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Working Paper No. 1014

Chinese Yuan Interest Rate Swap Yields

by

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The data set is available for replication: The data set used in the empirical part of this paper is available upon request to bona fide researchers for the replication and verification of the results.

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ABSTRACT

This paper models the dynamics of Chinese yuan (CNY)–denominated long-term interest rate swap yields. The financial sector plays a vital role in the Chinese economy, which has grown rapidly in the past several decades. Going forward, interest rate swaps are likely to have an important role in the Chinese financial system. This paper shows that the short-term interest rate exerts a decisive influence on the long-term swap yield after controlling for various macro-financial variables, such as inflation or core inflation, the growth of industrial production, percent change in the equity price index, and the percentage change in the CNY exchange rate. The autoregressive distributed lag (ARDL) approach is applied to model the dynamics of the long-term swap yield. The empirical findings show that the People’s Bank of China’s influence extends even to the over-the-counter derivative products, such as CNY interest rate swap yields, through the short-term interest rate. The findings reinforce and extend John Maynard Keynes’s notion that the central bank’s actions have a decisive role in setting the long-term interest rate in emerging market economies, such as China.

KEYWORDS: Chinese Yuan (CNY) Swaps; Interest Rate Swaps; Short-Term Interest Rate; Monetary Policy; The People’s Bank of China (PBOC)

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

SECTION I: INTRODUCTION

This paper econometrically models the dynamics of Chinese yuan (CNY)–denominated long-term interest rate swaps using monthly macroeconomic and financial data. The financial sector plays a vital role in the Chinese economy, which has grown rapidly in the past several decades. There has been a rapid growth of outstanding debt and fixed-income instruments, with notable developments in interest rate liberalization. Alongside these developments, there has been a spectacular rise in the country’s bond market and total social financing since the global financial crisis.

Interest rate swaps are likely to play an important role in the Chinese financial system, which has been changing from a bank-dominated system to one with more diverse financial institutions and increased market dominance, often characterized by liquidity shocks and spikes in interest rates in the interbank market. Although there is a growing literature studying the Chinese financial system (Armstrong-Taylor 2016; Walter and Howie 2012), CNY-denominated interest rate swap yields have not been econometrically modeled. The analysis of CNY-denominated swaps warrants careful study because of the increased financialization of the Chinese economy and the rise of the nation’s shadow banking system in which over-the-counter (OTC) derivatives, such as swaps, are likely to have an instrumental role.

This paper shows that the short-term interest rate exerts a decisive influence on the long-term swap 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 equity price index, and the CNY exchange rate. This finding is in concordance with John Maynard Keynes’s (1930, [1936] 2007) astute insight about the relationship between the long-term interest rate and the current short-term interest rate. The autoregressive distributed lag (ARDL) approach is applied to model the dynamics of the long-term swap yield using monthly data.

The paper proceeds as follows. Section II provides a short primer on interest rate swaps and briefly reviews the relevant literature on swaps and their applications. Section III outlines the macroeconomic environment in which the interest rate swap yields in China are evolving.

Section IV presents the data and sources used in the econometric modeling of swap yields, displays the summary statistics, and undertakes unit root and stationary tests. Section V lays out the framework for econometric models, reports and interprets the findings from the estimated models, and discusses the implications of the results. Section VI concludes.

SECTION II: INTEREST RATE SWAPS AND A BRIEF REVIEW OF THE LITERATURE

Interest rate swaps are contracts that enable two parties to exchange two interest rate cash flows with different features. Swaps are derivative contracts that trade over the counter. The principal amount, which is known as the notional principal of a swap, is the same for both parties. For plain-vanilla interest rate swaps, the swap buyer pays the fixed interest rate and receives the variable interest rate. The buyer is known as the receiver. The swap seller pays the variable interest rate and receives the fixed interest rate. The swap seller is known as the payer. The floating rate payments are based on some benchmark interest rates, such as the London Interbank Offer Rate (LIBOR), plus some agreed-upon markup. The swap yield, or the swap rate, is the fixed interest rate that the buyer or the receiver demands in exchange for the uncertainty of having to pay the short-term benchmark interest rate over time. Swaps are usually quoted in terms of this fixed rate. Swaps are also quoted in terms of the swap spread, which is the difference between the swap yield and the relevant benchmark government bond yield of the same maturity tenor. Corb (2012) explains the functions of interest rate swaps including usage, pricing, risks, and innovations.

Besides plain-vanilla interest rate swaps, there are other types of interest rate swaps, such as those that trade one floating rate for another. However, plain-vanilla swaps constitute the majority of the global swaps market. Swaps are used to hedge, speculate, and manage risks.

Bicksler and Chen (1986), Chernenko and Faulkender (2011), Kim and Koppenhaver (1993), and Visvanathan (1998) give overviews of the assorted use of swaps in various business and finance applications. Remolona and Wooldridge's (2003) survey of euro-denominated interest

rate swaps provides a valuable perspective on the size and the growth of the euro swap markets, the key participants of the market, pricing of the instruments, and market liquidity. The Bank for International Settlements' (2022) report on OTC derivatives statistics render comprehensive details about swaps, including interest rate swaps denominated in various currencies, in global financial markets.

Though there is a vast literature on swaps, the empirical modeling of swap yields has some critical gaps. Duffie and Huang (1996) and Duffie and Singleton (1997) have pioneered the empirical modeling of swaps yields, but these models fail to incorporate Keynes's (1930, [1936] 2007) insight, which tethers the long-term interest rate to the short-term interest rate. Kregel (2011) shows Keynes's insight drew on his own theoretical perspectives and Riefler's (1930) pioneering statistical analysis of bond yields in the United States in the 1920s. Keynes's insight on interest rate dynamics has also found support in recent empirical research. Several studies (Akram and Li 2020a, 2020b; Atesogulu 2003–4, 2005; Cook 2008; Deleidi and Levrero 2020; Gabrisch 2021; Kim 2020, 2021; Payne 2006–7; Simoski 2019; Vinod, Chakraborty, and Karun 2014) evince that there is a meaningful economic and statistically significant pass through from the central bank's policy rate to market interest rates. Akram (2021, 2022) has advanced quantitative models that formalize Keynes's insight linking the long-term interest rate to the short-term interest rate.

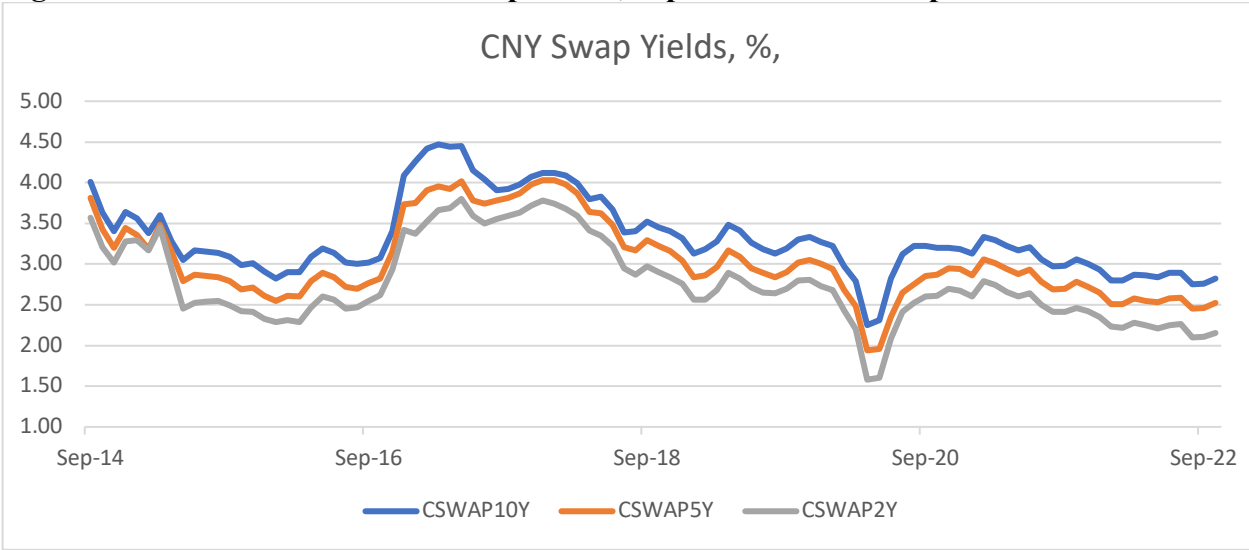
Most empirical studies showing the strong connection have been confined to government bond yields in advanced countries. Hence, it is relevant to ask whether Keynesian insight is generalizable beyond government bond yields in advanced countries. This paper contributes to the empirical literature by examining: (i) whether Keynes's conjecture is applicable to spread products and OTC financial derivatives, such as interest rate swaps, and (ii) whether it holds in emerging markets with rapidly evolving financial systems, such as China. Recently, Akram and Mamun (2022a, 2022b, 2022c) have shown that Keynes's conjecture is supported for Chilean peso (CLP), US dollar (USD), and UK pound (GBP) swaps.

SECTION III: THE MACROECONOMIC ENVIRONMENT SURROUNDING THE DYNAMICS OF SWAP YIELDS

An overview of the macroeconomic context surrounding the evolution of CNY-denominated swap yields in recent years is quite useful because it can provide an understanding of the relations between interest rate swap yields and key macroeconomic and financial variables.

Figure 1 displays the evolution of interest rate swaps in China during the study period, which is from September 2014 to September 2022. (The sources of the data used in the figures below are listed in Table 1 below). It shows that swap yields of various maturity tenors have generally moved together. Swap yields were trading between 3.5 percent to 4 percent in September 2014 but had gradually declined to a range of about 2.5 percent to 3 percent by September 2015. However, swap yields rose sharply in the following months, peaking between March and April of 2017. Subsequently, swap yields gradually declined from May 2017 to December 2019. With the onset of COVID-19 and the Great Lockdown, swap yields fell precipitously and sharply, bottoming out in May 2020. Swap yields recovered between June 2020 and August 2020, but were mostly unchanged from September 2020 until mid-2021, when they again gradually declined until the end of the study period in September 2022.

Figure 1: The Evolution of CNY Swap Yields, September 2014 to September 2022



The 10-year swap yield and the 3-month Treasury bill yield tend to move in concert, as shown in Figure 2, below. There are times when the long-term swap yield and the short-term interest rate diverge, such as in the first half of 2017, but these are the exceptions.

