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Abstract

The monetary policy of the People's Bank of China (PBoC) during 2001–2023 is assessed in terms of Taylor and McCallum rules, as well as a proposed composite monetary policy rule. PBoC policy is found to be responsive to the gap between target and actual nominal GDP in the McCallum rule, as well as the output and inflation gaps in the Taylor rule. We find a relatively close fit between actual and predicted monetary policy moves under both rules, and a superior fit with our composite rule incorporating monetary and interest-rate factors. The policy reactions persist across a series of transitions between high- and low-volatility regimes identified via Markov-switching regressions. The results are shown to be robust using several techniques.

Keywords: monetary policy, People's Bank of China, policy rules, inflation, deflation
JEL: E58, E52

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Non-technical summary

FOCUS

How best to model the monetary policy of China's central bank in terms of a policy rule that describes how People's Bank of China (PBoC) sets its monetary policy stance? We create a composite rule drawn from existing policy rules to evaluate monetary policy in advanced economies. Our hybrid rule fits the data especially well. A variety of econometric techniques are used to test the robustness of the main findings. Our proposed PBoC monetary policy rule is relatively complex compared to most monetary policy rules discussed in the literature.

CONTRIBUTION

John Taylor (1992) originally proposed a policy rule describing how the US Federal Reserve sets monetary policy based on the behavior of the central bank's policy rate. Bennett McCallum (1999) followed up with a competing rule that evaluates monetary policy in terms of the money supply's growth rate. Investigating the case of China, Burdekin and Siklos (2008) find McCallum's rule superior in describing how the PBoC sets its monetary policy stance. Since the global financial crisis, however, China has made significant changes in how it conducts monetary policy and its financial markets have developed. Accordingly, we derive a hybrid model that provides for changes in interest rates and the money supply that is relevant to the current post-pandemic environment. We argue that our approach gives a better description of how the PBoC sets monetary policy today.

FINDINGS

Monetary policy setting in China is a much more nuance process than in the past thanks to a broad array of policy tools available to PBoC. While the McCallum rule captures the broad trajectory of Chinese money growth over the 2001–2023 period, the relationship is subject to a series of shifts that can be captured econometrically. We then compare these results against those generated with the more widely used Taylor rule. Both policy rules are found wanting relative to our proposed composite rule, which combines elements from both McCallum and Taylor rules. Our composite rule generates a monetary conditions index based on interest rates, money supply growth, as well as changes in the required reserve ratio, currency depreciation against the US dollar, and changes in the ratio of total private non-financial credit to GDP. The closest fit between actual and predicted monetary policy is seen under our composite index.

The PBoC… will ensure that the growth rates of M2 and the AFRE [aggregate financing to the real economy] continue to be basically in line with nominal economic growth.

(Monetary Policy Analysis Group of the People's Bank of China, 2023, p. 47)

Maintaining price stability and pushing for a mild rebound in prices will be an important consideration. We will use interest rates, reserve requirements, and other policy instruments in a flexible manner while maintaining policy resolve and avoiding drastic policy swings.

(Pan Gongsheng, Governor of the People's Bank of China, June 19, 2024)[1]

1. Introduction

Given China's growing impact on other nations, including systemically important countries such as the United States, understanding Chinese monetary policy is more important than ever (Chen and Siklos, 2023). Chinese policy-setting has changed dramatically in recent years. Financial liberalization has augmented the central bank's tool kit as domestic interest rates are increasingly determined by the market. The key challenges have also shifted. The inflationary spikes of 1988–1989 and 1993–1994 were followed by significant deflationary pressures in the wake of the 1997 Asian financial crisis. Deflationary strains were amplified with commodity price declines in the years following the 2008 global financial crisis. Similar disinflationary impulses also emerged in the aftermath of the Covid-19 pandemic. Although disinflationary problems after 2008 were also experienced elsewhere, China's 2023 deflation woes contrasted sharply with advanced economies where central banks were battling persistent upward price pressures.

