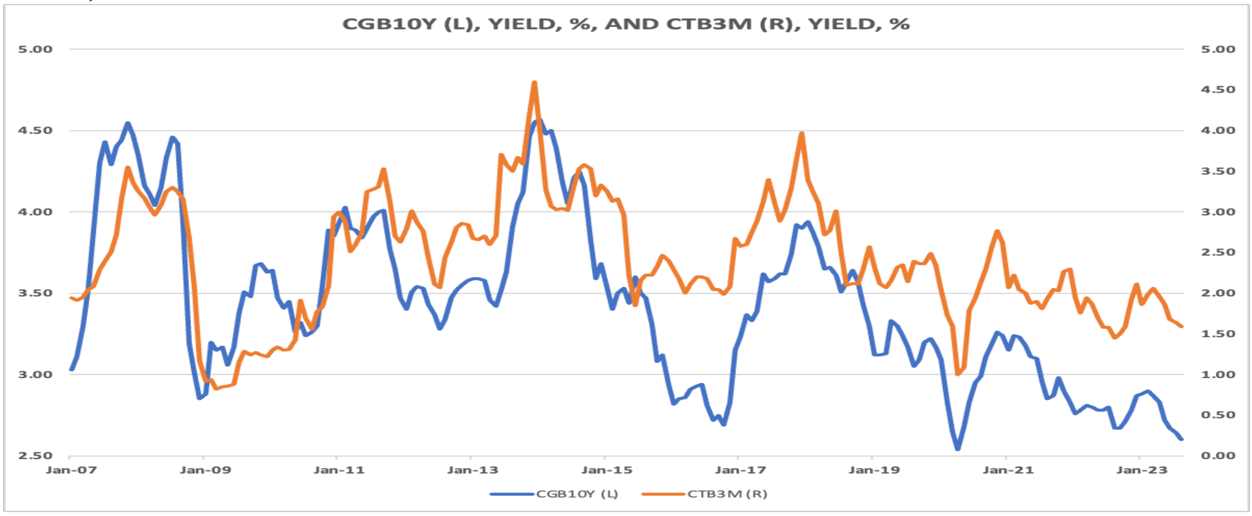


Figure 3 shows the coevolution of the 10-year CGB yield and the 3-month Treasury yield. It reveals that the long-term government bond yield and the short-term interest rate are positively and strongly correlated in China.

Figure 3. The Coevolution of 10-year Government Bond Yields and 3-month Treasury Bill Yields, 2007M01–2023M08



Inflation and government bond yields also tend to move in tandem. Figure 4 reveals that the 10-year CGB yield tended to be high (low) when core consumer price index (CPI) inflation is high (low). The correlation between the CGB yield and core inflation is positive, but not so high. Moreover, there are periods when the CGB yield and inflation tend to move in opposite directions and periods when the CGB yield may lead or lag core CPI inflation.

Figure 4. Inflation and Core Inflation in China, 2007M01–2023M08

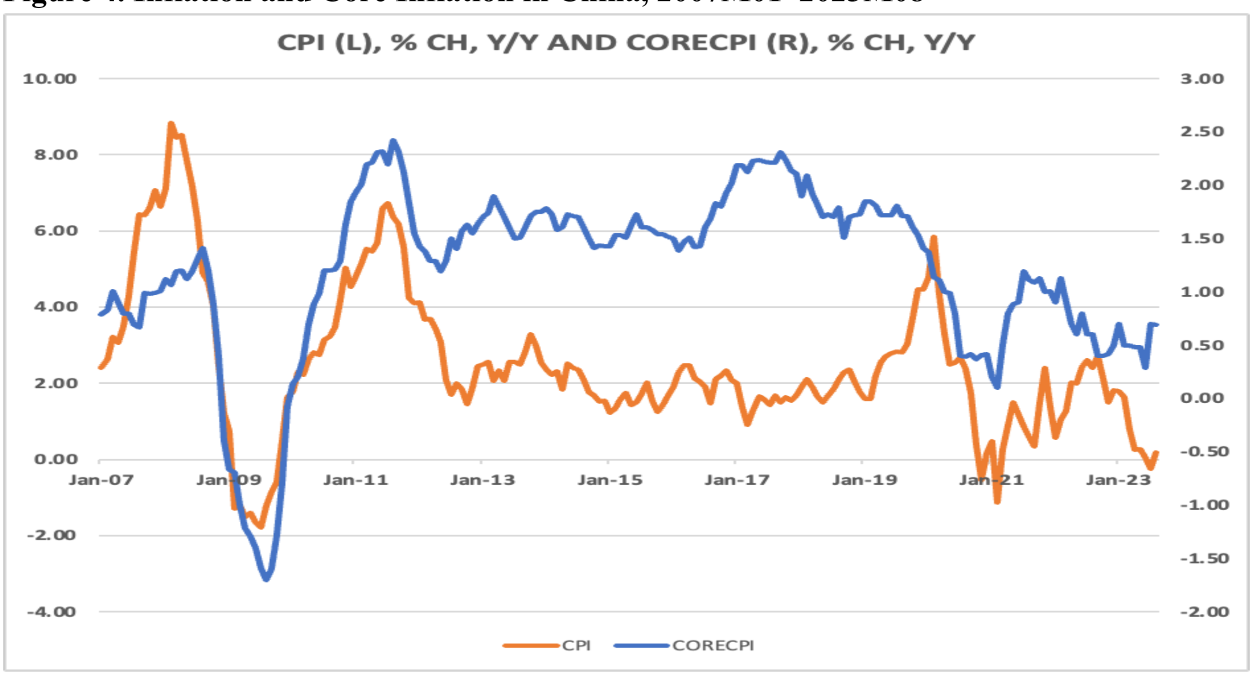


Figure 5 exhibits the growth of industrial production in China. Industrial production increased at an average pace of 9.2 percent year-over-year during the study period. Industrial production slowed during the global financial crisis, declined during the lockdowns at the start of the COVID-19 pandemic, and briefly declined again during the later lockdowns in March–April of 2022.

Figure 5. The Growth of Industrial Production in China, 2007M01–2023M08

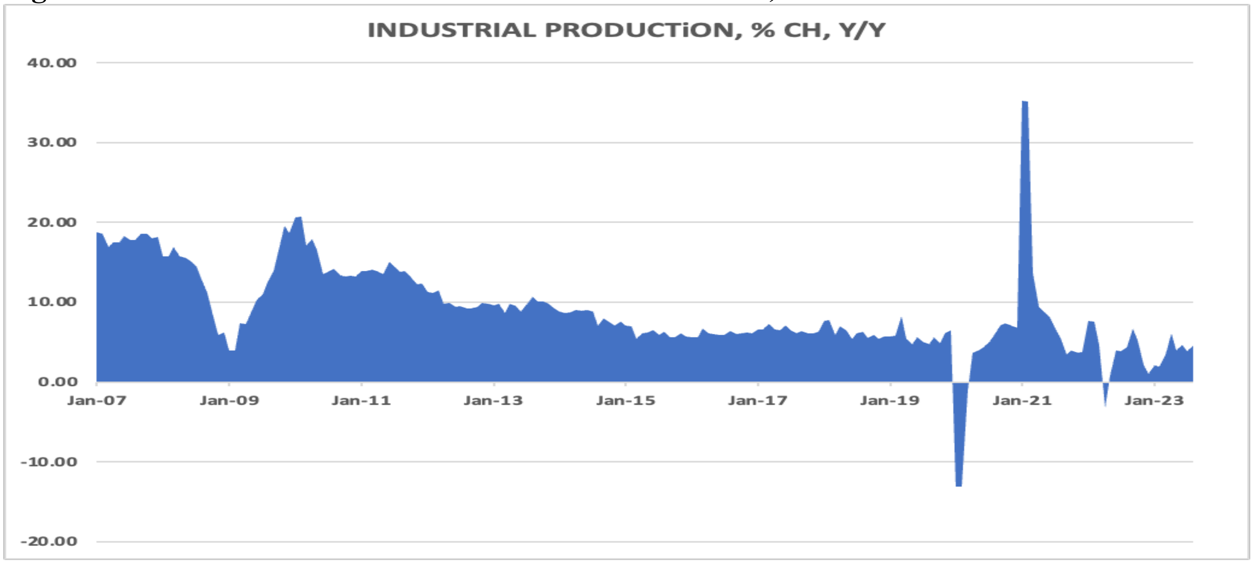


Figure 6 traces the evolution of the exchange rate of the Chinese yuan against the US dollar. It shows that, during the first year of the study period, the yuan appreciated against the dollar but it remained steady during the global financial crisis. The yuan again appreciated from mid-2010 to early 2014. From early 2016 to the end of the study period, the yuan fluctuated in the range between 6.2 to 7.3 yuan per dollar. The yuan's exchange rate is not determined by market forces, as the Chinese authorities have imposed a regime of managed float for the exchange rate.