Figure 2: The Coevolution of the 10-Year Swap Yield and 3-Month T-Bill Yield, September 2014 to September 2022

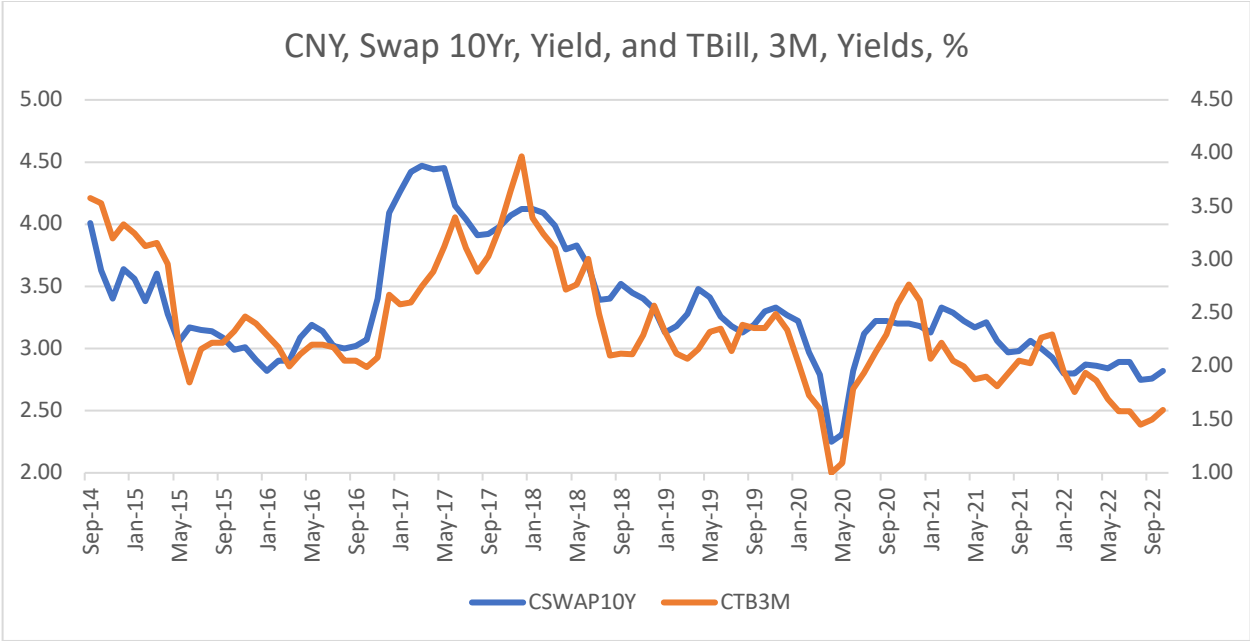


Figure 3 exhibits the evolution of the consumer price index (CPI) and core CPI inflation, year over year. Overall inflation and core inflation generally move in unison in China. However, overall inflation tends to be more volatile, owing to the higher volatility of energy and food prices. As a result, there are occasions when overall inflation and core inflation diverge.

Figure 3: The Evolution of Core CPI Inflation, September 2014 to September 2022

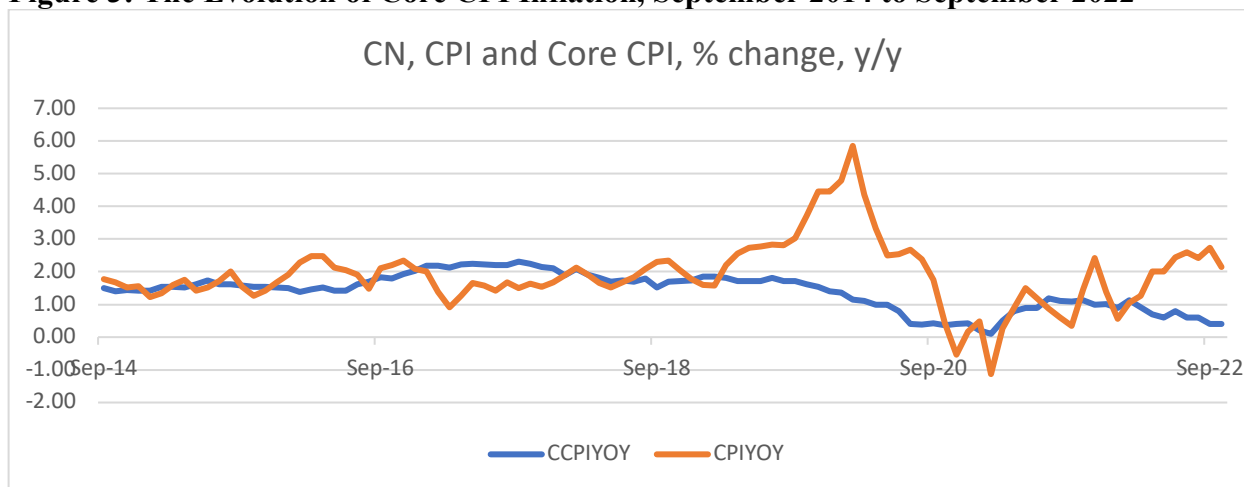
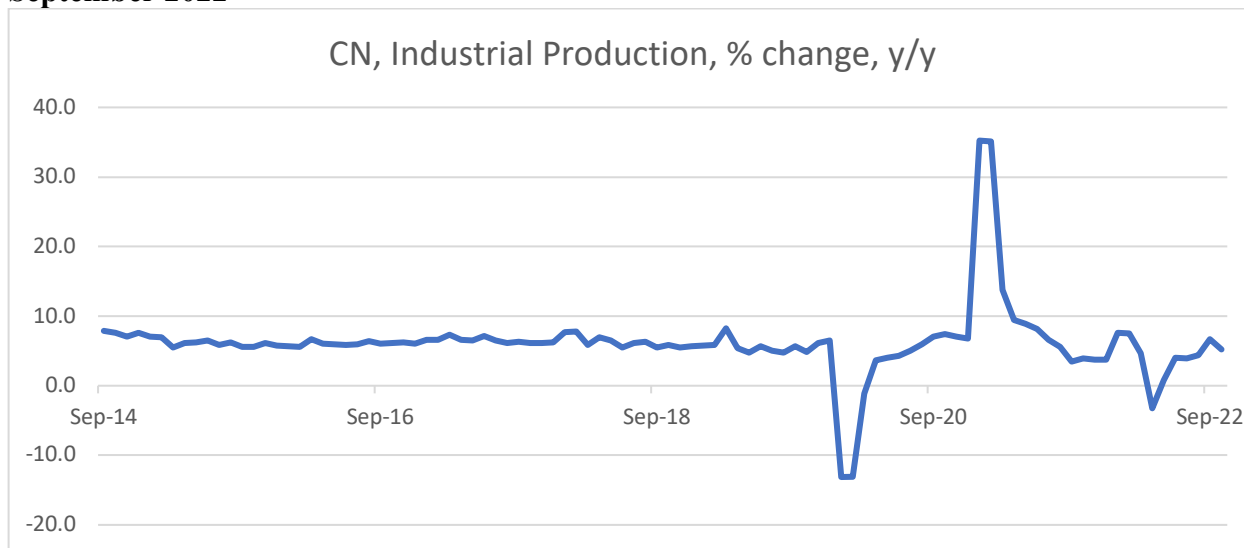


Figure 4 displays the growth of industrial production in China. Industrial production in China has been growing at a robust pace. However, industrial production fell sharply in early 2020 amid the Great Lockdown. It picked up in mid-2020. Industrial production again slowed down in early 2022 due to lockdowns in China.

Figure 4: The Evolution of the Growth of Industrial Production, September 2014 to September 2022

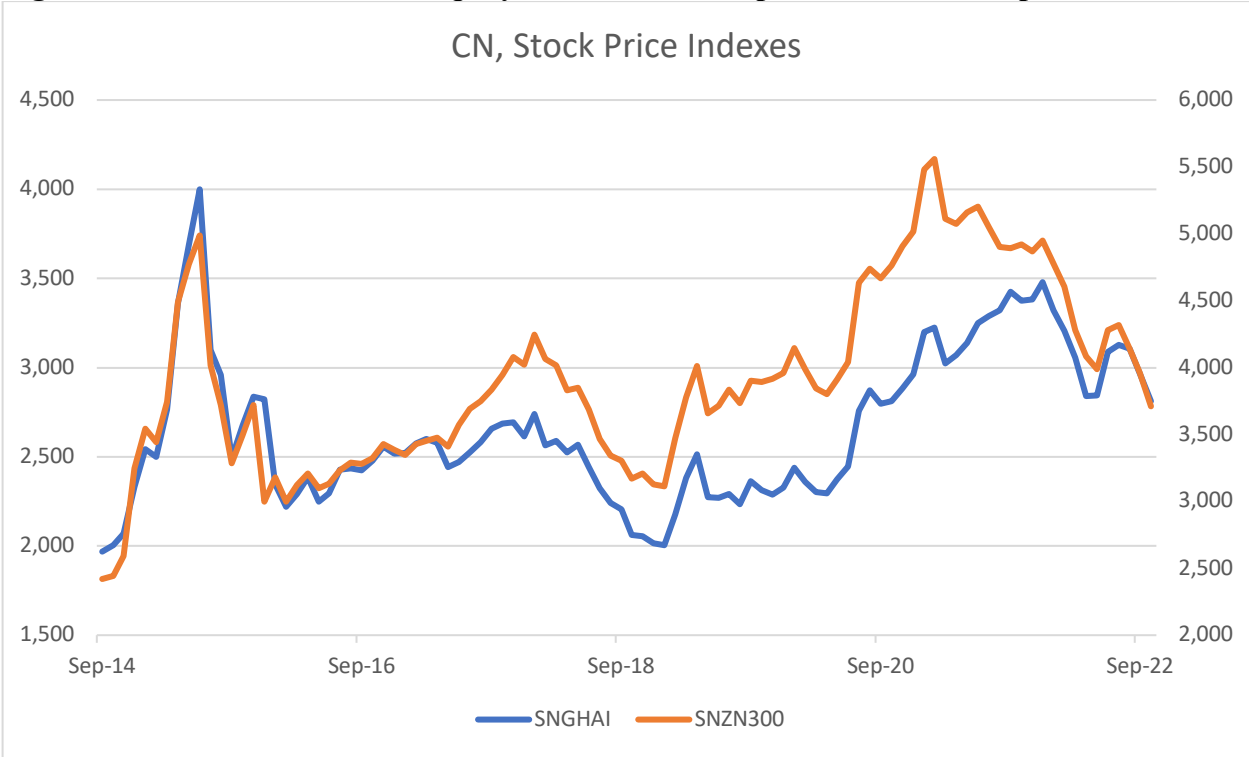


There are two main equity price indexes in China: the Shanghai and the Shenzhen composite indexes. The Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE) are the two major stock exchanges in mainland China. The companies listed on the SSE include state-owned

enterprises and large firms in financial services, real estate, energy, and infrastructure. In contrast, the SZSE includes more small- and medium-sized enterprises and private companies, with strong representation of technology firms. Figure 5 renders the evolution of the two equity price indexes.