A striking feature of 21st century deflationary pressure in China has been the discrepancy between consumer and producer price movements. For example, the gap between Chinese consumer and producer price movements approached 8 % in 2016. Burdekin and Hu (2018) find support that post-global financial crisis producer price declines were the result of commodity price declines and plunging oil prices – a phenomenon that re-emerged in 2022–2023.[2] In seeking to

[1] See Pan (2024).
[2] We have relegated to a separate appendix a plot comparing CPI and PPI inflation changes, and the evolving gap between the two series (Figure A19). As argued by Wei and Xie (2019), the correlation between the two series

combat such deflationary pressures, the People's Bank of China (PBoC) continued to attach considerable importance to the growth of monetary aggregates such as M2. The PBoC's own policy review for the first quarter of 2023 (Monetary Policy Analysis Group of the People's Bank of China, 2023) explicitly points to the link between the rates of money growth and nominal income. This comports with the emphasis on countercyclical (stabilizing) monetary responses to inflation and output movements seen over the 1990–2006 period in Burdekin and Siklos's (2008) analysis of PBoC policy.

Monetary policy analysis typically focuses on interest-rate-based Taylor rules, which was inappropriate for China's former setting based on administered interest rates. Taylor rules are also problematic during severe downturns such as 2020, the first year of the Covid-19 pandemic, when highly negative output and inflation gaps call for negative interest rates that cannot be delivered in practice. In such cases, the alternative McCallum (1999) rule, which focuses on targeting growth in monetary aggregates, becomes more appropriate because it functions even when interest rates reach the zero or effective lower bounds. The McCallum rule has nominal GDP growth as the objective variable, thereby multiplicatively combining the inflation and real GDP targets included in the Taylor rule. Unlike the fixed rate of money growth implied under Friedman's famous k % rule for monetary policy, the McCallum rule allows for monetary policy adjustments in the face of sustained velocity movements and/or deviations from the long-run target rate of nominal GDP growth. In addition to the McCallum rule estimates for China by Burdekin and Siklos (2008), Sun et al. (2012) find evidence that explicit adherence to the McCallum rule would have significantly reduced China's nominal GDP fluctuations over their 1994–2009 sample period.

We model PBoC policy first using McCallum and Taylor rules. These rules provide a relatively good fit whether expressed in terms of money growth or interest rate setting. These relationships are maintained through a series of shifts between low- and high-volatility conditions identified via Markov-switching analysis. The performance of these policy rules improves under a composite index that combines money and interest rate movements with other PBoC policy levers. Indeed, the complexity of China's monetary policy, owing to the multiplicity of instruments at the PBoC's disposal, limits the usefulness of simple rules and favors the use of hybrid rules that

remains positive (0.46 for the 2000–2023 sample), but falls in the period after the global financial crisis from a high of 0.77 prior to 2011.

accommodate subtleties of PBoC actions during a fairly eventful era. This approach also clarifies the quote of the PBoC's governor at the start of this paper. We describe these relationships in detail in the empirical section along with the shifts between low- and high-volatility states over our 2001–2023 sample period. The paper concludes with a summary and policy implications.

2. Recent additions to the PBoC's monetary policy toolbox

Although the PBoC was established in December 1948, it only began to function as a true central bank in September 1983. In its first three decades, it served as a "monobank" responsible for commercial banking and select central-bank functions – essentially an instrument for carrying out the government's credit plan for the economy. Passage of the Law of the People's Bank of China on March 18, 1995 clarified the PBoC's responsibilities with respect to monetary policy and financial regulation, and allowed for creation of a monetary policy committee. Crucial for its independence, this law was preceded by a 1994 budget law prohibiting the government from borrowing from the PBoC. The 1994 law weakened the link between fiscal and monetary policy and heralded an era of increased government reliance on debt financing.

Full independence was never the government's goal, however. Market-based monetary policymaking was handicapped by restrictions on interest rate liberalization even before Article 5 of the amended Law of the People's Republic of China on The People's Bank of China (2003) set clear limits on the central bank's statutory independence:

> The People's Bank of China shall submit to the State Council for approval its decisions concerning the annual money supply, interest rates, exchange rates and other important matters specified by the State Council and implement these decisions.