Figure 6. The Evolution of the Exchange Rate of the Chinese Yuan, 2007M01–2023M08

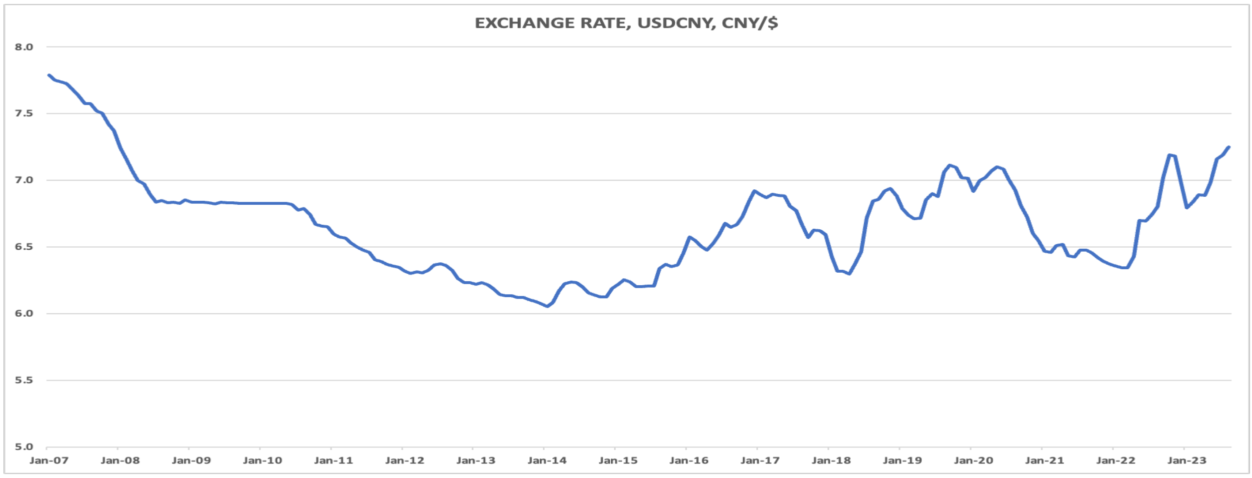


Figure 7 heralds the evolution of two stock price indexes in China, the Shanghai and the Shanghai-Shenzhen 300. The stock price indexes in China fluctuated considerably and have undergone some large appreciations followed by marked corrections several times during the study period.

Figure 7. The Evolution of the Shanghai and the Shanghai-Shenzhen 300 Stock Price Indexes, 2007M01–2023M08

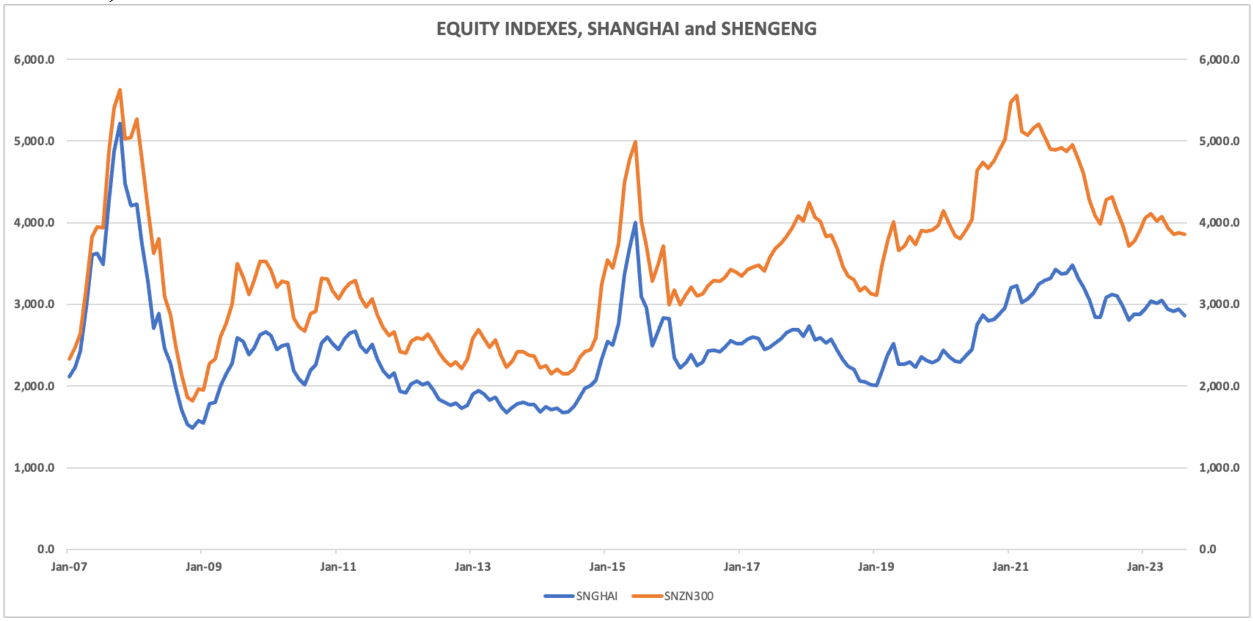
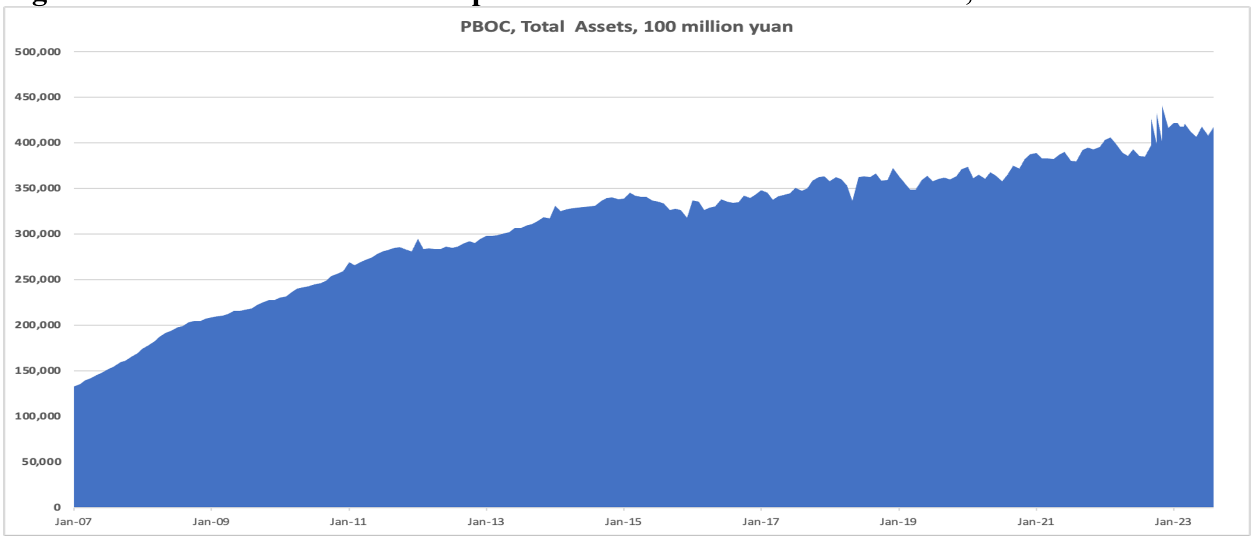


Figure 8 displays the evolution of the total assets on the PBOC's balance sheet. It shows the size of the PBOC's balance sheet has expanded substantially during the study period, rising from 13.2 trillion yuan in January 2007 to 41.7 trillion yuan in August 2023. The steady growth and elevated size of the PBOC's balance sheet conveys the vital role of the central bank in the country's financial system. It is also a testimony to the PBOC's crucial role in trying to ensure stability in China's financial system and financial markets.

Figure 8. The Evolution of the People's Bank of China's Balance Sheet, 2007M01–2023M08



SECTION 3: DATA DESCRIPTION AND THE TIME SERIES PROPERTIES OF THE VARIABLES

Table 1 summarizes the data used in the econometric models estimated in the paper. The first column lists the labels of the variables. The second column gives a description of the data and the date range of the time series. The third column contains information about the frequency of the data and whether higher-frequency data have been converted to monthly frequency. The final column provides the primary sources of the data.

The paper uses monthly time series data from January 2007 to August 2023. Each variable consists of 200 observations. There are two variables for the short-term interest rate: the 3-month and 6-month Treasury bill rates. The long-term bond yields are the CGB yields of various maturity tenors (3-, 5-, 7-, and 10-year) across the Treasury yield curve. Two different measures of inflation are used. These are the year-over-year percentage changes in the total consumer price index (CPI), which is the headline inflation, and the CPI excluding food and energy, which is the core inflation. Economic activity is gauged in the growth of industrial production, obtained as the year-over-year percentage change. Several financial variables have been incorporated in the dataset. There are two different indexes for the stock market, namely, the Shanghai stock price index and the Shanghai-Shenzhen 300 stock price index. The two measures of the exchange rate of Chinese yuan are as follows: CNY per US dollar (USDCNY), and CNY per euro (EURCNY). The PBOC's balance sheet is expressed as the total assets of the PBOC. The first difference of the natural log of several variables are used in the econometric models if their percent change from one month to the next is the relevant metric of interest for modeling purposes.

Table 1. Summary of the Data

Variables	Data description, date range	Frequency	Source
Short-term interest rates			
CTB3M	Chinese Treasury bill, 3-month, yield, %, average, January 2007–August 2023	Daily; converted to monthly	People's Bank of China
CTB6M	Chinese Treasury bill, 6-month, yield, %, average, January 2007–August 2023	Daily; converted to monthly	People's Bank of China
Long-term interest rates			
CGB3Y	Chinese government bond, 3-year, yield, %, January 2007–August 2023	Daily; converted to monthly	People's Bank of China
CGB5Y	Chinese government bond, 5-year, yield, %, January 2007–August 2023	Daily; converted to monthly	People's Bank of China
CGB7Y	Chinese government bond, 7-year, yield, %, January 2007–August 2023	Daily; converted to monthly	People's Bank of China
CGB10Y	Chinese government bond, 10-year, yield, %, January 2007–August 2023	Daily; converted to monthly	People's Bank of China
Inflation			
CPI	Consumer price index, all items, seasonally adjusted, % change, y/y, January 2007–August 2023	Monthly	China National Bureau of Statistics
CCPI	Consumer price index, all items excluding food and energy, seasonally adjusted, % change, y/y, January 2007–August 2023	Monthly	China National Bureau of Statistics
Economic activity			
IP	Index of industrial value added, seasonally adjusted, 2005=100, % change, y/y January 2007–August 2023	Monthly	China National Bureau of Statistics
Financial variables and stock indexes			
USDCNY	Exchange rate, yuan per US dollar, USDCNY, January 2007–August 2023	Daily; converted to monthly	Federal Reserve Board
EURCNY	Exchange rate, yuan per euro, EURCNY, January 2007–August 2023	Daily; converted to monthly	European Central Bank
SHNGHAI	Shanghai stock price index, January 2007–August 2023	Daily; converted to monthly	Shanghai Stock Exchange
SNZN300	Shanghai Shenzhen 300 stock price index, January 2007–August 2023	Daily; converted to monthly	Shanghai Stock Exchange
PBOC	People's Bank of China, balance sheet, total assets., end of period, not seasonally adjusted, 100 million yuan, January 2007–August 2023	Monthly	People's Bank of China

Notes: LNUSDCNY = LN(USDCNY); LNEURCNY = LN(EURCNY); LNSHNGHAI = LN(SHNGHAI); and LNSNZN300 =LN(SNZN300); where LN = natural log = $Log_e(.)$

Tables 2 and 3 present summary statistics of the variables at their level and first difference, respectively. There are 200 observations at level and 199 observations at first difference for all variables. Government bond yields are higher for longer maturities, as can be seen in the mean, median, maximum, and minimum values for CGB3Y, CGB5Y, CGB7Y, and CGB10Y in table 2. The same is evident for the Treasury bill rates—CTB3M and CTB6M.