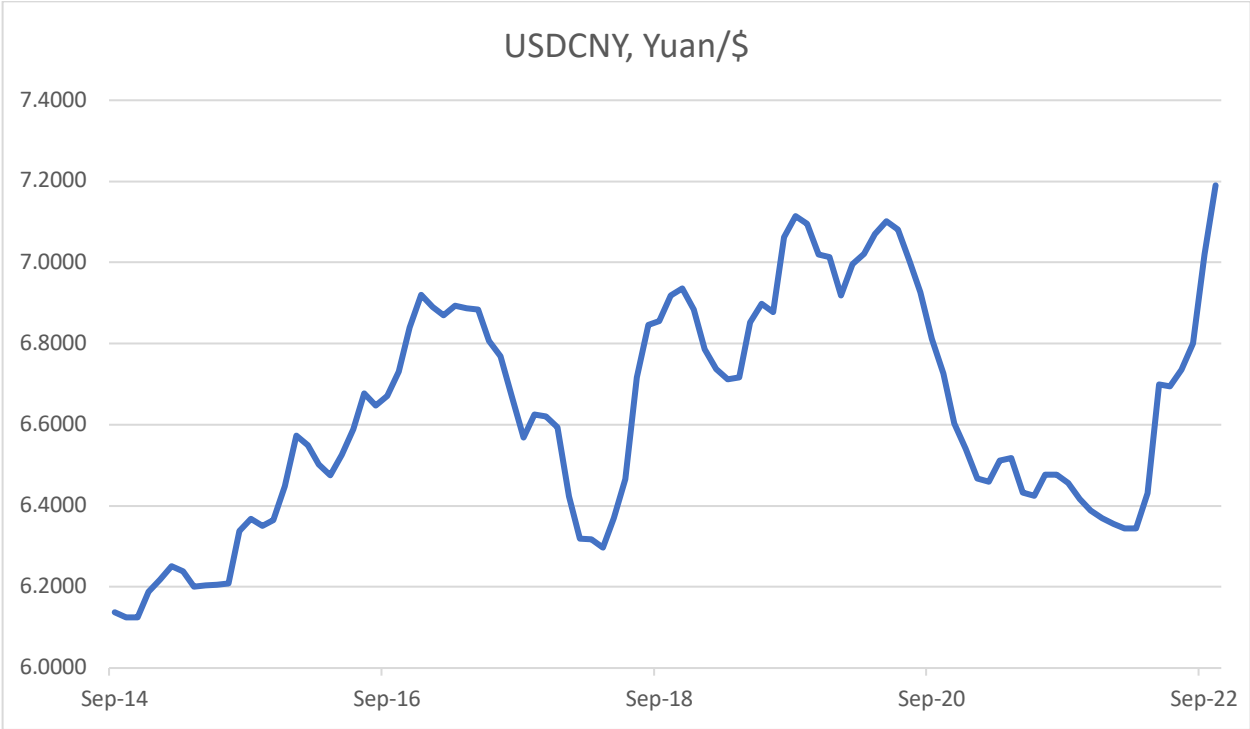
The equity price indexes rose at the beginning of the study period, reaching a peak in mid-2015, but tumbled in the following months and bottomed out in early 2016. The equity price indexes gradually recovered from early 2016 to late 2016, undergoing a moderate correction in 2017. The indexes continued to rise from January 2018 to January 2020. During the Great Lockdown the indexes fell, but less sharply than in advanced countries. However, the equity price indexes started recovering in April 2020 and continued to rise for several months thereafter. The SZSE index peaked in early 2021, while the SSE index peaked in late 2021. After peaking, both indexes declined until the end of the study period.

Figure 5: The Evolution of the Equity Price Indexes, September 2104 to September 2022



Chinese authorities have instituted a system of managed float for the CNY. The authorities allow a managed float against a basket of major currencies that includes the US dollar. During the study period, the exchange rate varied from slightly above USDCNY 6.1 to USDCNY 7.2. Figure 6 charts the evolution of the USDCNY exchange rate from September 2014 to September 2022.

Figure 6: The Evolution of the USDCNY Exchange Rate, September 2014 to September 2022



SECTION IV: DATA, SUMMARY STATISTICS, AND UNIT ROOT AND STATIONARITY TESTS

Table 1 displays a summary of the data used in the paper. The first column lists the variable labels. The second column furnishes the description of the variable and its date range. The third column tallies the frequency of the data and indicates whether daily data have been converted to monthly frequency. The final column catalogs the sources of the data.

Swap yields of three different maturity tenors are used. Two different variables for the short-term interest rate are obtained. These are based on Treasury bills of three-month and six-month tenors. Two different measures of inflation are used. These are the year-over-year percent change in the total CPI and the year-over-year percent change in the total CPI excluding food and energy, which is regarded as the core inflation. Economic activity is calibrated from the year-over-year growth of industrial production. Two different indexes of equity prices are used: one is based on an index of the SSE, while the other is the SZSE 300 stock index. The exchange rate is the value of CNY per US dollar. In the text and tables below, LN(.) indicates the (natural) logarithm of a variable.

Monthly data for these variables is used. The time-series data cover observations from September 2014 to September 2022. Thus, each time series consists of 98 observations.

Table 1: Summary of the Data

| Variable label | Description, date range | Frequency | Sources |
|----------------------------------|--|-----------------------------|-------------------------------------|
| <i>Swap yields</i> | | | |
| SWAP2Y | Interest rate swap, 2 years, CNY, % September 2014–September 2022 | Daily; converted to monthly | Tullet Prebon Information |
| SWAP5Y | Interest rate swap, 5 years, CNY, % September 2014–September 2022 | Daily; converted to monthly | Tullet Prebon Information |
| SWAP10Y | Interest rate swap, 10 years, CNY, %, September 2014–September 2022 | Daily; converted to monthly | Tullet Prebon Information |
| <i>Short-term interest rates</i> | | | |
| CTB3M | Treasury bill, 3 months, %, September 2014–September 2022 | Daily; converted to monthly | People’s Bank of China |
| CTB6M | Treasury bill, 6-months, %, September 2014–September 2022 | Daily; converted to monthly | People’s Bank of China |
| <i>Inflation</i> | | | |
| CPIYOY | Consumer price index, % change, y/y, September 2014–September 2022 | Monthly | China National Bureau of Statistics |
| CCPIYOY | Consumer price index excluding food and energy, % change, y/y, September 2014–September 2022 | Monthly | China National Bureau of Statistics |

| Variable label | Description, date range | Frequency | Sources |
|--------------------------|--|-----------------------------|-------------------------------------|
| <i>Economic activity</i> | | | |
| IPYOY | Industrial production: % change, y/y, September 2014–September 2022 | Monthly | China National Bureau of Statistics |
| <i>Financial market</i> | | | |
| SNGHAI | Shanghai Stock Exchange, Stock Price Index, close price, September 2014–September 2022 | Daily; converted to monthly | Shanghai Stock Exchange |
| SNZN300 | Shanghai-Shenzhen 300 Stock Price Index, close price, September 2014–September 2022 | Daily; converted to monthly | Shanghai Stock Exchange |
| <i>Exchange rate</i> | | | |
| USDCNY | Exchange rate, ¥/US\$, average, September 2014–September 2022 | Daily; converted to monthly | Federal Reserve Board |

The summary statistics of all variables in levels and first differences are presented in Tables 2A and 2B respectively. The average swap yields increase with the maturity tenors, as higher maturity indicates higher risk. Similarly, the mean of the six-month Treasury bill rate is higher than the mean of the three-month Treasury bill. The Jarque-Bera tests indicate that higher maturity swap yields, inflation and core inflation, and the growth of industrial production are not normally distributed in table 2A.

Table 2A: Summary Statistics of the Variables

| Vars | Obs | Mean | Std. Dev. | Max | Min | Skewness | Kurtosis | J-B | Probability |
|------------------|-----|------|-----------|-------|--------|----------|----------|---------|-------------|
| SWAP2Y | 98 | 2.77 | 0.51 | 3.80 | 1.58 | 0.42 | 2.53 | 3.72 | 0.16 |
| SWAP5Y | 98 | 3.04 | 0.48 | 4.03 | 1.94 | 0.54 | 2.62 | 5.28 | 0.07 |
| SWAP10Y | 98 | 3.32 | 0.47 | 4.47 | 2.25 | 0.72 | 3.12 | 8.53 | 0.01 |
| CTB3M | 98 | 2.36 | 0.57 | 3.97 | 1.00 | 0.48 | 3.02 | 3.78 | 0.15 |
| CTB6M | 98 | 2.48 | 0.56 | 3.92 | 1.10 | 0.42 | 2.93 | 2.88 | 0.24 |
| CPIYOY | 98 | 1.90 | 1.01 | 5.85 | -1.13 | 0.77 | 6.10 | 48.95 | 0.00 |
| CCPIYOY | 98 | 1.41 | 0.56 | 2.31 | 0.10 | -0.51 | 2.40 | 5.79 | 0.06 |
| IPYOY | 98 | 6.14 | 5.35 | 35.23 | -13.12 | 2.29 | 21.77 | 1523.83 | 0.00 |
| LNSNGHAI | 98 | 7.87 | 0.15 | 8.29 | 7.59 | 0.37 | 2.54 | 3.11 | 0.21 |
| LNSNZN300 | 98 | 8.26 | 0.18 | 8.62 | 7.79 | -0.05 | 2.80 | 0.21 | 0.90 |
| LNUSDCNY | 98 | 1.89 | 0.04 | 1.97 | 1.81 | -0.02 | 1.94 | 4.60 | 0.10 |

Table 2B shows the summary statistics of all the variables at their first difference. The short-run interest rates and swap rates are both more volatile at their first differences. None of the variables

have a normal distribution, according to the Jarque-Bera tests. The change in the growth of industrial production shows a large decline in March 2021, indicating the impact of the lockdowns on China's industrial sector.

Table 2B: Summary Statistics of the First Differences of the Variables

| Vars | Obs | Mean | Std. Dev. | Max | Min | Skewness | Kurtosis | J-B | Probability |
|--------------------|-----|--------|-----------|-------|--------|----------|----------|---------|-------------|
| Δ SWAP2Y | 97 | -0.015 | 0.17 | 0.49 | -0.62 | -0.32 | 6.01 | 38.27 | 0.00 |
| Δ SWAP5Y | 97 | -0.013 | 0.16 | 0.58 | -0.54 | 0.20 | 5.43 | 24.51 | 0.00 |
| Δ SWAP10Y | 97 | -0.012 | 0.16 | 0.69 | -0.54 | 0.70 | 6.98 | 72.05 | 0.00 |
| Δ CTB3M | 97 | -0.021 | 0.24 | 0.70 | -0.75 | -0.28 | 4.04 | 5.68 | 0.06 |
| Δ CTB6M | 97 | -0.021 | 0.21 | 0.75 | -0.61 | 0.04 | 4.98 | 15.85 | 0.00 |
| Δ CPIYOY | 97 | 0.004 | 0.51 | 1.39 | -1.62 | -0.50 | 4.43 | 12.31 | 0.00 |
| Δ CCPIYOY | 97 | -0.011 | 0.13 | 0.40 | -0.40 | 0.22 | 4.17 | 6.30 | 0.04 |
| Δ IPYOY | 97 | -0.027 | 4.57 | 28.43 | -21.42 | 0.78 | 25.04 | 1972.83 | 0.00 |
| Δ LNSNGHAI | 97 | 0.004 | 0.06 | 0.19 | -0.26 | -0.82 | 6.90 | 72.27 | 0.00 |
| Δ LNSNZN300 | 97 | 0.004 | 0.06 | 0.23 | -0.22 | -0.19 | 6.63 | 53.97 | 0.00 |
| Δ LNUSDCNY | 97 | 0.002 | 0.01 | 0.04 | -0.03 | 0.80 | 4.38 | 17.92 | 0.00 |

The unit root and stationarity tests' results are given in Tables 3A and 3B. Table 3A exhibits the unit root and stationarity tests of the variables at the level. It presents both augmented Dickey-Fuller (ADF) unit root tests and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) stationarity tests. The null hypotheses for the ADF and the KPSS tests are different. The unit root tests indicate most of the variables are stationary. The one strong exception is the growth in industrial production, which shows the presence of a unit root by both types of tests.