Experimentation with open market operations began in 1993, but the lack of a proper inter-bank market prompted a temporary suspension in 1997. The reintroduction of open market operations in May 1998 proved much more successful, with operations extended to include issuance of short-term government securities and a wide range of government instruments, policy financial bonds, and central bank bills. Central bank bills assumed a central role. Issuance of these short-term debt instruments by the PBoC was significantly expanded in 2002, and they became tradable on the inter-bank bond market in April 2003. After a US-style tender offering system was introduced in March 2006, central bank bills also became important in furthering the policy shift toward interest rate liberalization. Their use in open market operations has since been replace by reverse repo arrangements. The PBoC first relied on pledged reverse repos to manage market liquidity, with the bond collateral locked in the corresponding commercial bank accounts. Government and local government bonds were used as collateral. The introduction of outright reverse repos in October 2024 added to policy flexibility as the bonds were transferred to the PBoC's own account. The initial wave of outright reverse repo operations in 2024 was used to inject RMB 500 billion into the banking system (Zhou, 2024).

Using high frequency data, Kamber and Mohanty (2018) document how the transmission of monetary policy shocks in China began to resemble that of advanced economies in pre-pandemic years (see also Fernald et al., 2014 and Chen et al., 2023). Since the pandemic, the PBoC has used open market operations and increased reserve requirements to contain excess liquidity generated by inflows of funds from abroad and keep money growth rates from rising too rapidly. With the introduction of money supply targets in 1986 and the elimination of credit ceilings in 1998, money supply (principally M2) became the sole intermediate target officially directed toward achieving the ultimate goal of price stability. PBoC monetary policy director Dai Genyou (Dai, 2002), for example, noted the central bank's success in keeping M2 growth in the 14–15 % range over the 1998–2001 period. The lowered money growth targets after 1996 were accompanied by sharply declining rates of money growth and declining inflation. Indeed, actual M2 growth rates tended to be lower than their targets during the 1997–2001 deflationary period, when overly tight monetary policy apparently drove declining prices.

Girardin et al. (2017) suggest Chinese monetary policy shifted in 2002 after this deflationary episode. The change coincides with the year after China's WTO accession in 2001. Girardin et al. further identify a countercyclical response to inflation during 2002–2013 not found in the 1993–2001 period. Their analysis is based on a composite index comprising three interest rate measures, the required reserve ratio, and open market operations.[3] Although Girardin et al. (2017) point out smaller, but more frequent, moves during the 2002–2013 period, they also concede a fundamental shift in the components of their composite index. There were two reserve

[3] Klingelhöfer and Sun (2018) also rely on an ordinal indicator of PBoC policy driven by a narrative approach (ranging from +2 to -2 as introduced in Sun, 2015, 2018) to deal with model uncertainty.

requirement adjustments during 1993–2001 and 37 during 2002–2013. Even more strikingly, there were no open market operations over the earlier period and 27 in the latter. While these events certainly support the existence of a policy shift, it remains unclear whether this shift was simply the result of the PBoC exercising its newly-granted ability to pursue open market operations and seamlessly adjust reserve requirement ratios – novel powers long taken for granted in advanced economies.

Notwithstanding the increasingly market-based policy environment, the government still retains significant scope for influencing the actual course of Chinese monetary policy. The December 27, 2003 amendment to the Law of the People's Bank of China provided only limited enhancements to central bank autonomy. The central bank's monetary policy committee was still technically no more than an advisory committee, incorporating a handful of government officials such as the deputy finance minister (see Zhou and Li, 2007, pp. 80-84). However, the changed made it easier for the PBoC to focus on monetary policy instead of regulatory issues. A major step was the March 2003 establishment of the China Banking Regulatory Commission. This created a new agency in charge of financial industry supervision, a task that had previously fallen within the PBoC's purview.