Several types of unit root tests (Dickey and Fuller 1981;1979; Phillips and Perron 1988) are undertaken. Several types of stationarity tests (Kwiatkowski et al. 1992) are also conducted. The null hypothesis for these two tests is different. The null hypothesis of the unit root test is the presence of a unit root in the time series, whereas the null hypothesis of the stationarity test is that the time series is stationary. Table 4 shows that most of the variables are free of unit roots and are stationary at their level. At first difference, all the variables are stationary in one test or the other (Table 5). Hence, each of the variables are either I(0) or I(1).

Table 2. Summary Statistics (level)

Variables	Obs.	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
CGB10Y	200	3.43	3.41	4.57	2.54	0.50	0.42	2.40	8.84	0.01
CGB7Y	200	3.34	3.28	4.56	2.35	0.49	0.42	2.40	8.75	0.01
CGB5Y	200	3.15	3.07	4.43	1.98	0.53	0.34	2.42	6.69	0.04
CGB3Y	200	2.94	2.90	4.38	1.36	0.59	0.06	2.67	1.01	0.60
CTB6M	200	2.50	2.46	4.21	0.86	0.70	-0.07	2.58	1.66	0.44
CTB3M	200	2.41	2.33	4.60	0.82	0.73	0.08	2.69	1.05	0.59
CPI	200	2.50	2.13	8.83	-1.79	1.96	0.83	4.14	33.67	0.00
CCPI	200	1.20	1.43	2.42	-1.70	0.81	-1.43	5.43	117.11	0.00
IP	200	8.99	7.36	33.94	-13.91	5.68	0.54	7.57	183.40	0.00
LNPBOC	200	12.61	12.72	12.95	11.79	0.27	-1.19	3.66	50.88	0.00
LNSNGHAI	200	7.81	7.81	8.56	7.30	0.23	0.33	3.22	3.98	0.14
LNSNZN300	200	8.12	8.14	8.64	7.51	0.26	-0.15	2.27	5.23	0.07
LNEURCNY	200	2.10	2.07	2.40	1.90	0.12	0.78	2.77	20.47	0.00
LNUSDCNY	200	1.90	1.90	2.05	1.80	0.06	0.50	2.96	8.34	0.02

Table 3. Summary Statistics (first difference)

Variables	Obs.	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
ΔCGB10Y	199	0.00	0.01	0.42	-0.75	0.14	-0.58	7.56	183.46	0.00
ΔCGB7Y	199	0.00	0.00	0.47	-0.71	0.15	-0.25	5.83	68.36	0.00
ΔCGB5Y	199	0.00	0.00	0.62	-0.71	0.17	-0.19	5.76	64.41	0.00
ΔCGB3Y	199	0.00	-0.01	0.67	-0.76	0.19	-0.26	6.19	86.45	0.00
ΔCTB6M	199	0.00	0.02	0.81	-0.91	0.23	-0.12	5.43	49.35	0.00
ΔCTB3M	199	0.00	0.01	1.00	-0.90	0.26	-0.04	5.24	41.77	0.00
ΔCPI	199	-0.01	0.02	1.72	-2.03	0.55	-0.41	4.48	23.81	0.00
ΔCCPI	199	0.00	0.00	0.72	-0.79	0.16	-0.02	7.12	141.00	0.00
ΔIP	199	-0.07	-0.03	26.85	-20.87	3.22	0.62	42.87	13193.96	0.00
ΔLNPBOC	199	0.01	0.01	0.08	-0.05	0.02	0.15	4.94	31.97	0.00
ΔLNSNGHAI	199	0.00	0.01	0.20	-0.26	0.07	-0.23	4.93	32.47	0.00
ΔLNSNZN300	199	0.00	0.01	0.23	-0.22	0.07	0.00	4.85	28.50	0.00
ΔLNEURCNY	199	-0.00	-0.00	0.06	-0.08	0.02	-0.35	4.12	14.40	0.00
ΔLNUSDCNY	199	0.00	0.00	0.04	-0.03	0.01	0.93	6.39	123.83	0.00

Table 4. Unit Root and Stationarity Test (level)

Variables	ADF			PP			KPSS	
	With constant	With constant & trend	Without constant & trend	With constant	With constant & trend	Without constant & trend	With constant	With constant & trend
CGB10Y	-3.00**	-4.36***	-0.61	-2.33	-3.55**	-0.48	0.90***	0.08
CGB7Y	-3.52***	-4.22***	-0.63	-2.50	-3.18*	-0.41	0.54**	0.11
CGB5Y	-3.38**	-3.87**	-0.65	-2.79*	-3.28*	-0.44	0.41*	0.11
CGB3Y	-3.51***	-3.71**	-0.74	-2.90**	-3.10	-0.56	0.23	0.13*
CTB6M	-3.49***	-3.55**	-0.81	-2.84*	-2.90	-0.79	0.19	0.17**
CTB3M	-3.48***	-3.58**	-0.87	-2.92**	-3.01	-0.86	0.23	0.19**
CPI	-4.02***	-4.26***	-2.60***	-2.92**	-3.37*	-1.92*	0.44*	0.04
CCPI	-2.50	-2.49	-1.23	-2.39	-2.35	-1.35	0.26	0.23***
IP	-3.26**	-4.28***	-1.95**	-4.09***	-5.53***	-2.15**	1.21***	0.10
LNPBOC	-6.20***	-4.92***	4.77	-6.51***	-5.07***	4.20	1.55***	0.38***
LNSNGHAI	-2.90**	-2.99	0.08	-3.01**	-3.08	0.13	0.33	0.19**
LNSNZN300	-2.67*	-2.99	0.23	-2.93**	-3.24*	0.27	0.83***	0.20**
LNEURCNY	-2.03	-2.32	-0.79	-1.98	-2.24	-0.80	1.29***	0.33***
LNUSDCNY	-2.66*	-2.44	-0.30	-2.55	-2.19	-0.44	0.32	0.31***

Notes

a: Significance levels: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

b: Lag length based on Schwartz information criterion (SIC).

c: Probability based on MacKinnon (1996) one-sided p-values (ADF and PP) and Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1) (KPSS).

d: Null hypothesis (H_0): ADF and PP: the variable has a unit root; KPSS: the variable is stationary.

Table 5. Unit Root and Stationarity Tests (first difference)

Variables	ADF			PP			KPSS	
	With constant	With constant & trend	Without constant & trend	With constant	With constant & trend	Without constant & trend	With constant	With constant & trend
ΔCGB10Y	-8.64***	-8.64***	-8.65***	-8.00***	-8.01***	-8.03***	0.11	0.06
ΔCGB7Y	-8.52***	-8.52***	-8.54***	-7.75***	-7.75***	-7.78***	0.14	0.03
ΔCGB5Y	-9.34***	-9.34***	-9.36***	-8.95***	-8.95***	-8.98***	0.12	0.05
ΔCGB3Y	-9.02***	-9.017***	-9.05***	-8.55***	-8.54***	-8.57***	0.07	0.03
ΔCTB6M	-9.36***	-9.35***	-9.38***	-9.14***	-9.12***	-9.17***	0.05	0.03
ΔCTB3M	-10.02***	-10.01***	-10.04***	-9.80***	-9.78***	-9.83***	0.06	0.03
ΔCPI	-6.36***	-6.41***	-6.30***	-10.68***	-10.66***	-10.70***	0.04	0.03
ΔCCPI	-9.24***	-9.23***	-9.26***	-9.80***	-9.79***	-9.82***	0.06	0.03
ΔIP	-14.75***	-14.72***	-14.78***	-18.15***	-18.18***	-17.87***	0.07	0.05
ΔLNPBOC	-14.99***	-11.99***	-13.44***	-15.03***	-16.19***	-14.29***	1.16***	0.28***
ΔLNSNGHAI	-10.06***	-10.04***	-10.09***	-10.18***	-10.15***	-10.20***	0.03	0.03
ΔLNSNZN300	-10.25***	-10.23***	-10.27***	-10.54***	-10.52***	-10.55***	0.03	0.03
ΔLNEURCNY	-10.91***	-10.93***	-10.90***	-10.92***	-10.94***	-10.93***	0.11	0.03
ΔLNUSDCNY	-8.13***	-8.39***	-8.15***	-8.17***	-8.25***	-8.18***	0.46*	0.06

Notes

a: Significance levels: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

b: Lag length based on Schwartz information criterion (SIC).

c: Probability based on MacKinnon (1996) one-sided p-values (ADF and PP), and Kwiatkowski-Phillips-Schmidt-Shin (1992, Table 1) (KPSS).

d: Null hypothesis (H_0): ADF and PP: the variable has a unit root; KPSS: the variable is stationary.