Table 3A: Unit Root and Stationarity Tests of the Variables

| Variables at Level | ADF Unit Root Tests (H ₀ : Has Unit Root) | | | KPSS Tests (H ₀ : Stationarity) | |
|--------------------|--|-----------|---------|--|--------|
| | None | Intercept | Trend | Intercept | Trend |
| SWAP2Y | -0.77 | -2.11 | -2.46 | 0.44* | 0.14* |
| SWAP5Y | -0.67 | -2.11 | -2.34 | 0.42* | 0.14* |
| SWAP10Y | -0.58 | -2.37 | -2.69 | 0.41* | 0.15** |
| CTB3M | -1.38 | -2.69* | -3.41* | 0.60** | 0.09 |
| CTB6M | -1.49 | -2.65* | -2.93 | 0.50** | 0.10* |
| CPIYOY | -1.10 | -2.53 | -2.52 | 0.10 | 0.10 |
| CCPIYOY | -0.96 | -0.38 | -1.57 | 0.75*** | 0.21** |
| IPYOY | -2.03** | -3.06** | -3.58** | 0.05 | 0.05 |
| LNSNGHAI | -0.54 | -2.44 | -2.37 | 0.50** | 0.18** |
| LNSNZN300 | -0.64 | -2.84* | -2.49 | 0.81*** | 0.07 |
| LNUSDCNY | -0.88 | -2.21 | -2.41 | 0.36* | 0.17** |

Note: Significance levels: *** for 1 percent, ** for 5 percent, and * for 10 percent

Table 3B shows the unit root and the stationarity tests of the variables in their first difference. All the variables become stationary at their first difference per both ADF and KPSS tests. In a few cases, KPSS tests rejected the null hypothesis of stationarity. However, the overall picture provides pretty strong support for stationarity at the first difference.

Table 3B: Unit Root and Stationarity Tests of the First Differences of the Variables

| Variables at First Difference | ADF Unit Root Tests (H ₀ : Has Unit Root) | | | KPSS Tests (H ₀ : Stationarity) | |
|-------------------------------|--|-----------|-----------|--|---------|
| | None | Intercept | Trend | Intercept | Trend |
| Δ SWAP2Y | -7.32*** | -7.29*** | -7.25*** | 0.07 | 0.07 |
| Δ SWAP5Y | -7.59*** | -7.55*** | -7.51*** | 0.07 | 0.07 |
| Δ SWAP10Y | -7.09*** | -7.06*** | -7.02*** | 0.06 | 0.06 |
| Δ CTB3M | -7.32*** | -7.29*** | -7.25*** | 0.60* | 0.09 |
| Δ CTB6M | -7.32*** | -7.29*** | -7.25*** | 0.49* | 0.10 |
| Δ CPIYOY | -5.36*** | -5.33*** | -5.31*** | 0.05 | 0.05 |
| Δ CCPIYOY | -9.40*** | -9.41*** | -9.56*** | 0.22 | 0.07 |
| Δ IPYOY | -10.81*** | -10.76*** | -10.70*** | 0.30 | 0.30*** |
| Δ LNSNGHAI | -6.15*** | -6.13*** | -6.12*** | 0.08 | 0.07 |
| Δ LNSNZN300 | -7.92*** | -7.91*** | -8.02*** | 0.18 | 0.08 |
| Δ LNUSDCNY | -5.50*** | -5.57*** | -5.54*** | 0.09 | 0.09 |

Note: Significance levels: *** for 1 percent, ** for 5 percent, and * for 10 percent

SECTION V: ECONOMETRIC FRAMEWORK, FINDINGS OF THE ESTIMATED MODELS, AND INTERPRETATIONS

Econometric Framework

Given the time-series properties of the data examined in the previous section, the ARDL approach is deemed the most appropriate for modeling the dynamics of CNY interest rate swaps as the variables are either stationary, I(0), or integrated in the first order, I(1). Estimates based on the ARDL approach can reveal both the short- and long-run effects of the independent variables on swap yields.

Three different models are estimated. In the simple model, the swap yield is just a function of the short-term interest rate. In the basic model, the swap yield is a function of the short-term interest rate, inflation or core inflation, and the growth of industrial production. In the extended model, the swap yield is a function not just of the short-term interest rate, inflation or core inflation, and the growth of industrial production, but also the month-over-month percentage change in the

equity price index and the month-over-month percentage change in the exchange rate. For each model, swap yields of three different maturity tenors—namely two-year, five-year, and ten-year—are used as the dependent variables in the regression equations.

Econometric Results

The main results are displayed in Tables 4 and 5. Table 4 shows estimations using the yield of three-month Treasury bills, which is the main variable of interest. In all models with three different maturity levels of swap yields, the yield of the three-month Treasury bills has a positive and statistically significant effect on the swap yield. A 100-basis point increase in three-month Treasury bill increases the two-year swap yield by 43–45 basis points. The effect declines with a higher maturity tenor for the swap. The effect of the Treasury bill yield declines to 36–37 basis points for a 10-year swap. The long-term relationship between the three-month Treasury bill yield and the swap yield is also revealed. The long-run relationship varies significantly from the two-year maturity term to 10-year maturity. The rate of adjustment to any shock to the long-run relationship between the Treasury bill yield and the swap yield differs for different maturities. A shock dissipates somewhere between 4.5 months to 7 months, after which the relation between the Treasury bill and the swap yield returns to its long-run equilibrium. Among the control variables, the core inflation rate, the growth of industrial production, and the percentage change in the SSE have a positive impact on the swap rates. A higher level of core inflation requires a higher swap yield, whereas stronger growth in industrial production and/or a rise in the equity index leads to a higher swap yield.

The adjusted R^2 implies that much of the variance in the swap yield is explained by the Treasury bill yield and its lags as well as the autoregressive variables. The Akaike Information Criterion (AIC) also shows a good fit for all the models.

Table 4: ARDL (p, q) Model (with CTB3M)

| | SWAP2Y | SWAP2Y | SWAP2Y | SWAP5Y | SWAP5Y | SWAP5Y | SWAP10Y | SWAP10Y | SWAP10Y |
|--|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Main equation | | | | | | | | | |
| CTB3M | 0.45*** (0.00) | 0.43*** (0.00) | 0.43*** (0.00) | 0.41*** (0.00) | 0.39*** (0.00) | 0.40*** (0.00) | 0.37*** (0.00) | 0.36*** (0.00) | 0.36*** (0.00) |
| CTB3M(-1) | -0.51*** (0.00) | -0.47*** (0.00) | -0.49*** (0.00) | -0.49*** (0.00) | -0.47*** (0.00) | -0.49*** (0.00) | -0.49*** (0.00) | -0.48*** (0.00) | -0.51*** (0.00) |
| SWAP_iY(-1) | 1.10*** (0.00) | 1.07*** (0.00) | 1.08*** (0.00) | 1.11*** (0.00) | 1.08*** (0.00) | 1.09*** (0.00) | 1.24*** (0.00) | 1.21*** (0.00) | 1.22*** (0.00) |
| CCPIYOY | | 0.06** (0.04) | 0.07** (0.02) | | 0.06* (0.08) | 0.06* (0.05) | | 0.08** (0.04) | 0.08** (0.02) |
| IPYOY | | 0.005*** (0.00) | 0.004** (0.01) | | 0.005*** (0.00) | 0.004*** (0.00) | | 0.005*** (0.00) | 0.005*** (0.00) |
| ΔLNSNGHAI | | | 0.35 (0.24) | | | 0.41* (0.07) | | | 0.50** (0.03) |
| ΔLNUSDCNY | | | -0.37 (0.72) | | | -0.18 (0.88) | | | 0.12 (0.91) |
| Intercept | 0.15* (0.05) | 0.18** (0.03) | 0.19** (0.01) | 0.20** (0.01) | 0.24*** (0.00) | 0.23*** (0.00) | 0.26** (0.01) | 0.36*** (0.00) | 0.34*** (0.00) |
| Cointegrating relationship | | | | | | | | | |
| Long-term Coefficient | 0.81*** (0.00) | 0.61*** (0.00) | 0.55*** (0.00) | 0.72*** (0.00) | 0.48*** (0.00) | 0.40* (0.05) | 0.61*** (0.00) | 0.29*** (0.00) | 0.21 (0.34) |
| Rate of Adjustment | -0.18*** (0.00) | -0.22*** (0.00) | -0.21*** (0.00) | -0.15** (0.01) | -0.19*** (0.00) | -0.17*** (0.00) | -0.14*** (0.00) | -0.19*** (0.00) | -0.17*** (0.00) |
| Model information | | | | | | | | | |
| Obs | 96 | 96 | 96 | 95 | 95 | 95 | 96 | 95 | 95 |
| Adj R² | 0.94 | 0.94 | 0.94 | 0.94 | 0.95 | 0.94 | 0.93 | 0.93 | 0.94 |
| AIC | -1.32 | -1.34 | -1.34 | -1.32 | -1.34 | -1.34 | -1.27 | -1.29 | -1.32 |
| Diagnostic Tests | | | | | | | | | |
| Joint Significance F-Test | 309.56 (0.00) | 230.51 (0.00) | 182.64 (0.00) | 236.96 (0.00) | 184.70 (0.00) | 151.97 (0.00) | 248.65 (0.00) | 164.51 (0.00) | 137.68 (0.00) |
| Serial Correlation Durbin-Watson Stat | 1.94 | 1.99 | 1.98 | 1.99 | 2.05 | 2.03 | 1.96 | 2.03 | 2.04 |
| Serial Correlation Breusch-Godfrey LM Test | 0.26 (0.77) | 0.39 (0.67) | 0.81 (0.45) | 0.01 (0.99) | 0.92 (0.40) | 0.62 (0.53) | 0.11 (0.89) | 0.72 (0.49) | 0.68 (0.51) |
| Heteroskedasticity Breusch-Pagan-Godfrey Test | 1.34 (0.25) | 0.97 (0.46) | 2.64 (0.01) | 1.39 (0.23) | 1.24 (0.28) | 2.22 (0.02) | 1.75 (0.13) | 1.44 (0.19) | 1.86 (0.06) |
| Normality Test Jarque-Bera Stat | 20.58 (0.00) | 19.96 (0.00) | 76.21 (0.00) | 1.13 (0.57) | 1.10 (0.57) | 9.12 (0.01) | 4.58 (0.11) | 1.55 (0.46) | 14.35 (0.00) |
| Stability Diagnostic Ramsey RESET Test | 0.64 (0.53) | 0.47 (0.63) | 0.56 (0.57) | 0.30 (0.74) | 0.28 (0.76) | 0.13 (0.88) | 0.24 (0.79) | 0.36 (0.70) | 0.23 (0.80) |

Note: *p*-values are in parenthesis. ***, **, * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively. BG LM is with two lags and Ramsey RESET test is fitted with two terms.