Even though China's banks lacked most of the direct exposure to the failed derivative trades that plagued US and western European economies, the global financial crisis ushered in a period of heightened volatility in China. Robust Chinese growth was maintained through a huge fiscal stimulus package equivalent to $600 billion (20 % of China's GDP at the time) launched in November 2008, and a ratcheting up of Chinese state-owned bank lending following the PBoC's relaxation of lending constraints imposed on banks prior to the crisis (Burdekin and Weidenmier, 2015). Inflationary concerns soon led to restrictive measures by the PBoC, with worsening conditions evident after M2 money growth decelerated from 19.7 % in 2010 to 13.6 % in 2011 (Monetary Policy Analysis Group of the People's Bank of China, 2012). The bursting of China's real estate market bubble was accompanied by falling Chinese exports and reduced expectations of economic growth that reduced the attractiveness of investing in China (Burdekin and Zhang, 2019). The key challenge soon shifted from inflation to deflationary pressures associated with declining commodity prices. A similar pattern, marked by a growing gap between producer prices and consumer prices, re-emerged in the aftermath of the pandemic.

3. From financial market liberalization to post-pandemic framework

Open market operations to adjust the nation's monetary base are the key policy tool employed by major Western central banks such as the US Federal Reserve (Fed). Consistent use of this policy tool by the PBoC evolved from the use of tradeable central bank bills to pledged reverse repos to outright reverse repos. Interest rate policy modernization lagged, however, with deposit and lending rates still directly set by the PBoC. Key early liberalization steps included the liberalization of long-term deposit rates in 1999 and the removal of the ceiling on lending rates in 2004. Nevertheless, benchmark lending and deposit rates remained in place until the 2019 loan market quotation rate reform ushered in a new market-based loan prime rate. The PBoC's influence in interest rate setting went from direct to indirect (Yuan et al., 2022), an approach more in line with US policies, whereby banks adjust interest rates in response to central bank policy moves (as opposed to having rates dictated to them).[4]

Kim and Chen (2022) find that the Chinese interest rate liberalization was accompanied by growing relevance of lending and seven-day repo rates over time. Specifically, more significant effects are seen on total loans, M2 money supply, and industrial production.

While consistent with greater PBoC use of short-term interest rates as a policy instrument, the role of M2 as an intermediate target appears to have remained intact throughout the pandemic (Monetary Policy Analysis Policy Group of the People's Bank of China, 2023). Foreign exchange intervention is a complicating factor, however. Considering episodes of strong exchange rate intervention between 2009 and 2017, Lu et al. (2022) find that money supply growth in their estimated policy rule evinced weaker responses to domestic GDP and inflation movements.[5]

The onset of the pandemic afforded an opportunity to assess the PBoC's crisis response in the liberalized interest rate setting facilitated by the 2019 loan market quotation rate reform. Funke and Tsang (2020), for example, characterize this as a shift to a mix of new and traditional measures. PBoC reliance on open market operations vastly exceeded the injections seen at the time of the global financial crisis. Gross injections amounted to RMB 982.5 billion during September-

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[4] Das and Song (2022) point to a need for further liberalization after finding only limited evidence of pass-through to other interest rates arising from PBoC policy moves. However, even though their sample extends into 2020, most observations are drawn from years prior to the 2019 reform.

[5] Zhong et al. (2022) find less evidence of a role for exchange-market stress, but their results are based on applying an interest-rate-based Taylor rule to data starting from 1996.

December 2008, and RMB 5.08 trillion during February-June 2020 (Funke and Tsang, 2020, pp. 470-471). The upgrades to PBoC's monetary toolkit were supplemented with a RMB 2.007 trillion medium-term lending facility, a feature that did not exist in 2008. Despite multiple interest-rate cuts, Funke and Tsang (2020) calculate that the liquidity effects fell well below the injections facilitated by the PBoC's open market purchases.

Further expansionary measures followed amidst China's sluggish recovery from the pandemic. For example, the seven-day reverse repo rate, which had been maintained at 2.2 % through 2021, was reduced to 2.0 % during 2022 and 2023 before a series of 2024 cuts took it down to 1.5 %. This was accompanied by a reduction in the interest-rate corridor (Maher, 2024, p. 89), which used the PBoC's standing lending facility as the ceiling and the interest rate paid on bank excess reserves as the floor. Further PBoC expansionary measures included cuts in the required reserve ratio in February and September 2024. Continued post-pandemic deflationary pressures led to adjustment of the official stance on monetary policy in December 2024 from "prudent" to "moderately loose," a stance not seen since the emergency measures adopted in response to the 2008 global financial crisis (Leahy, Sandlund, and Smith, 2024).