SECTION 4: ECONOMETRIC MODELS AND THE FINDINGS OF THE ESTIMATED MODELS

The results of the unit root and stationarity tests, conducted in the previous section, show that the series of interest are integrated at either I(0) or I(1). The objective here is to model the long-term CGB yield. The short- and long-run effects of the short-term interest rate on long-term CGB yields for different maturity tenors are examined. Given the nature of the data and the research question, the ARDL approach is the most germane for modeling the dynamics of CGB yields.

The ARDL models estimated here can be used to examine the dynamic relationships with time series data in a single-equation framework. In its error correction (EC) representation, the ARDL model may be used to distinguish the long- and short-run effects. It can be applied to test if there is any cointegration between the short- and the long-term interest rates. It can also be used to examine if there are any long-run relationships among the variables that have been selected to econometrically model the dynamics of CGB yields.

The regression specification for the ARDL(p,q) models is as follows:

$$CGB_iY_t = \alpha_0 + \sum_{p=1}^{12} \alpha_p (CGB_iY_{t-p}) + \sum_{q=0}^{12} \beta_q (CTB3M_{t-q}) + \sum_{j=1}^{m} \gamma_j X_{j,t} + \varepsilon_t$$

i is used for 3-, 5-, 7-, and 10-year tenors.

Here the dependent variable is yield of different maturity tenors, represented by *i*. The main independent variables are the short-term interest rate and its lags. The other independent variables are the lagged government bond yield and $X_{j,t}$, which represents other control variables, namely: core inflation (CCPI), the growth of industrial production (IP), and the percent changes in the yuan–dollar exchange rate (ΔLNUSDCNY), the Shanghai stock price index (ΔLNSNGHAI), and the total assets of the central bank (ΔLNPBOC).

There are two different model specifications. The simple model is based on the 3-year Treasury bill rate and its lags, the lags of the dependent variable, and two control variables: core inflation and the growth of industrial production. The extended model is also based on the 3-year Treasury bill rate and its lags, the lags of the dependent variable, and five control variables: core inflation, the growth of industrial production, and the percentage changes in the USDCNY exchange rate, the Shanghai stock price index, and the total assets of the PBOC.

The time series data used in this study is monthly. The maximum lag chosen for the estimation is 12. The lags for the models are automatically selected based on the Akaike information criteria (AIC).

The results from the front end and back end of the Treasury yield curve are presented in Tables 6 and 7, respectively. However, the results from the belly of the Treasury yield curve are presented in Appendix B. Model information and diagnostic tests are displayed at the bottom of each table.

Table 6 presents regression results for CGB3Y as dependent on CTB3M. The model selected is ARDL(10,10) for both the simple and extended specifications. The current 3-month Treasury bill rate is positively associated with the CGB3Y yield. The association is slightly lower when additional controls are introduced. The effect for lags of CTB3M on CGB3Y varies widely depending on the number of lags. Core inflation is not statistically significant. The growth of industrial production is statistically significant but its effect is miniscule. In the extended model, the percentage change in the USDCNY exchange has a negative effective, but is statistically insignificant. The percentage change in the Shanghai stock price index has a positive and statistically significant effect. However, the percentage change in the total assets of the PBOC has a positive but statistically insignificant effect.

Both of these models have strong fit, as shown by the R^2 and adjusted R^2, which are each 0.97. In the Breusch-Godfrey serial correlation test, the null hypothesis is that the residuals are serially uncorrelated. An F-statistic p-value higher than 0.05 in both models indicates the failure to reject the null hypothesis of serially uncorrelated residuals. In the Breusch-Pagan-Godfrey heteroscedasticity test, the null hypothesis is that the residuals are homoscedastic. The F-statistic p-value for the model indicates the failure to reject the null hypothesis of homoscedasticity. The F-statistic value for the bounds test is evidently above the I(0) and I(1) critical value bound. Hence, the null hypothesis that there is no equilibrating relationship can be rejected. The bounds test rejects the null hypothesis of no relationship in levels (no cointegration) for both the simple model and the extended model. The Ramsey RESET test fails to reject the null hypothesis that the model is correctly specified. The negative and highly significant EC term suggests that the variables are indeed cointegrated in both models. The EC terms suggest that about 28–30 percent of any movements into disequilibrium are corrected within one month. Figure 9 displays the results of the CUSUM and CUSUMSQ tests (Brown, Durbin, and Evans 1975) in panels A and B. The left charts are for the simple model, while the right charts are for the extended model. The CUSUM tests for both models indicate stability in the estimated equations during the sample period. The CUSUMSQ of both models are within the 5 percent significance lines, suggesting that the residual variance is stable in both. Model selection criteria other than AIC, such as SIC, change the lag structure of the models but the overall effects of CTB3M on CGB3Y are similar in most cases.

Table 6. Regression Results and Tests, ARDL (10,10): Simple and Extended Models for CGB3Y (with CTB3M)

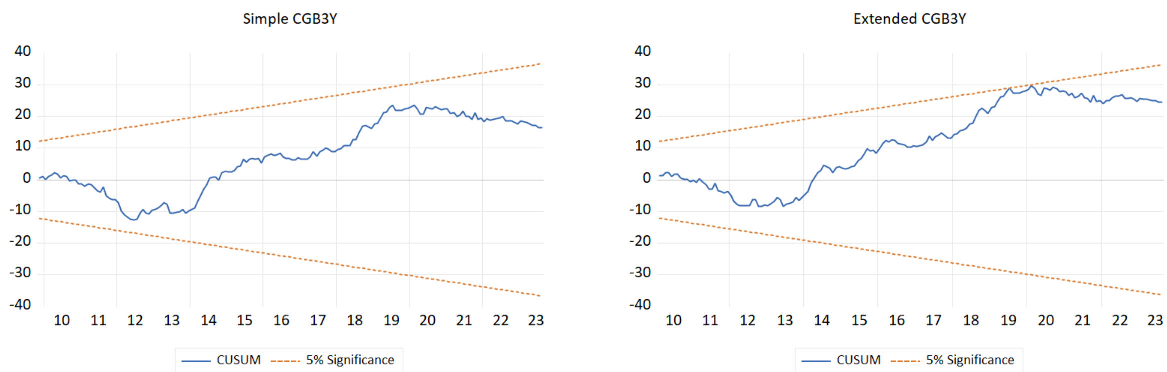
Variable	Coefficient (SE)	Coefficient (SE)
CGB3Y(-1)	1.12*** (0.08)	1.15*** (0.08)
CGB3Y(-2)	-0.42*** (0.11)	-0.45*** (0.11)
CGB3Y(-3)	0.21* (0.11)	0.25** (0.11)
CGB3Y(-4)	-0.25** (0.11)	-0.27** (0.11)
CGB3Y(-5)	0.11 (0.11)	0.10 (0.11)
CGB3Y(-6)	0.07 (0.11)	0.06 (0.11)
CGB3Y(-7)	-0.16 (0.11)	-0.12 (0.11)
CGB3Y(-8)	0.24** (0.11)	0.18 (0.11)
CGB3Y(-9)	-0.32*** (0.11)	-0.28** (0.11)
CGB3Y(-10)	0.10 (0.07)	0.10 (0.07)
CTB3M	0.51*** (0.04)	0.50*** (0.04)
CTB3M(-1)	-0.52*** (0.07)	-0.53*** (0.07)
CTB3M(-2)	0.24*** (0.08)	0.23*** (0.08)
CTB3M(-3)	-0.19** (0.08)	-0.19** (0.08)
CTB3M(-4)	0.14* (0.08)	0.14* (0.08)
CTB3M(-5)	0.06 (0.08)	0.09 (0.08)
CTB3M(-6)	-0.22*** (0.08)	-0.24*** (0.08)
CTB3M(-7)	0.24*** (0.08)	0.23*** (0.08)
CTB3M(-8)	-0.20** (0.08)	-0.17** (0.08)
CTB3M(-9)	0.27*** (0.07)	0.24*** (0.08)
CTB3M(-10)	-0.14*** (0.05)	-0.12** (0.05)
CCPI	-0.01 (0.01)	0.001 (0.01)
IP	0.004** (0.002)	0.004** (0.002)
Δ(LNUSDCNY)		-0.41 (0.93)
Δ(LNSNGHAI)		0.31** (0.15)
Δ(LNPBOC)		0.90 (0.57)
Constant	0.34*** (0.08)	0.31*** (0.08)
Model information		
R-squared	0.97	0.97
Adjusted R-squared	0.97	0.97
S.E. of regression	0.11	0.11
Sum squared resid	2.04	1.96
Log likelihood	161.29	164.99
F-statistic (prob)	230.86 (0.00)	208.75 (0.00)
Akaike info criterion	-1.45	-1.45
Durbin-Watson stat	1.98	1.99
Diagnostic tests		
Breusch-Godfrey serial correlation LM test. (Null hypothesis: No serial correlation at up to 10 lags)		
F-statistic (prob)	0.97 (0.47)	1.08 (0.38)
Heteroskedasticity test: Breusch-Pagan-Godfrey. (Null hypothesis: Homoskedasticity)		
F-statistic (prob)	1.16 (0.29)	1.09 (0.36)
Bounds test (Null hypothesis: No relationship in levels, that is, no cointegration)		
F-statistic	7.89	6.81
10%: I(0) 3.020 I(1) 3.510;		
5%: I(0) 3.620 I(1) 4.160;		
1%: I(0) 4.940 I(1) 5.580		
Ramsey RESET test:		
F-statistic for 2 fitted terms (Prob)	0.45 (0.64)	0.23 (0.79)
Error correction		
COINTEQ* (Prob)	-0.30 (0.00)	-0.28 (0.00)

Notes:

1. The model is run in EViews 13 using ARDL models.
2. Heteroscedasticity and Autocorrelation Corrected [HAC (Newey-West)] standard errors.
3. Significance levels: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Figure 9. CUSUM and CUSUMSQ Stability Diagnostic for Simple and Extended Model for CGBT3M

Panel A: CUSUM for both models



Panel B: CUSUM of squares for both models

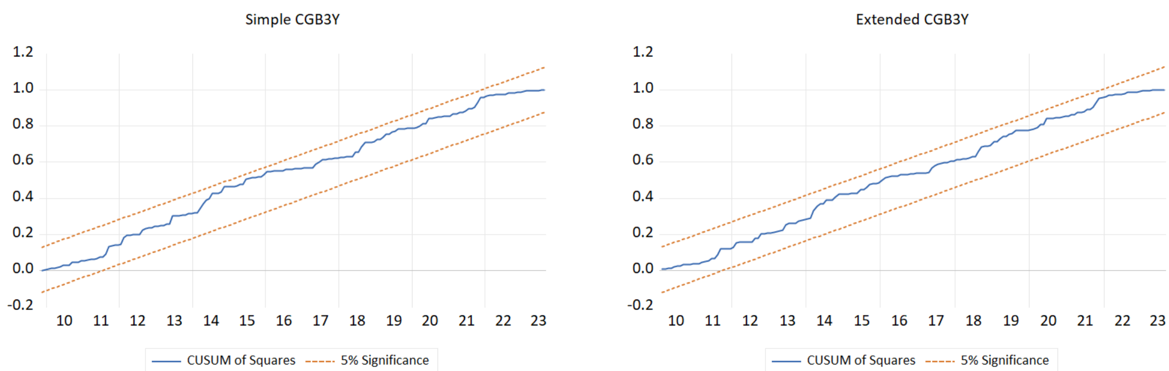


Table 7 presents regression results for CGB10Y as a function of CTB3M. In the automatic AIC–lag selection process, the simple specification of the model is ARDL(5,8) and the extended specification is also ARDL(5,8). The 3-month Treasury bill rate is positively associated with the 10-year government bond yield, which is unchanged for additional controls. The effect for lags of CTB3M on CGB10Y varies widely with regard to the lags. The core inflation does not have any statistically significant effect. However, once again the growth of industrial production has an extremely minute effect even though it is statistically significant. The effect of the percentage change in the USDCNY exchange rate is negative but statistically insignificant. The effects of the percentage changes of the Shanghai stock price index and the total assets of the PBOC are positive and statistically significant.

The estimated models have a strong fit, as shown by the R^2 and adjusted R^2, which are between 0.96 and 0.97. In the serial correlation test, the null hypothesis is that the residuals are serially uncorrelated. An F-statistic p-value higher than 0.05 in both models indicates the failure to reject this null hypothesis. In the heteroscedasticity test, the null hypothesis is that the residuals are homoscedastic. The F-statistic p-values for the models indicate the rejection of the null hypothesis of homoskedasticity of the simple model at the 10 percent level of significance and again at the 5 percent level of significance. The F-statistic value for the bounds test for the extended model suggests that the null hypothesis of no cointegration can be rejected. The F-statistic value for the bounds test for the simple model suggests that the null hypothesis of no cointegration cannot be rejected at a 5 percent level of significance. The Ramsey RESET test fails to reject the null hypothesis that the model is correctly specified. The negative and highly significant EC term suggests that the variables are indeed cointegrated. About 9–10 percent of a movement into disequilibrium is corrected within one month. The results for the CUSUM and CUSUMSQ tests are displayed in Figure 10 in the same manner as in Figure 9. The CUSUM tests for both models indicate instability of the equation's parameters during the sample period. The CUSUMSQ moves outside of and within the 5 percent significance lines, suggesting that the estimated parameters are somewhat unstable. In essence, the CUMSUM and CUMSUMSQ tests suggest the estimated coefficients sometimes breach the bounds of stability.

Table 7. Regression Results and Tests, ARDL (5,8): Simple and Extended Models of CGB10Y (with CTB3M)

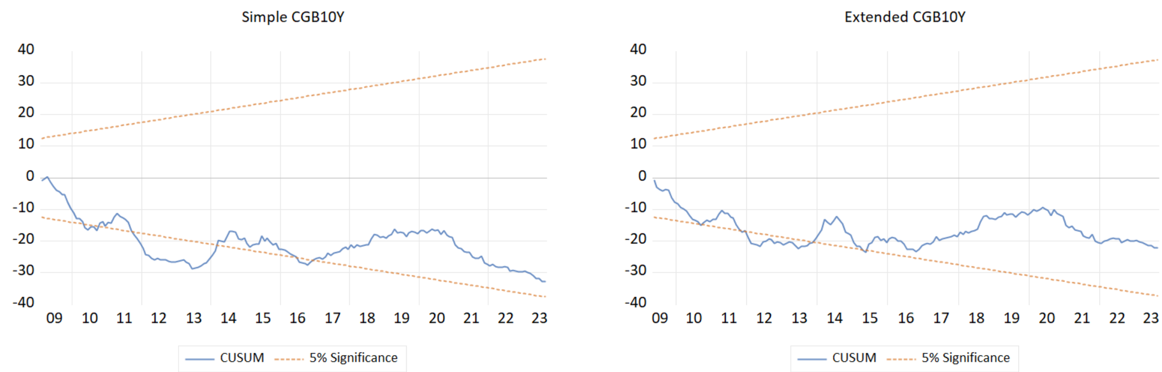
Variable	Coefficient (SE)	Coefficient (SE)
CGB10Y(-1)	1.27*** (0.08)	1.29*** (0.07)
CGB10Y(-2)	-0.42*** (0.12)	-0.44*** (0.11)
CGB10Y(-3)	0.08 (0.12)	0.12 (0.11)
CGB10Y(-4)	-0.18 (0.12)	-0.20* (0.11)
CGB10Y(-5)	0.15** (0.07)	0.14** (0.07)
CTB3M	0.23*** (0.04)	0.23*** (0.03)
CTB3M(-1)	-0.29*** (0.06)	-0.29*** (0.05)
CTB3M(-2)	0.19*** (0.06)	0.18*** (0.06)
CTB3M(-3)	-0.13** (0.06)	-0.13** (0.06)
CTB3M(-4)	0.08 (0.06)	0.09 (0.06)
CTB3M(-5)	0.02 (0.06)	0.05 (0.06)
CTB3M(-6)	-0.13** (0.06)	-0.15*** (0.06)
CTB3M(-7)	0.14** (0.06)	0.15*** (0.05)
CTB3M(-8)	-0.06* (0.03)	-0.07** (0.03)
CCPI	-0.02 (0.01)	-0.01 (0.01)
IP	0.004** (0.002)	0.004** (0.002)
ΔLNUSDCNY		-0.14 (0.81)
ΔLNSNGHAI		0.66*** (0.12)
ΔLNPBOC		0.88* (0.48)
Constant	0.21*** (0.07)	0.16** (0.06)
Model information		
R-squared	0.96	0.97
Adjusted R-squared	0.96	0.96
S.E. of regression	0.11	0.10
Sum squared resid	1.95	1.64
Log likelihood	168.38	184.92
F-statistic (prob)	255.72 (0.00)	253.15 (0.00)
Akaike info criterion	-1.58	-1.72
Durbin-Watson stat	1.96	1.99
Diagnostic tests		
Breusch-Godfrey serial correlation LM test. Null hypothesis: (No serial correlation at up to lags 5)		
F-statistic (prob)	0.73 (0.61)	0.32 (0.90)
Heteroskedasticity test: Breusch-Pagan-Godfrey. (Null hypothesis: Homoskedasticity)		
F-statistic (prob)	1.63 (0.07)	1.73 (0.04)
Bounds test (Null hypothesis: No relationship in levels)		
F-statistic	3.78	2.82
10%: I(0) 3.020 I(1) 3.510; 5%: I(0) 3.620 I(1) 4.160; 1%: I(0) 4.940 I(1) 5.580		
Ramsey RESET test:		
F-statistic for 2 fitted terms (prob)	0.10 (0.90)	0.77 (0.47)
Error correction		
COINTEQ* (prob)	-0.10 (0.00)	-0.09 (0.00)

Notes:

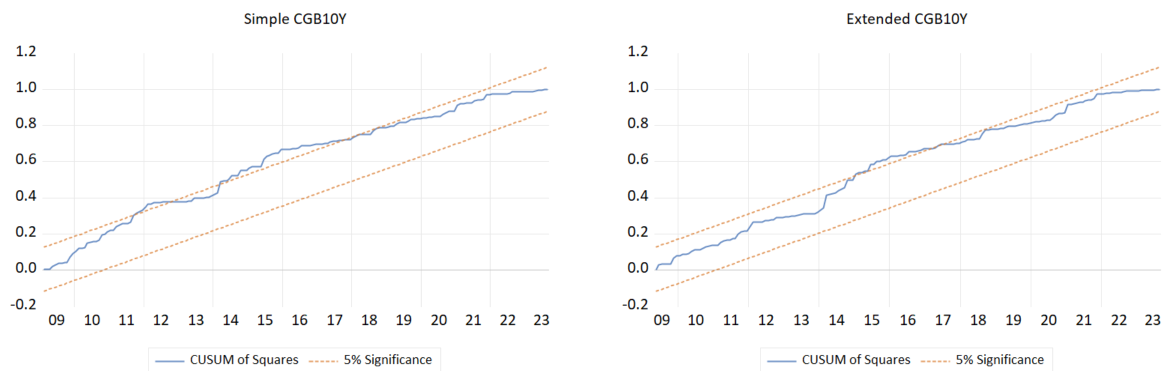
1. The model is run in EViews 13 using ARDL models.
2. Heteroscedasticity and Autocorrelation Corrected [HAC (Newey-West)] standard errors.
3. Significance levels: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Figure 10. CUSUM and CUSUMSQ Stability Diagnostic for CGBT1OY Simple and Extended Models

Panel A: CUSUM for both models



Panel B: CUSUM of squares for both models



Based on the above findings from the models estimated here and the additional findings from models estimated in Appendix A, it is clear that the 3-month Treasury bill rate is positively associated with the long-term CGB yield of different maturity tenors. However, the magnitude of the association declines with bond yields of higher tenors—0.50–0.51 for CGB3Y, 0.38 for CGB5Y, 0.28–0.29 for CGB7Y, and 0.23 for CGB10Y. The models are more reliable and stable for CGBs in the front end and the belly of the Treasury yield curve compared to in the back end of the Treasury yield curve, as can be seen from different diagnostic tests. Nevertheless, these models have good fit; all models bring out the connection between the current short-term interest rate and the CGB yield as reflected in the positive and statistically and economically significant effects.