A panel of postestimation diagnostic tests is also displayed. The joint significance tests show a strong rejection of the insignificance of the regressors. The Durbin-Watson statistics and Breusch-Godfrey Lagrange Multiplier tests indicate there is no serial correlation for the error terms in these models. The correlogram Q-statistics (reported in appendix A) show that the mean equations in these models are correctly specified and there are no remaining serial correlations. The Breusch-Pagan-Godfrey heteroskedasticity tests fail to reject the null hypothesis of homoscedasticity in all models except one at the five-percent significance level. The Jarque-Bera tests indicate that the error terms are not normally distributed, which is a not an uncommon phenomenon for financial variables. Last but not least, tests of model specification and stability tests are conducted. The Ramsey RESET tests indicate all the models are well-specified. CUSUM and CUSUM-SQ tests of the basic and extended models for all three maturity tenors are reported in Appendix B. Brown, Durbin, and Evans (1975) showed that the CUSUM test is a test of instability in the equation. Hansen (1991) established that the CUSUM-SQ is a test of the instability in the variance of the regression errors (. The CUSUM and the CUSUM-SQ tests show that all these models are well specified and stable in both intercept- and regression-error variances.

Robustness checks are conducted by changing some variables. The three-month Treasury bill yield is replaced with the six-month Treasury bill yield. A measure of total CPI inflation instead of the core CPI inflation is used, and the SZSE index replaces the SSE index. The main findings are essentially unchanged, as displayed in Table 5. However, the effects of the six-month Treasury bill yield on the swap yield are somewhat larger than the three-month Treasury bill yield. While the long-term relation between the swap yield and six-month Treasury bill yield remain very similar to the results in Table 4, the rate of adjustment takes longer: increasing from five months to nine months. Unlike the core inflation, the total inflation shows no statistically significant effect on the swap yield. The SZSE index has a slightly stronger positive effect on the swap yield. The adjusted R^2 , AIC, and diagnostic test results in Table 5 are identical to their counterparts in Table 4.

Table 5: ARDL (p, q) Model (with CTB6M)

| | SWAP2Y | SWAP2Y | SWAP2Y | SWAP5Y | SWAP5Y | SWAP5Y | SWAP10Y | SWAP10Y | SWAP10Y |
|--|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| Main equation | | | | | | | | | |
| CTB6M | 0.52*** (0.00) | 0.55*** (0.00) | 0.52*** (0.00) | 0.47*** (0.00) | 0.50*** (0.00) | 0.48*** (0.00) | 0.43*** (0.00) | 0.43*** (0.00) | 0.42*** (0.00) |
| CTB6M(-1) | -0.53*** (0.00) | -0.46*** (0.00) | -0.57*** (0.00) | -0.48*** (0.00) | -0.43*** (0.00) | -0.47*** (0.00) | -0.52*** (0.00) | -0.50*** (0.00) | -0.55*** (0.00) |
| SWAP_Y(-1) | 1.04*** (0.00) | 0.86*** (0.00) | 1.05*** (0.00) | 1.05*** (0.00) | 0.88*** (0.00) | 0.93*** (0.00) | 1.21*** (0.00) | 1.18*** (0.00) | 1.23*** (0.00) |
| CPIYOY | | 0.01 (0.17) | 0.07 (0.58) | | 0.02 (0.14) | 0.01 (0.31) | | 0.01 (0.38) | 0.04 (0.70) |
| IPYOY | | 0.005** (0.01) | 0.003 (0.12) | | 0.005*** (0.00) | 0.004*** (0.01) | | 0.004** (0.01) | 0.003* (0.08) |
| ΔLNSNZN300 | | | 0.48 (0.14) | | | 0.56** (0.02) | | | 0.62** (0.02) |
| ΔLNUSDCNY | | | 0.08 (0.92) | | | 0.40 (0.70) | | | 0.42 (0.73) |
| Intercept | 0.14** (0.049) | 0.08 (0.29) | 0.12* (0.05) | 0.19** (0.01) | 0.12 (0.22) | 0.12 (0.21) | 0.27** (0.01) | 0.23** (0.03) | 0.23** (0.01) |
| Cointegrating relationship | | | | | | | | | |
| Long-term Coefficient | 0.82*** (0.00) | 0.69*** (0.00) | 0.73*** (0.00) | 0.76*** (0.00) | 0.59** (0.03) | 0.22 (0.77) | 0.60*** (0.00) | 0.58*** (0.00) | 0.42 (0.14) |
| Rate of Adjustment | -0.20*** (0.00) | -0.14** (0.02) | -0.16** (0.01) | -0.17*** (0.00) | -0.12** (0.02) | -0.07** (0.03) | -0.15*** (0.00) | -0.14*** (0.00) | -0.11** (0.01) |
| Model information | | | | | | | | | |
| Obs | 96 | 97 | 96 | 95 | 97 | 97 | 96 | 96 | 96 |
| Adj R² | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.94 | 0.93 | 0.93 | 0.93 |
| AIC | -1.32 | -1.27 | -1.32 | -1.34 | -1.29 | -1.33 | -1.27 | -1.25 | -1.30 |
| Diagnostic tests | | | | | | | | | |
| Joint Significance F-Test | 310.71 (0.00) | 294.35 (0.00) | 179.32 (0.00) | 289.04 (0.00) | 274.24 (0.00) | 209.06 (0.00) | 249.15 (0.00) | 179.69 (0.00) | 148.86 (0.00) |
| Serial Correlation Durbin-Watson Stat | 1.97 | 1.71 | 1.98 | 2.01 | 1.71 | 1.69 | 1.99 | 2.00 | 2.02 |
| Serial Correlation Breusch-Godfrey LM Test | 0.21 (0.81) | 2.35 (0.11) | 1.15 (0.32) | 0.01 (0.99) | 1.13 (0.32) | 1.25 (0.29) | 0.03 (0.96) | 0.15 (0.86) | 0.27 (0.76) |
| Heteroskedasticity Breusch-Pagan-Godfrey Test | 1.20 (0.31) | 1.03 (0.40) | 2.64 (0.01) | 0.09 (0.91) | 0.64 (0.67) | 1.67 (0.13) | 2.37 (0.05) | 1.64 (0.13) | 1.95 (0.06) |
| Normality Test Jarque-Bera Stat | 24.09 (0.00) | 6.82 (0.03) | 123.52 (0.00) | 4.16 (0.12) | 4.11 (0.13) | 8.89 (0.01) | 4.99 (0.08) | 6.34 (0.04) | 31.16 (0.00) |
| Stability Diagnostic Ramsey RESET Test | 0.14 (0.87) | 0.29 (0.74) | 0.33 (0.72) | 0.003 (0.99) | 0.10 (0.90) | 0.30 (0.74) | 0.31 (0.73) | 0.32 (0.72) | 0.04 (0.96) |

Note: *p*-values are in parenthesis. ***, **, * implies statistical significance at 1 percent, 5 percent, and 10 percent, respectively. BG LM is with two lags and Ramsey RESET test is fitted with two terms.

Implications of the Findings

These findings imply that the People's Bank of China (PBOC), the country's central bank, can influence interest rate swap yields of different maturity tenors through the effects of its policy rate and monetary policy actions on the short-term interest rate. This suggests that the PBOC can influence borrowing and lending rates on a range of fixed-income instruments, including swaps and swaptions. This gives the PBOC enormous clout over China's financial system. It vindicates and extends Keynes's view that the central bank's actions have a decisive effect on the long-term interest rate in two consequential ways. First, it shows that Keynes's hypothesis about the effect of a central bank's actions on the long-term interest rate is also applicable for interest rate swap yields, not just government bond yields. Second, it shows that Keynes's conjecture about the strong connection between the current short-term interest rate and the long-term interest rate is not merely confined to advanced capitalist economies, such as the United States and the United Kingdom, but also holds in emerging market economies, such as China.

SECTION VI: CONCLUSION

The empirical findings presented in this paper illustrate that the short-term interest rate has an economically and statistically significant effect on the CNY-denominated, long-term interest rate swap yield, after controlling for key macroeconomic variables, such as inflation or core inflation, the growth of industrial production, the percentage change in the equity market index, and the percentage change in the exchange rate of the currency. Three different models of the long-term swap yield of different maturity tenors are estimated to show these results are quite robust, irrespective of the specifications of the estimated regression equation. Alternative choices of independent variables bear that the empirical findings are well-grounded.

There is a lacuna in the empirical modeling of interest rate swap yields in emerging markets. However, the role of interest rate swaps in the financial systems of an emerging market economy, such as China, is likely to grow with the rise of the financial sector in such emerging markets and their increasing financialization. The financial sector already plays a stalwart role in the Chinese economy. This paper fills a gap in the empirical modeling of interest rate swap

yields in China. The empirical modeling of interest rate swaps in emerging markets, such as China, can enable policymakers and investors to go beyond just understanding the dynamics of swap yields. It can illuminate the workings of the financial system and capital markets and assess the effectiveness of the monetary transmission mechanism in China and other emerging economies. It can be valuable in asset allocation, risk management, and real investment decisions.

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



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APPENDIX A: Correlogram – Q -Stat ARDL (p, q) Models with CTB3M

Table A1: SWAP2Y = $\phi^1(C, CTB3M)$

Sample (adjusted): 2014M11 2022M10

Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* | |
|---|---|----|--------|--------|--------|-------|
|  |  | 1 | 0.030 | 0.030 | 0.0909 | 0.763 |
|  |  | 2 | -0.040 | -0.041 | 0.2499 | 0.883 |
|  |  | 3 | 0.141 | 0.144 | 2.2681 | 0.519 |
|  |  | 4 | -0.147 | -0.162 | 4.4813 | 0.345 |
|  |  | 5 | 0.082 | 0.115 | 5.1843 | 0.394 |
|  |  | 6 | 0.199 | 0.160 | 9.3293 | 0.156 |
|  |  | 7 | -0.035 | -0.003 | 9.4567 | 0.222 |
|  |  | 8 | 0.184 | 0.167 | 13.071 | 0.109 |
|  |  | 9 | 0.003 | -0.045 | 13.072 | 0.159 |
|  |  | 10 | -0.108 | -0.041 | 14.349 | 0.158 |
|  |  | 11 | 0.000 | -0.083 | 14.349 | 0.214 |
|  |  | 12 | -0.069 | -0.057 | 14.889 | 0.248 |
|  |  | 13 | -0.155 | -0.181 | 17.602 | 0.173 |
|  |  | 14 | -0.025 | -0.102 | 17.673 | 0.222 |
|  |  | 15 | 0.044 | 0.070 | 17.899 | 0.268 |
|  |  | 16 | -0.075 | -0.077 | 18.566 | 0.292 |
|  |  | 17 | 0.020 | 0.054 | 18.615 | 0.351 |
|  |  | 18 | -0.099 | -0.074 | 19.787 | 0.345 |
|  |  | 19 | -0.257 | -0.161 | 27.885 | 0.086 |
|  |  | 20 | 0.008 | 0.026 | 27.893 | 0.112 |
|  |  | 21 | 0.050 | 0.099 | 28.203 | 0.134 |
|  |  | 22 | -0.131 | -0.095 | 30.387 | 0.109 |
|  |  | 23 | 0.157 | 0.100 | 33.548 | 0.072 |
|  |  | 24 | -0.055 | -0.019 | 33.939 | 0.086 |
|  |  | 25 | -0.162 | -0.084 | 37.418 | 0.053 |
|  |  | 26 | 0.110 | 0.063 | 39.058 | 0.048 |
|  |  | 27 | -0.187 | -0.161 | 43.842 | 0.021 |
|  |  | 28 | 0.057 | 0.121 | 44.288 | 0.026 |
|  |  | 29 | 0.134 | -0.048 | 46.820 | 0.019 |
|  |  | 30 | -0.046 | 0.091 | 47.116 | 0.024 |
|  |  | 31 | 0.004 | -0.139 | 47.119 | 0.032 |
|  |  | 32 | -0.042 | -0.109 | 47.377 | 0.039 |
|  |  | 33 | -0.174 | -0.098 | 51.879 | 0.019 |
|  |  | 34 | 0.164 | 0.153 | 55.965 | 0.010 |
|  |  | 35 | 0.005 | -0.011 | 55.969 | 0.014 |
|  |  | 36 | -0.082 | -0.108 | 57.016 | 0.014 |

*Probabilities may not be valid for this equation specification.