Despite recent challenges, China's maturing financial system is exemplified by Shieh (2024), who extracts term-structure information (along the lines pioneered by Gürkaynak et al., 2005, for the US) to demonstrate the PBoC's ability to shape expectations of future monetary policy. Maher (2024) further shows PBoC influence at the short end of the yield curve arising through liquidity operations and adjustments to the interest-rate corridor. Even with these recent studies, however, the PBoC's rapidly-evolving framework remains complex and largely opaque.

4. Empirical perspectives on PBoC monetary policy

Besides the pandemic and post-pandemic periods, the trajectory of Chinese inflation is similar to that taken by US inflation (Figure 1). From the first quarter of 2001 through the second quarter of 2023, China's mean inflation rate was 2.14 %, only slightly less that US mean inflation of 2.52 %. The standard deviation of Chinese inflation is 1.87 % and 1.80 % for the US. The output gaps diverge with the onset of the global financial crisis, however, reflecting China's much larger stimulus package (relative to the size of its economy) compared to the US response, as well as continued bank lending that allowed China to escape the plunging money multiplier seen in most Western countries (Burdekin and Weidenmier, 2015).

In estimating possible PBoC policy rules, the tendency in the literature has been to adopt some version of the Taylor rule. In its most straightforward form, estimates of inflation and output gaps drive an interest rate selected to serve as the policy rate. The sophistication of Taylor rules used in China analysis has increased over time with inclusion of such factors as the time-varying nature of monetary policy, non-linearities driving the monetary policy stance, as well as extensions to capture the idiosyncracies of PBoC monetary policy. Studies in this vein include Fan et al. (2011), Zheng et al. (2012), Li and Liu (2017), and Liu et al. (2018). Although the McCallum rule has not been completely ignored, its role has diminished in recent years (and despite, as noted in the introduction, statements from PBoC officials as to their unwavering focus on money supply targets).

4.1 McCallum rule estimation

In the following, we assess PBoC policymaking over the 2001–2023 period in terms of Taylor and McCallum policy rules. While the more familiar Taylor rule separates inflation and real GDP targets, they are combined in the McCallum (1999) rule with nominal GDP growth as the objective variable.[6] The McCallum rule, which also focuses on money growth like Friedman's famous k% rule for monetary policy, allows for monetary policy adjustments in the face of sustained velocity movements, deviations from the long-run target rate of nominal GDP growth, or both. The velocity term in equation (1) allows money supply growth to adjust upward in the face of any money demand expansion implied by declining velocity of circulation:

$$\Delta m_t = \Delta x^* - \Delta \mathrm{v}_t + 0.5(\Delta x^* - \Delta x_{t-1}) \quad (1)$$

[6] Chen et al. (2018) estimate a Taylor-like policy rule to explain money growth. Inflation shocks and exchange rate shocks, as well as variables such as credit growth, are used to model money growth. A similar specification is used to explain the impact of shadow banking in China. Lu et al. (2022) also use a similar specification to examine foreign exchange interventions to support the RMB.

where Δm_t is the percentage growth of the monetary aggregate, Δx_t is the growth rate of nominal GDP, Δx^* is the target growth rate of nominal GDP, and Δv_t is the average growth rate of velocity over the same period.

In applying the McCallum rule to PBoC policy, we replace McCallum's 0.5 value in the calibrated version of his rule with a coefficient estimate as in Burdekin and Siklos (2008). Also following Burdekin and Sikos (2008), we include a constant to replace the first two terms and extend the specification to allow for responses to the changes in the real exchange rate and RMB foreign exchange reserves. A negative coefficient on the real exchange rate variable would be consistent with real exchange rate depreciation leading to a negative (countercyclical) M2 response, while a positive reaction to growth in foreign exchange reserves would be implied by pass-through from reserve accumulation to monetary expansion. M2 data are drawn from the PBoC, RMB foreign exchange reserves from the Bloomberg terminal, the (broad) real exchange rate from the Bank for International Settlements, and other series from the Federal Reserve Bank of Atlanta.[7] Jones and Bowman (2019) provide estimates of the PBoC's inflation target, which we update with releases from the PBoC.