4.1: Robustness Checks with Alternative Independent Variables

To check the robustness of the findings, an alternative specification of both the simple and extended models is undertaken. The alternative specification uses the 6-month Treasury bill rate for the short-term interest rate instead of the 3-month Treasury bill rate. Moreover, the control variables used in the alternative specification are as follows: CPI instead of CCPI, ΔLNEURCNY instead of ΔLNUSDCNY, and ΔLNSNZN300 instead of ΔLNSNGHAI. However, two of the control variables remain the same, namely, the growth of industrial production (IP) and the percentage change in the total assets of the central bank (ΔLNPBOC). The simple version has the following two control variables: CPI and IP. The extended version has the following five control variables: CPI, IP, ΔLNEURCNY, ΔLNSNZN300, and ΔLNPBOC.

The government bond yields of different maturity tenors are modeled as follows:

$$CGB_iY_t = \alpha_0 + \sum_{p=1}^{12} \alpha_p \left(CGB_iY_{t-p}\right) + \sum_{q=0}^{12} \beta_q \left(CTB6M_{t-q}\right) + \gamma_j X_{jt} + \varepsilon_t$$

i is used for 3-, 5-, 7-, and 10-year tenors. Here, X_{jt} represents the other control variables.

Table 8 presents regression results from the extended models for CGBs of different maturity tenors, dependent on CTB6M. (The results of the simple modes for CGBs are presented in Appendix B.) The lag structures chosen for the models below are the same as those for the relevant extended models estimated earlier. Hence, the model for the 3-year bond yield is ARDL(10,10), 5-year bond yield is ARDL(5,5), 7-year bond yield is ARDL(5,8), and 10-year bond yield is ARDL(5,8). The 6-month Treasury bill rate is positively associated with all CGB yields, similar to the results obtained when using the 3-month Treasury bill rate for the short-term interest rate. The CPI inflation has a slightly positive but statistically insignificant effect. The growth of industrial production has a miniscule but statistically significant positive effect. The percentage change of the EURCNY exchange rate has a positive and statistically significant effect. The percentage change of the Shanghai-Shenzhen 300 stock price index has a positive and statistically significant effect. The percentage change of the total assets of the PBOC has a positive but statistically insignificant effect.

Table 8. Regression Results ARDL (p,q): Extended Models for CGB$_J$ (with CTB6M)

Variable	CGB3Y (10,10)	CGB5Y (5,5)	CGB7Y (5,8)	CGB10Y (5,8)
	Coefficient (SE)	**Coefficient (SE)**	**Coefficient (SE)**	**Coefficient (SE)**
CGB$_J$(-1)	1.01*** (0.07)	1.06*** (0.07)	1.20*** (0.07)	1.20*** (0.07)
CGB$_J$(-2)	-0.19* (0.11)	-0.21** (0.10)	-0.31*** (0.11)	-0.27** (0.11)
CGB$_J$(-3)	0.18* (0.10)	0.08 (0.10)	0.12 (0.11)	0.07 (0.11)
CGB$_J$(-4)	-0.31*** (0.10)	-0.24** (0.10)	-0.29*** (0.10)	-0.28*** (0.10)
CGB$_J$(-5)	0.04 (0.10)	0.16** (0.07)	0.18*** (0.07)	0.21*** (0.07)
CGB$_J$(-6)	0.16 (0.10)			
CGB$_J$(-7)	-0.09 (0.10)			
CGB$_J$(-8)	0.03 (0.10)			
CGB$_J$(-9)	-0.18* (0.10)			
CGB$_J$(-10)	0.08 (0.07)			
CTB6M	0.63*** (0.04)	0.47*** (0.04)	0.35*** (0.04)	0.27*** (0.03)
CTB6M(-1)	-0.58*** (0.07)	-0.48*** (0.07)	-0.39*** (0.06)	-0.32*** (0.06)
CTB6M(-2)	0.07 (0.08)	0.12 (0.08)	0.10 (0.07)	0.10 (0.06)
CTB6M(-3)	-0.11 (0.08)	-0.10 (0.08)	-0.05 (0.07)	-0.03 (0.06)
CTB6M(-4)	0.17** (0.08)	0.15** (0.07)	0.09 (0.07)	0.06 (0.06)
CTB6M(-5)	0.10 (0.08)	-0.08 (0.05)	0.01 (0.07)	0.02 (0.06)
CTB6M(-6)	-0.26*** (0.08)		-0.12* (0.06)	-0.13** (0.06)
CTB6M(-7)	0.17** (0.08)		0.13** (0.06)	0.14** (0.06)
CTB6M(-8)	-0.10 (0.08)		-0.05 (0.04)	-0.07** (0.03)
CTB6M(-9)	0.21*** (0.08)			
CTB6M(-10)	-0.10* (0.06)			
CPI	0.01 (0.005)	0.003 (0.005)	0.01 (0.004)	0.003 (0.005)
IP	0.004*** (0.002)	0.005*** (0.002)	0.004** (0.002)	0.004** (0.002)
ΔLNEURCNY	0.90** (0.37)	1.41*** (0.40)	1.34*** (0.36)	1.30*** (0.36)
ΔLNSNZN300	0.55*** (0.12)	0.55*** (0.13)	0.67*** (0.12)	0.65*** (0.11)
ΔLNPBOC	0.11 (0.48)	0.02 (0.53)	0.07 (0.47)	0.10 (0.46)
Constant	0.20*** (0.07)	0.17 (0.07)	0.16** (0.07)	0.11* (0.06)
Model information				
R-squared	0.98	0.96	0.97	0.97
Adjusted R-squared	0.98	0.96	0.96	0.96
S.E. of regression	0.09	0.11	0.09	0.09
Sum squared resid	1.42	2.13	1.54	1.50
Log likelihood	195.64	163.60	190.54	193.20
F-statistic	290.59	276.93	258.50	276.77
Prob (F-statistic)	0.00	0.00	0.00	0.00
Mean dependent var	2.93	3.15	3.34	3.42
S.D. dependent var	0.60	0.53	0.49	0.50
Akaike info criterion	-1.78	-1.50	-1.78	-1.80
Durbin-Watson stat	2.08	2.19	2.07	2.07

Notes:

1. CGB$_J$(t) indicates the relevant bond, where $_J$=3, 5, 7, and 10, respectively, when the dependent variables are, respectively, CBG3Y, CGB5Y, CGB5Y, and CGB10Y in the second, third, fourth, and fifth column of the table.
2. The model is run in EViews 13 using ARDL models.
3. Heteroscedasticity and Autocorrelation Corrected [HAC (Newey-West)] standard errors.
4. The model selection criterion is the same lag structure of the extended models estimated earlier.
5. Significance levels: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

SECTION 5: CONCLUSION

The empirical findings of the estimated models are pertinent for macroeconomics, public finance, and development economics. The findings show that an increase (decrease) in the short-term interest rate is associated with an increase (decrease) in CGB yields, after controlling for macroeconomic and financial variables, including lagged values of the CGB yield, lagged values of the short-term interest rate, inflation or core inflation, the growth of industrial production, and the percentage changes in the stock price index, the exchange rate, and the PBOC's total asset balance. Two different models of CGB yields, across the Treasury yield curve, are estimated. Both models show similar results for the effect of short-term interest rate on CGB yields of different maturity tenors. Alternative independent variables are used to examine if the findings are well-grounded. Models that use alternative independent variables produce similar results.

The estimated CGB models show that the short-term interest rate has an economically and statistically significant effect on CGB yields of different maturity tenors, even after controlling for relevant macroeconomic and financial variables. This means that the PBOC's actions can have marked effects on CGB yields through the influence of its policy rate and other monetary policy measures on short-term interest rates, such as the CTB3M and CTB6M rates. When the PBOC sets its policy rate, undertakes various monetary policy measures, and adjusts its balance sheet, it affects CGB yields and the shape of the yield curve. This implies that policymakers in China have considerable leeway in fiscal and monetary operations, government deficit finance, and central government debt management, as the PBOC's actions influence borrowing and lending rates in the banking system and affect a range of fixed income products including bonds and derivatives. With the rise in outstanding CGBs in the previous decades, the empirical modeling of CGB yields undertaken in this paper could be useful for policymakers and investors who are interested in examining the workings of the monetary transmission mechanism and the operational dynamics of the financial system and capital markets in China.

The results of the estimated models further vindicate Keynes's claim that the central bank influences the long-term interest rate through the short-term interest rate. These results confirm that Keynes's claim holds for financial markets in China. Previous studies have disclosed that

Keynes's conjecture holds in financial markets in advanced countries, such as the United States, United Kingdom, Japan, Australia, Canada, the countries of the eurozone, and some emerging markets, such as Brazil, Mexico, and India. This paper shows that the empirical relationship between the short-term interest rate and the long-term interest rate observed in other financial markets is also manifest in China's financial market.