Table A2: SWAP2Y = $\phi^2(C, CTB3M, CCPIYOY, IPYOY)$

Sample (adjusted): 2014M11 2022M10

Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* |
|-----------------|---------------------|-----------|--------|--------|-------|
| | | 1 0.004 | 0.004 | 0.0016 | 0.968 |
| | | 2 -0.070 | -0.070 | 0.4876 | 0.784 |
| | | 3 0.141 | 0.142 | 2.4932 | 0.477 |
| | | 4 -0.122 | -0.133 | 4.0102 | 0.405 |
| | | 5 0.105 | 0.136 | 5.1396 | 0.399 |
| | | 6 0.192 | 0.152 | 8.9961 | 0.174 |
| | | 7 -0.074 | -0.033 | 9.5743 | 0.214 |
| | | 8 0.127 | 0.119 | 11.285 | 0.186 |
| | | 9 -0.002 | -0.041 | 11.286 | 0.257 |
| | | 10 -0.059 | 0.005 | 11.667 | 0.308 |
| | | 11 0.024 | -0.065 | 11.732 | 0.384 |
| | | 12 -0.093 | -0.093 | 12.708 | 0.391 |
| | | 13 -0.162 | -0.182 | 15.680 | 0.267 |
| | | 14 -0.042 | -0.108 | 15.879 | 0.321 |
| | | 15 0.032 | 0.054 | 15.998 | 0.382 |
| | | 16 -0.078 | -0.091 | 16.722 | 0.404 |
| | | 17 0.028 | 0.066 | 16.812 | 0.467 |
| | | 18 -0.099 | -0.076 | 17.985 | 0.457 |
| | | 19 -0.271 | -0.188 | 26.944 | 0.106 |
| | | 20 -0.002 | -0.004 | 26.944 | 0.137 |
| | | 21 0.056 | 0.078 | 27.344 | 0.160 |
| | | 22 -0.155 | -0.109 | 30.393 | 0.109 |
| | | 23 0.137 | 0.107 | 32.819 | 0.084 |
| | | 24 -0.062 | -0.022 | 33.325 | 0.097 |
| | | 25 -0.168 | -0.099 | 37.068 | 0.057 |
| | | 26 0.116 | 0.038 | 38.865 | 0.050 |
| | | 27 -0.196 | -0.193 | 44.123 | 0.020 |
| | | 28 0.038 | 0.106 | 44.322 | 0.026 |
| | | 29 0.112 | -0.053 | 46.068 | 0.023 |
| | | 30 -0.056 | 0.085 | 46.516 | 0.028 |
| | | 31 0.005 | -0.142 | 46.519 | 0.036 |
| | | 32 -0.031 | -0.113 | 46.656 | 0.046 |
| | | 33 -0.161 | -0.118 | 50.538 | 0.026 |
| | | 34 0.178 | 0.136 | 55.338 | 0.012 |
| | | 35 0.026 | 0.027 | 55.439 | 0.015 |
| | | 36 -0.059 | -0.050 | 55.990 | 0.018 |

*Probabilities may not be valid for this equation specification.

Table A3: SWAP2Y = $\varphi^3(C, CTB3M, CCPIYOY, IPYOY, \Delta LNSNGHAI, \Delta LNUSDCNY)$

Sample (adjusted): 2014M11 2022M10

Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* |
|-----------------|---------------------|-----------|--------|--------|-------|
| | | 1 0.009 | 0.009 | 0.0075 | 0.931 |
| | | 2 -0.106 | -0.106 | 1.1275 | 0.569 |
| | | 3 0.134 | 0.138 | 2.9564 | 0.398 |
| | | 4 -0.126 | -0.147 | 4.5908 | 0.332 |
| | | 5 0.052 | 0.095 | 4.8720 | 0.432 |
| | | 6 0.185 | 0.136 | 8.4608 | 0.206 |
| | | 7 -0.049 | -0.010 | 8.7155 | 0.274 |
| | | 8 0.132 | 0.146 | 10.576 | 0.227 |
| | | 9 0.003 | -0.045 | 10.577 | 0.306 |
| | | 10 -0.077 | 0.003 | 11.230 | 0.340 |
| | | 11 0.028 | -0.040 | 11.319 | 0.417 |
| | | 12 -0.084 | -0.089 | 12.108 | 0.437 |
| | | 13 -0.152 | -0.161 | 14.718 | 0.325 |
| | | 14 0.026 | -0.044 | 14.795 | 0.392 |
| | | 15 0.078 | 0.091 | 15.501 | 0.416 |
| | | 16 -0.063 | -0.070 | 15.972 | 0.455 |
| | | 17 0.041 | 0.067 | 16.168 | 0.512 |
| | | 18 -0.075 | -0.066 | 16.840 | 0.534 |
| | | 19 -0.239 | -0.164 | 23.792 | 0.204 |
| | | 20 0.012 | -0.000 | 23.808 | 0.251 |
| | | 21 0.033 | 0.018 | 23.946 | 0.296 |
| | | 22 -0.160 | -0.139 | 27.183 | 0.204 |
| | | 23 0.112 | 0.059 | 28.794 | 0.187 |
| | | 24 -0.068 | -0.066 | 29.396 | 0.206 |
| | | 25 -0.186 | -0.121 | 34.003 | 0.108 |
| | | 26 0.117 | 0.074 | 35.857 | 0.094 |
| | | 27 -0.214 | -0.202 | 42.128 | 0.032 |
| | | 28 0.015 | 0.136 | 42.159 | 0.042 |
| | | 29 0.105 | -0.061 | 43.707 | 0.039 |
| | | 30 -0.043 | 0.128 | 43.969 | 0.048 |
| | | 31 0.012 | -0.105 | 43.989 | 0.061 |
| | | 32 -0.022 | -0.075 | 44.062 | 0.076 |
| | | 33 -0.187 | -0.100 | 49.257 | 0.034 |
| | | 34 0.137 | 0.090 | 52.124 | 0.024 |
| | | 35 0.006 | -0.026 | 52.130 | 0.031 |
| | | 36 -0.067 | -0.067 | 52.840 | 0.035 |

*Probabilities may not be valid for this equation specification.

Table A4: SWAP5Y = $\phi^4(C, CTB3M)$

Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* |
|-----------------|---------------------|-----------|--------|--------|-------|
| | | 1 -0.000 | -0.000 | 9.E-06 | 0.998 |
| | | 2 0.007 | 0.007 | 0.0051 | 0.997 |
| | | 3 0.100 | 0.100 | 1.0020 | 0.801 |
| | | 4 -0.229 | -0.231 | 6.3137 | 0.177 |
| | | 5 -0.007 | -0.004 | 6.3184 | 0.276 |
| | | 6 0.149 | 0.152 | 8.6081 | 0.197 |
| | | 7 -0.059 | -0.021 | 8.9666 | 0.255 |
| | | 8 0.276 | 0.238 | 17.034 | 0.030 |
| | | 9 0.030 | -0.013 | 17.127 | 0.047 |
| | | 10 -0.090 | -0.033 | 18.011 | 0.055 |
| | | 11 -0.039 | -0.108 | 18.179 | 0.078 |
| | | 12 -0.074 | 0.013 | 18.779 | 0.094 |
| | | 13 -0.116 | -0.091 | 20.292 | 0.088 |
| | | 14 -0.033 | -0.130 | 20.414 | 0.118 |
| | | 15 0.081 | 0.101 | 21.175 | 0.131 |
| | | 16 -0.052 | -0.120 | 21.487 | 0.161 |
| | | 17 0.020 | 0.017 | 21.533 | 0.203 |
| | | 18 -0.054 | -0.080 | 21.878 | 0.237 |
| | | 19 -0.242 | -0.162 | 28.961 | 0.067 |
| | | 20 0.059 | 0.092 | 29.392 | 0.080 |
| | | 21 0.112 | 0.162 | 30.944 | 0.075 |
| | | 22 -0.135 | -0.081 | 33.247 | 0.058 |
| | | 23 0.151 | 0.001 | 36.167 | 0.040 |
| | | 24 -0.078 | -0.051 | 36.950 | 0.044 |
| | | 25 -0.186 | -0.117 | 41.505 | 0.020 |
| | | 26 0.128 | 0.102 | 43.682 | 0.016 |
| | | 27 -0.188 | -0.128 | 48.486 | 0.007 |
| | | 28 0.095 | 0.138 | 49.730 | 0.007 |
| | | 29 0.123 | -0.095 | 51.833 | 0.006 |
| | | 30 -0.076 | 0.039 | 52.641 | 0.006 |
| | | 31 -0.029 | -0.145 | 52.763 | 0.009 |
| | | 32 -0.039 | -0.070 | 52.980 | 0.011 |
| | | 33 -0.163 | -0.018 | 56.942 | 0.006 |
| | | 34 0.136 | 0.131 | 59.741 | 0.004 |
| | | 35 -0.009 | 0.031 | 59.753 | 0.006 |
| | | 36 -0.022 | -0.163 | 59.831 | 0.008 |

*Probabilities may not be valid for this equation specification.