The estimation results reported in Table 1 allow for shifts in the relationship over time via regime changes incorporated in Markov-switching analysis (Hamilton, 1988). We also estimate versions of (1) by allowing for structural breaks to test the sensitivity of the results discussed below. For the sake of brevity, some results have been relegated to a separate appendix that is available from the authors upon request. Our conclusions remained largely unchanged.[8] A bivariate Markov-switching model can itself be expressed as:

$$y_t = \alpha_{s_t} + x_t\beta_{s_t} + z_t\gamma + \varepsilon_{s_t,t} \quad (2)$$

where the dependent variable y_t is the M2 growth rate; x_t is a vector of independent variables with state-dependent coefficients β_{s_t}; α_{s_t} is the state-dependent intercept; and z_t includes independent variables with coefficients assumed to stay constant across states. There are two regimes, $s_t \in$

7 The data are found at https://www.atlantafed.org/cqer/research/china-macroeconomy.
8 We rely on the multiple break tests of Bai and Perron (1998, 2003a, 2003b). As in Burdekin and Siklos (2008), our estimated versions of (1) using GMM hold for our original conclusions (see Table A13).

$\{s_1, s_2\}$, representing high and low uncertainty states.[9] The error term $\varepsilon_{s_t,t} \sim N(0, \sigma^2_{s_t})$ is *i.i.d.* with a variance $\sigma^2_{s_t}$ that switches across the two regimes. Finally, the state variable s_t is defined by the following transition probabilities:

$$p_{ji} = Pr(s_{t+1} = j | s_t = i), \sum_{j=1}^{M} p_{ji} = 1 \;\; \forall\, i, j \; \in [1, 2]. \tag{3}$$

where P_{11} is the probability of remaining in State 1 in the next period (given that the current state is State 1), and P_{21} is the probability of transition from State 1 to State 2.

Table 1's Markov-switching results show that the expected significant positive reaction to the output gap is maintained in high-volatility and low-volatility states. The estimated coefficient is larger in the low-volatility state, however. Although there is no significant real exchange rate response in either state, growth in RMB foreign exchange reserves exerts a statistically significantly positive effect on M2 growth in both states. As with the output gap, the size of the response is greater in the low-volatility state. As shown in Figure 2, transition to the high- volatility state is evident at the time of the global financial crisis and this state persists until 2011. As discussed earlier, this is when sharp reductions in M2 money growth and other PBOC restrictive measures were employed to rein in inflation. The ensuing low volatility is sustained until 2016, when a brief high-volatility interval is followed by a return to the low-volatility state over the remainder of our sample period.

The second high-volatility period falls in the aftermath of the 2015 stock market collapse and surprise devaluation of the renminbi against the dollar on August 11, 2015. Relative to the June 2015 peak, the Shanghai Composite lost 25 %. The losses on the tech-dominated Shenzhen Stock Exchange were even heavier. The overall \$3.5 trillion loss matched the entire Chinese market capitalization as recently as 2012. The Chinese government responded to the stock market collapse with heavy interference, ordering brokerages to buy and forbidding shareholder selling (Burdekin and Zhang, 2019). The collapse was accompanied with a slowdown in GDP growth to 7 %, a level well below preceding years. In terms of monetary policy *per se*, Figure 3 reveals a

[9] Regime probabilities are assumed to be exogenous. We experimented with probabilities as a function of the CPI-PPI inflation gap, oil price inflation, and the credit gap, but our conclusions were unaffected (see Tables A12 and A13).