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APPENDIX A: MODELS OF CGB YIELDS IN THE BELLY OF THE TREASURY YIELD CURVE

A1.1: Models for CGB5Y

Table A1 presents regression results for CGB5Y outcomes, dependent on CTB3M and other control variables. Using the AIC–model selection method, the simple specification of the model is ARDL(2,4) and the extended is ARDL(5,5). The CTB3M is positively associated with the CGB5Y yield, which is unchanged for additional controls. The effect for lags of CTB3M on CGB5Y varies with respect to the lags. The growth of industrial production has a positive and significant effect but the magnitude is small. The extended model shows that percentage change in the Shanghai stock price index and the percentage change in the total assets of the PBOC both have statistically significant effects. Inflation has a statistically insignificant negative effect.

Several diagnostic tests are conducted to evaluate the models. In the serial correlation test, the null hypothesis is that the residuals are serially uncorrelated. An F-statistic p-value bigger than 0.05 in all the models indicates the failure to reject this null hypothesis of serially uncorrelated residuals. The F-statistic p-value for the model indicates the failure to reject the null hypothesis of homoscedasticity. The F-statistic value for the bounds test is evidently above the I(0) and I(1) critical value bound for both the simple and the extended models. Hence, the null hypothesis that there is no equilibrating relationship that can be rejected for both models. The bounds test rejects the null hypothesis of no relationship in levels, indicating the possibility of cointegration. The Ramsey RESET test fails to reject the null hypothesis that the model is correctly specified. The negative and highly significant EC term suggests that the variables are indeed cointegrated. The coefficients of the EC term (–0.21 and –0.18) suggest that about 18–21 percent of the discrepancy between the long and the short run is corrected within a month. The CUSUM and the CUSUMSQ tests shown in Figure A1 are displayed as in the previous figures in the paper. The CUSUM test for both models indicates stability in the equation during the sample period. However, the CUSUMSQ tests of both models are sometimes outside the 5 percent significance line, indicating instability of the residual variance.

The models are well suited to explain the behavioral dynamics, as shown by R^2 and adjusted R^2, which are each 0.95.

Table A1. Regression Results and Tests, ARDL (p,q): CGB5Y and CTB3M

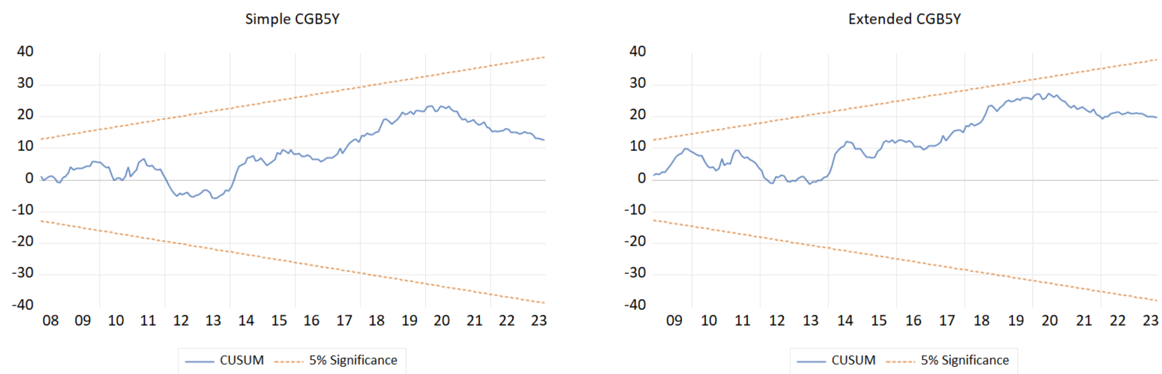
Variable	Coefficient (SE)	Coefficient (SE)
CGB5Y(-1)	1.13*** (0.07)	1.16*** (0.07)
CGB5Y(-2)	-0.34*** (0.07)	-0.40*** (0.11)
CGB5Y(-3)		0.17 (0.11)
CGB5Y(-4)		-0.25** (0.10)
CGB5Y(-5)		0.14** (0.07)
CTB3M	0.38*** (0.04)	0.38*** (0.04)
CTB3M(-1)	-0.39*** (0.06)	-0.42*** (0.06)
CTB3M(-2)	0.23*** (0.07)	0.24*** (0.07)
CTB3M(-3)	-0.17*** (0.06)	-0.22*** (0.07)
CTB3M(-4)	0.09** (0.04)	0.21*** (0.07)
CTB3M(-5)		-0.07 (0.05)
CCPI	-0.02 (0.02)	-0.01 (0.02)
IP	0.01*** (0.002)	0.01*** (0.002)
ΔLNUSDCNY		-0.46 (0.97)
ΔLNSNGHAI		0.52*** (0.14)
ΔLNPBOC		0.96* (0.58)
Constant	0.31*** (0.07)	0.25*** (0.07)
Model information		
R-squared	0.95	0.95
Adjusted R-squared	0.95	0.95
S.E. of regression	0.12	0.12
Sum squared resid	2.88	2.51
Log likelihood	135.38	147.51
F-statistic (prob)	375.37 (0.00)	233.09 (0.00)
Akaike info criterion	-1.28	-1.34
Durbin-Watson stat	2.02	2.07
Diagnostic tests		
Breusch-Godfrey serial correlation LM test. Null hypothesis: No serial correlation at up to model no. lags		
F-statistic (prob)	1.31 (0.27)	1.02 (0.41)
Heteroskedasticity test: Breusch-Pagan-Godfrey. Null hypothesis: Homoskedasticity		
F-statistic (prob)	0.99 (0.45)	0.65 (0.84)
Bounds test (Null hypothesis: No relationship in levels)		
F-statistic	10.01	5.59
10%: I(0) 3.020 I(1) 3.510;		
5%: I(0) 3.620 I(1) 4.160;		
1%: I(0) 4.940 I(1) 5.580		
Ramsey RESET test		
F-statistic (2 fitted terms)	1.02 (0.36)	0.61 (0.54)
Error correction		
COINTEQ* (prob)	-0.21 (0.00)	-0.18 (0.00)

Notes:

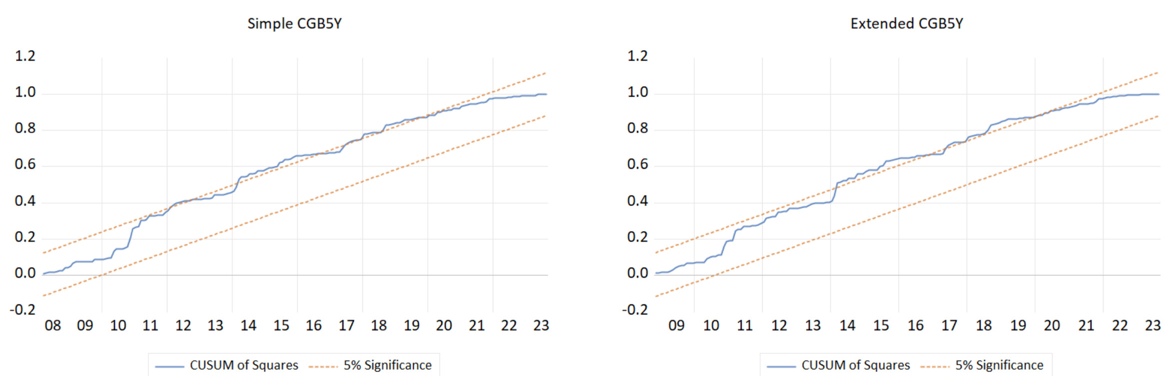
1. The model is run in EViews 13 using ARDL models.
2. Heteroscedasticity and Autocorrelation Corrected [HAC (Newey-West)] standard errors.
3. Significance levels: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Figure A1. CUSUM and CUSUMSQ Stability Diagnostic for Simple and Extended Models for CGB5Y

Panel A: CUSUM for both models



Panel B: CUSUM of squares for both models



A1.2: Models for CGB7Y

Table A2 presents regression results for CGB7Y's outcome, dependent on CTB3M and other variables. The specification of the simple model is ARDL(2,8), while the specification of the extended model is ARDL(5,8) based on AIC. The 3-month Treasury bill rate is positively associated with the 7-year government bond yield, which is unchanged for additional controls. The effect for the lags of CTB3M on CGB7Y varies with the lags. Here again the growth of industrial production has a very small positive effect on the bond yield, though it is statistically significant. In the extended model, the percentage changes in the Shanghai stock market index and the total asset of the PBOC have positive and statistically significant effects.

Some diagnostics tests are carried out to assess the models. In the serial correlation test, the null hypothesis is that the residuals are serially uncorrelated. The F-statistic p-value is bigger than 0.05 in all the models, indicating the failure to reject this null hypothesis. In the heteroscedasticity test, the null hypothesis is that the residuals are homoscedastic. The F-statistic p-value for the model indicates the failure to reject the null hypothesis, even at the 10 percent significance level. The F-statistic value of the simple model for the bounds test is above the I(0) and I(1) critical value bound. Hence, the null hypothesis that there is no equilibrating relationship can be rejected. The F-statistic value of the extended model for the bounds test is above the I(0) and I(1) critical value bound at the 10 percent significance level, but not at 5 percent level. Hence, the null hypothesis of no cointegration cannot be rejected at a 5 percent level of significance. The Ramsey RESET test fails to reject the null hypothesis that the model is correctly specified. The negative and highly significant EC term suggests that the variables are indeed cointegrated. About 13–17 percent of the discrepancy between the short and long run is corrected in one month. The CUSUM and CUSUMSQ tests are displayed in Figure A2. The CUSUM test for both models indicates stability in the equation during the sample period. The CUSUMSQ is generally within the 5 percent significance lines, suggesting that the residual variance is somewhat stable. The models are quite judicious, as shown by R^2 and adjusted R^2, which are 0.95 and 0.96, respectively.