Table A5: SWAP5Y = $\phi^5(C, CTB3M, CCPIYOY, IPYOY)$

Sample (adjusted): 2014M12 2022M10

Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* |
|-----------------|---------------------|-----------|--------|--------|-------|
| | | 1 -0.035 | -0.035 | 0.1193 | 0.730 |
| | | 2 -0.019 | -0.020 | 0.1540 | 0.926 |
| | | 3 0.105 | 0.103 | 1.2486 | 0.741 |
| | | 4 -0.207 | -0.202 | 5.5676 | 0.234 |
| | | 5 0.027 | 0.022 | 5.6424 | 0.343 |
| | | 6 0.147 | 0.136 | 7.8667 | 0.248 |
| | | 7 -0.106 | -0.066 | 9.0420 | 0.250 |
| | | 8 0.216 | 0.184 | 13.966 | 0.083 |
| | | 9 0.012 | -0.004 | 13.982 | 0.123 |
| | | 10 -0.045 | 0.030 | 14.202 | 0.164 |
| | | 11 -0.013 | -0.092 | 14.221 | 0.221 |
| | | 12 -0.092 | -0.041 | 15.167 | 0.232 |
| | | 13 -0.125 | -0.122 | 16.931 | 0.202 |
| | | 14 -0.058 | -0.135 | 17.320 | 0.240 |
| | | 15 0.062 | 0.095 | 17.757 | 0.276 |
| | | 16 -0.059 | -0.120 | 18.159 | 0.315 |
| | | 17 0.027 | 0.031 | 18.244 | 0.374 |
| | | 18 -0.056 | -0.102 | 18.615 | 0.416 |
| | | 19 -0.250 | -0.193 | 26.174 | 0.125 |
| | | 20 0.056 | 0.070 | 26.554 | 0.148 |
| | | 21 0.113 | 0.149 | 28.155 | 0.136 |
| | | 22 -0.163 | -0.095 | 31.516 | 0.086 |
| | | 23 0.128 | 0.001 | 33.608 | 0.071 |
| | | 24 -0.085 | -0.048 | 34.547 | 0.075 |
| | | 25 -0.186 | -0.151 | 39.097 | 0.036 |
| | | 26 0.134 | 0.050 | 41.482 | 0.028 |
| | | 27 -0.201 | -0.167 | 46.959 | 0.010 |
| | | 28 0.077 | 0.137 | 47.775 | 0.011 |
| | | 29 0.096 | -0.093 | 49.052 | 0.011 |
| | | 30 -0.085 | 0.024 | 50.082 | 0.012 |
| | | 31 -0.022 | -0.174 | 50.152 | 0.016 |
| | | 32 -0.038 | -0.104 | 50.364 | 0.021 |
| | | 33 -0.156 | -0.048 | 53.977 | 0.012 |
| | | 34 0.144 | 0.107 | 57.093 | 0.008 |
| | | 35 -0.001 | 0.067 | 57.093 | 0.011 |
| | | 36 -0.002 | -0.121 | 57.094 | 0.014 |

*Probabilities may not be valid for this equation specification.

Table A6: SWAP5Y = $\phi^6(C, CTB3M, CCPIYOY, IPYOY, \Delta LNSNGHAI, \Delta LNUSDCNY)$

Sample (adjusted): 2014M12 2022M10

Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* |
|-----------------|---------------------|-----------|--------|--------|-------|
| | | 1 -0.027 | -0.027 | 0.0692 | 0.793 |
| | | 2 -0.047 | -0.048 | 0.2924 | 0.864 |
| | | 3 0.105 | 0.102 | 1.3875 | 0.708 |
| | | 4 -0.214 | -0.214 | 6.0386 | 0.196 |
| | | 5 -0.031 | -0.028 | 6.1349 | 0.293 |
| | | 6 0.139 | 0.114 | 8.1398 | 0.228 |
| | | 7 -0.077 | -0.038 | 8.7577 | 0.271 |
| | | 8 0.226 | 0.211 | 14.169 | 0.077 |
| | | 9 0.031 | -0.011 | 14.275 | 0.113 |
| | | 10 -0.067 | 0.014 | 14.761 | 0.141 |
| | | 11 -0.008 | -0.066 | 14.768 | 0.193 |
| | | 12 -0.085 | -0.032 | 15.574 | 0.212 |
| | | 13 -0.121 | -0.096 | 17.224 | 0.189 |
| | | 14 0.008 | -0.066 | 17.232 | 0.244 |
| | | 15 0.103 | 0.128 | 18.460 | 0.239 |
| | | 16 -0.048 | -0.112 | 18.725 | 0.283 |
| | | 17 0.048 | 0.041 | 19.002 | 0.328 |
| | | 18 -0.035 | -0.070 | 19.146 | 0.383 |
| | | 19 -0.230 | -0.168 | 25.581 | 0.142 |
| | | 20 0.059 | 0.076 | 26.014 | 0.165 |
| | | 21 0.087 | 0.099 | 26.949 | 0.173 |
| | | 22 -0.155 | -0.102 | 29.979 | 0.119 |
| | | 23 0.098 | -0.046 | 31.214 | 0.118 |
| | | 24 -0.082 | -0.081 | 32.078 | 0.125 |
| | | 25 -0.206 | -0.170 | 37.686 | 0.050 |
| | | 26 0.129 | 0.081 | 39.924 | 0.040 |
| | | 27 -0.233 | -0.208 | 47.301 | 0.009 |
| | | 28 0.061 | 0.138 | 47.806 | 0.011 |
| | | 29 0.105 | -0.088 | 49.348 | 0.011 |
| | | 30 -0.067 | 0.065 | 49.988 | 0.012 |
| | | 31 -0.015 | -0.126 | 50.020 | 0.017 |
| | | 32 -0.019 | -0.075 | 50.075 | 0.022 |
| | | 33 -0.194 | -0.040 | 55.655 | 0.008 |
| | | 34 0.104 | 0.055 | 57.284 | 0.007 |
| | | 35 -0.015 | 0.030 | 57.320 | 0.010 |
| | | 36 -0.009 | -0.114 | 57.334 | 0.013 |

*Probabilities may not be valid for this equation specification.

Table A7: SWAP10Y = $\phi^7(C, CTB3M)$

Sample (adjusted): 2014M11 2022M10

Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* |
|-----------------|---------------------|-----------|--------|--------|-------|
| | | 1 0.018 | 0.018 | 0.0325 | 0.857 |
| | | 2 -0.004 | -0.005 | 0.0343 | 0.983 |
| | | 3 0.130 | 0.130 | 1.7359 | 0.629 |
| | | 4 -0.193 | -0.202 | 5.5644 | 0.234 |
| | | 5 -0.018 | -0.004 | 5.5984 | 0.347 |
| | | 6 0.114 | 0.101 | 6.9499 | 0.326 |
| | | 7 -0.058 | -0.017 | 7.3096 | 0.397 |
| | | 8 0.216 | 0.196 | 12.282 | 0.139 |
| | | 9 0.024 | -0.029 | 12.345 | 0.195 |
| | | 10 -0.084 | -0.039 | 13.124 | 0.217 |
| | | 11 0.022 | -0.035 | 13.179 | 0.282 |
| | | 12 -0.079 | -0.022 | 13.872 | 0.309 |
| | | 13 -0.066 | -0.031 | 14.373 | 0.348 |
| | | 14 -0.055 | -0.127 | 14.715 | 0.398 |
| | | 15 0.043 | 0.086 | 14.933 | 0.456 |
| | | 16 -0.048 | -0.103 | 15.200 | 0.510 |
| | | 17 0.027 | 0.043 | 15.284 | 0.575 |
| | | 18 -0.087 | -0.118 | 16.198 | 0.579 |
| | | 19 -0.189 | -0.163 | 20.571 | 0.361 |
| | | 20 0.003 | 0.039 | 20.572 | 0.423 |
| | | 21 0.113 | 0.149 | 22.169 | 0.390 |
| | | 22 -0.117 | -0.074 | 23.917 | 0.352 |
| | | 23 0.105 | 0.006 | 25.341 | 0.333 |
| | | 24 -0.062 | -0.084 | 25.851 | 0.361 |
| | | 25 -0.159 | -0.082 | 29.210 | 0.255 |
| | | 26 0.109 | 0.115 | 30.807 | 0.236 |
| | | 27 -0.132 | -0.085 | 33.186 | 0.191 |
| | | 28 0.102 | 0.155 | 34.626 | 0.181 |
| | | 29 0.082 | -0.110 | 35.581 | 0.186 |
| | | 30 -0.070 | 0.037 | 36.284 | 0.199 |
| | | 31 -0.012 | -0.101 | 36.305 | 0.235 |
| | | 32 0.001 | -0.015 | 36.305 | 0.275 |
| | | 33 -0.126 | -0.028 | 38.691 | 0.228 |
| | | 34 0.104 | 0.047 | 40.345 | 0.210 |
| | | 35 0.003 | 0.064 | 40.347 | 0.246 |
| | | 36 -0.074 | -0.195 | 41.200 | 0.254 |

*Probabilities may not be valid for this equation specification.

Table A8: SWAP10Y = $\phi^8(C, CTB3M, CCPIYOY, IPYOY)$

Sample (adjusted): 2014M12 2022M10

Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* |
|-----------------|---------------------|-----------|--------|--------|-------|
| | | 1 -0.033 | -0.033 | 0.1049 | 0.746 |
| | | 2 -0.022 | -0.023 | 0.1517 | 0.927 |
| | | 3 0.096 | 0.094 | 1.0664 | 0.785 |
| | | 4 -0.151 | -0.147 | 3.3895 | 0.495 |
| | | 5 0.017 | 0.014 | 3.4184 | 0.636 |
| | | 6 0.114 | 0.103 | 4.7733 | 0.573 |
| | | 7 -0.127 | -0.099 | 6.4551 | 0.488 |
| | | 8 0.143 | 0.125 | 8.6290 | 0.375 |
| | | 9 0.007 | -0.010 | 8.6336 | 0.472 |
| | | 10 -0.057 | -0.005 | 8.9852 | 0.534 |
| | | 11 0.025 | -0.030 | 9.0538 | 0.617 |
| | | 12 -0.097 | -0.076 | 10.090 | 0.608 |
| | | 13 -0.110 | -0.091 | 11.458 | 0.573 |
| | | 14 -0.080 | -0.143 | 12.189 | 0.591 |
| | | 15 0.028 | 0.070 | 12.282 | 0.658 |
| | | 16 -0.043 | -0.075 | 12.500 | 0.709 |
| | | 17 0.040 | 0.033 | 12.686 | 0.757 |
| | | 18 -0.089 | -0.108 | 13.626 | 0.753 |
| | | 19 -0.194 | -0.190 | 18.194 | 0.509 |
| | | 20 0.007 | 0.006 | 18.200 | 0.574 |
| | | 21 0.132 | 0.148 | 20.379 | 0.497 |
| | | 22 -0.117 | -0.075 | 22.120 | 0.453 |
| | | 23 0.082 | 0.001 | 22.991 | 0.461 |
| | | 24 -0.071 | -0.077 | 23.637 | 0.483 |
| | | 25 -0.146 | -0.129 | 26.426 | 0.385 |
| | | 26 0.116 | 0.042 | 28.220 | 0.348 |
| | | 27 -0.130 | -0.124 | 30.521 | 0.291 |
| | | 28 0.107 | 0.165 | 32.082 | 0.271 |
| | | 29 0.029 | -0.120 | 32.196 | 0.311 |
| | | 30 -0.085 | -0.020 | 33.224 | 0.313 |
| | | 31 -0.022 | -0.149 | 33.291 | 0.356 |
| | | 32 -0.020 | -0.108 | 33.351 | 0.401 |
| | | 33 -0.112 | -0.049 | 35.206 | 0.364 |
| | | 34 0.127 | 0.062 | 37.625 | 0.307 |
| | | 35 -0.015 | 0.068 | 37.660 | 0.348 |
| | | 36 -0.032 | -0.147 | 37.818 | 0.386 |

*Probabilities may not be valid for this equation specification.

Table A9: SWAP10Y = ϕ^9 (C, CTB3M, CCPIYOY, IPYOY, Δ LNSNGHAI, Δ LNUSDCNY)

Sample (adjusted): 2014M12 2022M10

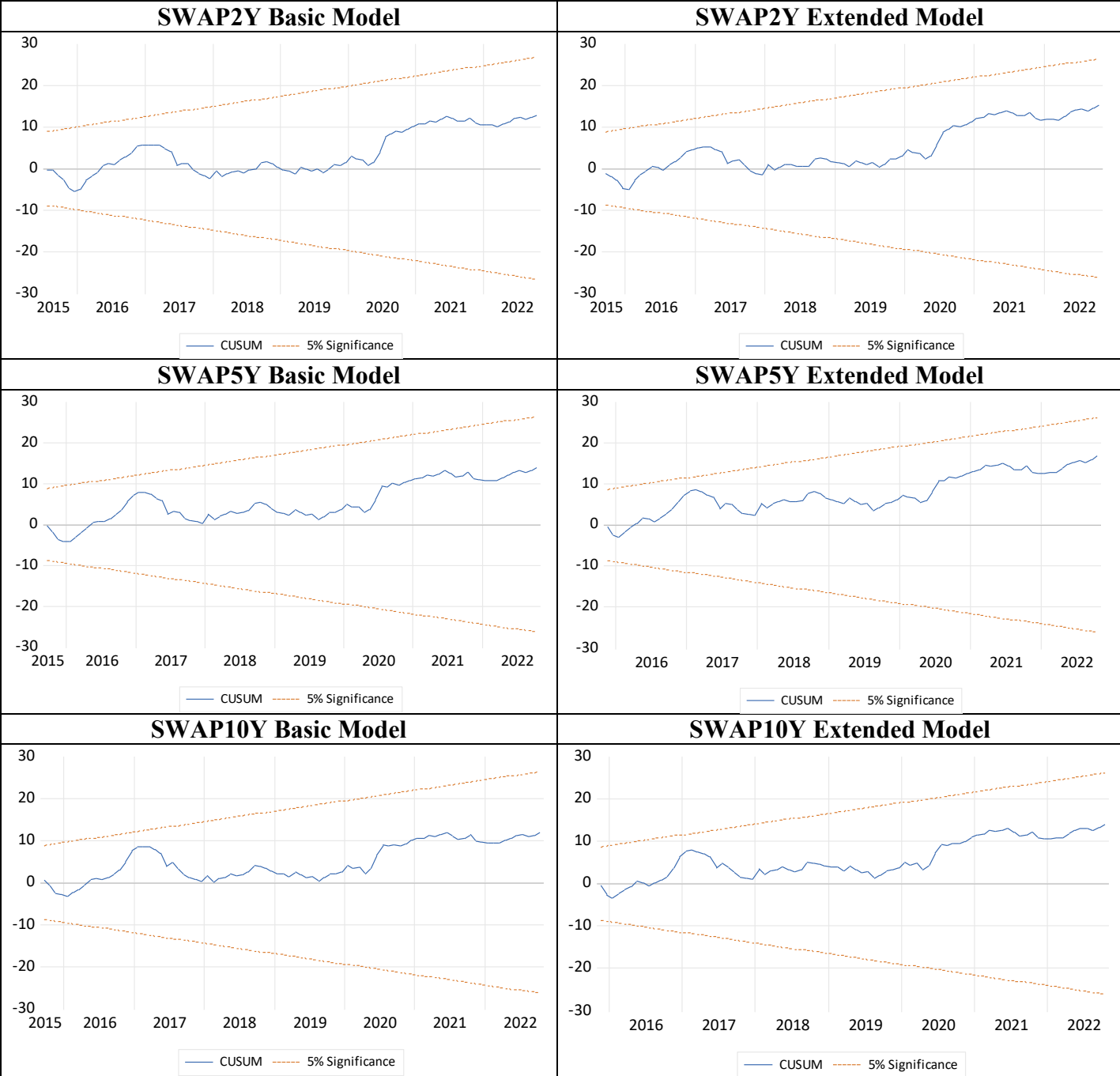
Q-statistic probabilities adjusted for 2 dynamic regressors

| Autocorrelation | Partial Correlation | AC | PAC | Q-Stat | Prob* |
|-----------------|---------------------|-----------|--------|--------|-------|
| | | 1 -0.032 | -0.032 | 0.1030 | 0.748 |
| | | 2 -0.044 | -0.046 | 0.2989 | 0.861 |
| | | 3 0.101 | 0.098 | 1.3106 | 0.727 |
| | | 4 -0.157 | -0.155 | 3.8081 | 0.433 |
| | | 5 -0.061 | -0.062 | 4.1944 | 0.522 |
| | | 6 0.091 | 0.067 | 5.0510 | 0.537 |
| | | 7 -0.087 | -0.062 | 5.8490 | 0.557 |
| | | 8 0.154 | 0.152 | 8.3766 | 0.398 |
| | | 9 0.037 | 0.003 | 8.5263 | 0.482 |
| | | 10 -0.084 | -0.041 | 9.2838 | 0.505 |
| | | 11 0.034 | -0.002 | 9.4139 | 0.584 |
| | | 12 -0.072 | -0.058 | 9.9860 | 0.617 |
| | | 13 -0.096 | -0.052 | 11.032 | 0.608 |
| | | 14 -0.021 | -0.078 | 11.082 | 0.680 |
| | | 15 0.076 | 0.101 | 11.742 | 0.698 |
| | | 16 -0.033 | -0.053 | 11.870 | 0.753 |
| | | 17 0.072 | 0.048 | 12.481 | 0.770 |
| | | 18 -0.068 | -0.085 | 13.030 | 0.790 |
| | | 19 -0.174 | -0.166 | 16.702 | 0.610 |
| | | 20 0.012 | 0.012 | 16.718 | 0.671 |
| | | 21 0.098 | 0.121 | 17.921 | 0.654 |
| | | 22 -0.103 | -0.061 | 19.259 | 0.629 |
| | | 23 0.033 | -0.064 | 19.397 | 0.678 |
| | | 24 -0.076 | -0.117 | 20.137 | 0.689 |
| | | 25 -0.183 | -0.173 | 24.552 | 0.488 |
| | | 26 0.111 | 0.091 | 26.184 | 0.453 |
| | | 27 -0.166 | -0.149 | 29.928 | 0.317 |
| | | 28 0.102 | 0.163 | 31.351 | 0.302 |
| | | 29 0.042 | -0.113 | 31.592 | 0.338 |
| | | 30 -0.062 | -0.000 | 32.132 | 0.361 |
| | | 31 -0.010 | -0.083 | 32.145 | 0.410 |
| | | 32 0.005 | -0.070 | 32.148 | 0.459 |
| | | 33 -0.160 | -0.050 | 35.949 | 0.332 |
| | | 34 0.091 | 0.039 | 37.203 | 0.324 |
| | | 35 -0.018 | 0.029 | 37.255 | 0.366 |
| | | 36 -0.045 | -0.124 | 37.569 | 0.397 |

*Probabilities may not be valid for this equation specification.

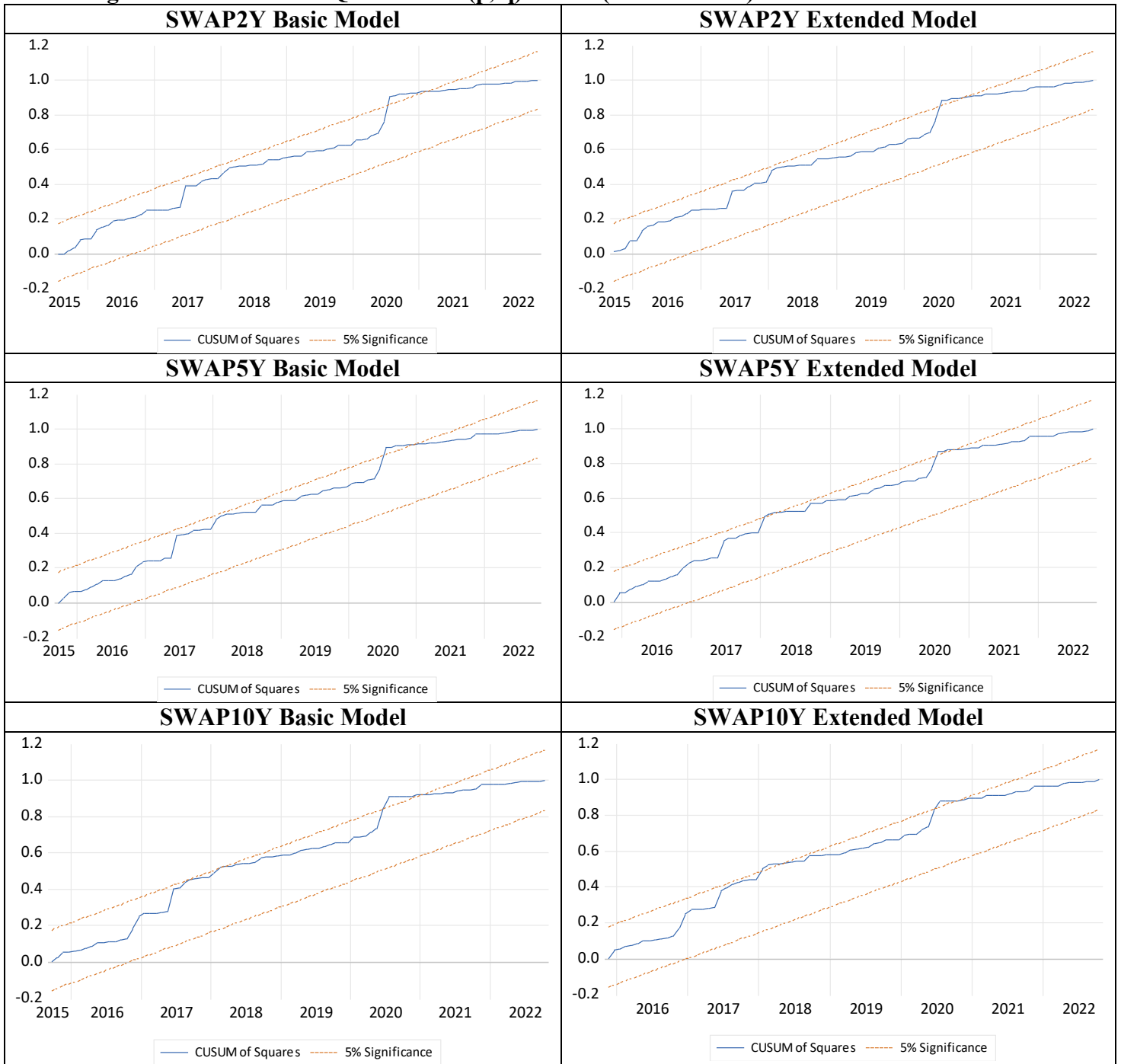
APPENDIX B: CUSUM and CUSUM-SQ tests

Figure B1: CUSUM for ARDL (p, q) Model (with CTB3M)



Note: ARDL (p, q) models include the change in the short-term interest rate (CTB3M) and the controls (namely CCPIYOY and IPYOY in the basic model and CCPIYOY, IPYOY, ΔLNSNGHAI, and ΔLNUSDCNY in the extended model).

Figure B2: CUSUM – SQ for ARDL (p, q) Model (with CTB3M)



Note: ARDL (p, q) models include the change in the short-term interest rate (CTB3M) and the controls (namely CCPIYOY and IPYOY in the basic model and CCPIYOY, IPYOY, Δ LN SNGHAI, and Δ LNUSDCNY in the extended model).