Table A2. Regression Results and Tests, ARDL (p,q): CGB7Y and CTB3M

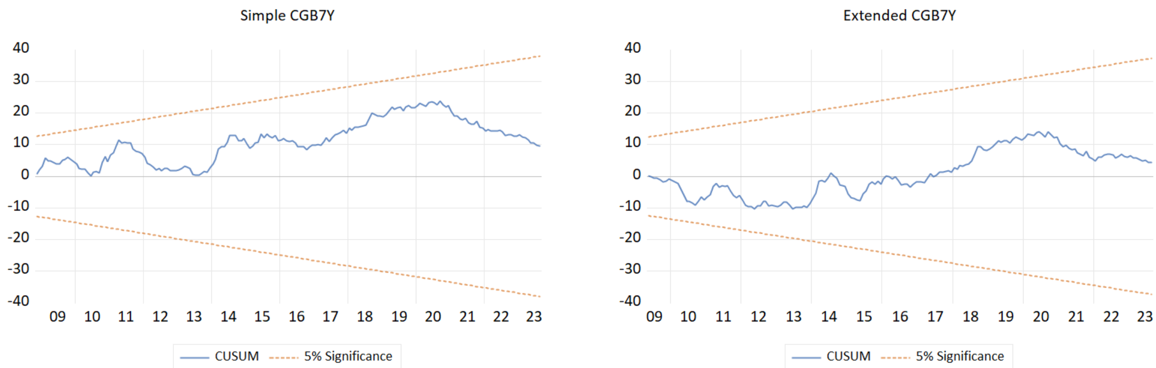
Variable	Coefficient (SE)	Coefficient (SE)
CGB7Y(-1)	1.25*** (0.07)	1.29*** (0.07)
CGB7Y(-2)	-0.42*** (0.07)	-0.48*** (0.11)
CGB7Y(-3)		0.17 (0.12)
CGB7Y(-4)		-0.24** (0.11)
CGB7Y(-5)		0.13* (0.07)
CTB3M	0.29*** (0.04)	0.28*** (0.03)
CTB3M(-1)	-0.34*** (0.06)	-0.35*** (0.05)
CTB3M(-2)	0.20*** (0.06)	0.20*** (0.06)
CTB3M(-3)	-0.13** (0.06)	-0.15** (0.06)
CTB3M(-4)	0.07 (0.06)	0.12* (0.06)
CTB3M(-5)	0.05 (0.06)	0.04 (0.06)
CTB3M(-6)	-0.14** (0.06)	-0.14** (0.06)
CTB3M(-7)	0.15*** (0.06)	0.14** (0.05)
CTB3M(-8)	-0.06 (0.04)	-0.06* (0.03)
CCPI	-0.01 (0.01)	-0.004 (0.01)
IP	0.01*** (0.002)	0.004** (0.002)
ΔLNUSDCNY		-0.18 (0.84)
ΔLNSNGHAI		0.65*** (0.13)
ΔLNPBOC		0.95* (0.50)
Constant	0.31*** (0.07)	0.22*** (0.07)
Model information		
R-squared	0.95	0.96
Adjusted R-squared	0.95	0.96
S.E. of regression	0.11	0.10*
Sum squared resid	2.10	1.77
Log likelihood	161.19	177.65
F-statistic (prob)	284.37 (0.00)	224.87 (0.00)
Akaike info criterion	-1.53	-1.64
Durbin-Watson stat	1.94	1.96
Diagnostic tests		
Breusch-Godfrey serial correlation LM test. Null hypothesis: No serial correlation at up to lags (model number)		
F-statistic (prob)	0.20 (0.82)	0.83 (0.53)
Heteroskedasticity test: Breusch-Pagan-Godfrey. Null hypothesis: Homoskedasticity		
F-statistic (prob)	0.93 (0.52)	0.90 (0.58)
Bounds test (Null hypothesis: No relationship in levels)		
F-statistic	8.38	3.73
10%: I(0) 3.020 I(1) 3.510;		
5%: I(0) 3.620 I(1) 4.160;		
1%: I(0) 4.940 I(1) 5.580		
Ramsey RESET test:		
F-statistic (2 fitted terms)	1.24 (0.29)	1.51 (0.22)
Error correction		
COINTEQ* (prob)	-0.17 (0.00)	-0.13 (0.00)

Notes:

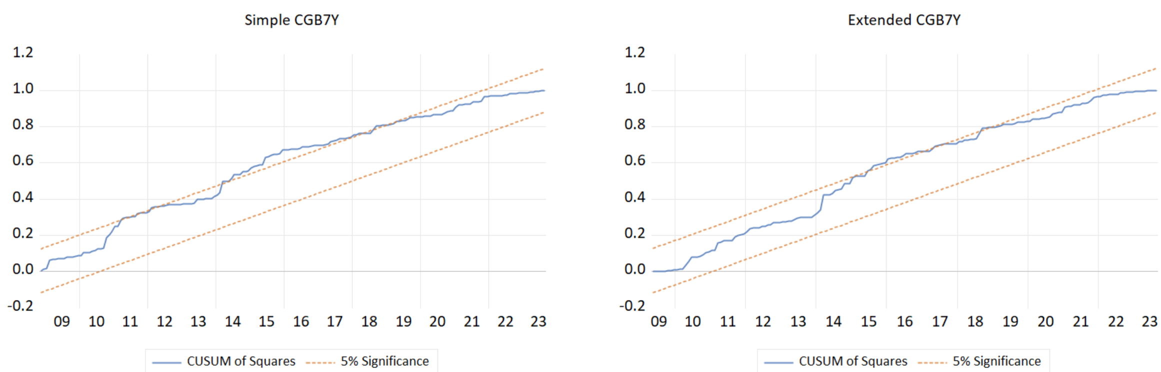
1. The model is run in EViews 13 using ARDL.
2. Heteroscedasticity and Autocorrelation Corrected [HAC (Newey-West)] standard errors.
3. Significance levels: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Figure A2. CUSUM and CUSUMSQ Stability Diagnostic for Simple and Extended Models for CGB7Y

Panel A: CUSUM for both models



Panel B: CUSUM of squares for both models



APPENDIX B: THE SIMPLE MODEL WITH ALTERNATIVE INDEPENDENT VARIABLES

Table B1. Regression Results ARDL (p,q): Simple Models of CGB_jY (with CTB6M)

Variable	**Coefficient (std. error)**	**Coefficient (std. error)**	**Coefficient (std. error)**	**Coefficient (std. error)**
	CGB3Y (10,10)	**CGB5Y (2,4)**	**CGB7Y (2,8)**	**CGB10Y (5,8)**
$CGB_jY(-1)$	1.00*** (0.08)	1.06*** (0.07)	1.20*** (0.07)	1.22*** (0.08)
$CGB_jY(-2)$	-0.23** (0.11)	-0.28*** (0.07)	-0.36*** (0.07)	-0.33*** (0.12)
$CGB_jY(-3)$	0.12 (0.11)			0.06 (0.12)
$CGB_jY(-4)$	-0.24** (0.11)			-0.22* (0.12)
$CGB_jY(-5)$	0.07 (0.11)			0.17** (0.07)
$CGB_jY(-6)$	0.13 (0.11)			
$CGB_jY(-7)$	-0.15 (0.11)			
$CGB_jY(-8)$	0.14 (0.11)			
$CGB_jY(-9)$	-0.25** (0.11)			
$CGB_jY(-10)$	0.10 (0.08)			
CTB6M	0.63*** (0.04)	0.47*** (0.04)	0.35*** (0.04)	0.27*** (0.04)
CTB6M(-1)	-0.57*** (0.07)	-0.46*** (0.07)	-0.38*** (0.07)	-0.32*** (0.06)
CTB6M(-2)	0.13 (0.09)	0.18** (0.08)	0.16** (0.07)	0.14** (0.07)
CTB6M(-3)	-0.11 (0.09)	-0.10 (0.07)	-0.08 (0.07)	-0.07 (0.07)
CTB6M(-4)	0.16* (0.09)	0.06 (0.04)	0.05 (0.07)	0.07 (0.07)
CTB6M(-5)	0.05 (0.08)		0.03 (0.07)	-0.01 (0.07)
CTB6M(-6)	-0.21** (0.08)		-0.10 (0.07)	-0.11 (0.07)
CTB6M(-7)	0.18* (0.09)		0.13** (0.07)	0.13** (0.06)
CTB6M(-8)	-0.11 (0.09)		-0.05 (0.04)	-0.06 (0.04)
CTB6M(-9)	0.22*** (0.08)			
CTB6M(-10)	-0.12** (0.06)			
CCPI	-0.02 (0.01)	-0.03 (0.02)	-0.02 (0.01)	-0.02 (0.01)
IP	0.003** (0.002)	0.01*** (0.002)	0.004** (0.002)	0.004* (0.002)
C	0.28*** (0.08)	0.27*** (0.06)	0.28*** (0.07)	0.19*** (0.06)
Model information				
R-squared	0.98	0.95	0.95	0.96
Adjusted R-squared	0.97	0.95	0.95	0.95
S.E. of regression	0.10	0.12	0.11	0.11
Sum squared resid	1.65	2.63	2.06	1.96
Log likelihood	181.03	144.45	162.87	167.80
F-statistic	285.83	413.77	289.65	254.11
Prob(F-statistic)	0.00	0.00	0.00	0.00
Mean dependent var	2.93	3.16	3.34	3.42
S.D. dependent var	0. 60	0.53	0.49	0.50
Akaike info criterion	-1.65	-1.37	-1.55	-1.57
Durbin-Watson stat	2.04	2.04	1.97	1.96

Notes:
1. The model is run in EViews 13 using ARDL.
2. Heteroscedasticity and Autocorrelation Corrected [HAC (Newey-West)] standard errors.
3. Significance levels: * significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.