marked increase in the scale of PBoC open market operations in 2016 (see also Maher, 2024, p. 88) matching the indicated timing of the regime shift. This follows the PBoC's February 18, 2016 move from twice-weekly to daily open market operations (Monetary Policy Analysis Group of the People's Bank of China, 2016, p. 17). The high volatility indicated in 2016 does not re-emerge during the pandemic, however. The PBoC's policy moves in 2020 were far more muted than in the United States and most Western countries owing to China's initial containment of the Covid-19 outbreak.[10]

The overall performance of the estimated McCallum rule over time is depicted in Figure 4. Although the spike in actual M2 growth following the onset of the global financial crisis in 2008 is over 5 % larger than the predicted value, both actual and fitted values show sharp upward moves at this time. This is followed by a greater-than-predicted monetary retrenchment in 2011 coinciding with the transition to high volatility indicated in the Markov-switching estimation. Higher-than-predicted M2 money growth in 2015 switches to lower-than-expected money growth starting in 2016, which again coincides with an indicated switch to a high-volatility regime.[11]

The McCallum rule can be expressed in interest rate form where we examine its implications for the setting of the central bank's policy rate. If the relationship between base money and the policy rate is stable, Razzak (2003) shows that equation (1) can be modified by effectively replacing money growth with *changes* in the policy rate. The estimated specification is written as:

$$\Delta V_t = f(\Delta i_t) + \varphi_t \tag{4}$$

$$\Delta i_t = (\overline{\Delta V}_t - (1 + \lambda_{\Delta x})(\overline{\Delta x} - \Delta x))/k \quad \text{(calibrated)} \tag{5}$$

$$\Delta i_t = \varphi_0 + \varphi_1 \overline{(\Delta V/k)}_t - \varphi_1(\overline{\Delta x} - \Delta x)/k \quad \text{(estimated)} \tag{6}$$

[10] Allowance for structural breaks in conventional OLS estimation of the McCallum rule confirm the 2011 and 2016 break points suggested in Figure 2 (see Appendix, Table A1). Similarly, OLS estimation confirms the significance of the output gap and foreign exchange reserves, and insignificance of the real exchange rate, shown in Table 1 (see Appendix, Table A2). This same pattern is maintained under a GMM estimation (see Table A6).
[11] Estimates with the lagged CPI-PPI inflation gap and oil price inflation (mean of West Texas Intermediate and Brent prices) as common determinants also had no effect on our conclusions (see Tables A12 and A13).

Equation (4) tests the stability of velocity vis-à-vis changes in the policy rate. This confirms the stability of the relationship in the sense that no structural breaks are found (see Table A4).[12] The next two equations represent the transformation of the McCallum rule into a difference rule in terms of the policy rate. As with the original McCallum rule, equation (5), the calibrated version, has some coefficients theoretically defined, as with k=50 in Razzak (2003), and a three-year moving average is used for $\overline{\Delta x}$).[13] Equation (6) is the same rule written in regression form.

In China's case, this policy rate is represented by the seven-day interbank rate. Table 2 shows the results of regressing this modified McCallum policy rule, on the moving average of M2 velocity and the output gap. Although this modified McCallum rule does not fit as well as the original rule based on (adjusted) R-squared, the signs of the coefficients remain correct. *Ceteris paribus*, we see that policy tightens when velocity rises, and policy loosens when the nominal GDP growth target exceeds actual nominal GDP growth. Higher interest rates when velocity rises are consistent with the predicted tightening of money growth in the original rule, just as lower interest rates accompanying below-target output growth in line with monetary expansion. Both effects are significant at better than the 99 % confidence level. Figure 5, which provides a graphical look at the fit when the dependent variable is turned into levels, suggests a relatively close relationship between the actual and fitted values over the sample period.[14]

4.2 Taylor rule estimation

The standard Taylor rule regresses the central bank's policy rate on the output gap and inflation gap. There are predicted positive interest-rate responses to output being above potential output and inflation being above its target level. The inflation rate series is drawn from the Bank of International Settlements and two versions of the output gap were used. The first is based on the

[12] Up to two structural breaks were allowed for using the Bai-Perron test.

[13] Values of k ranging from 1 to 25 were also tried with no apparent impact on our conclusions (see Figure A13 and related comments).

[14] In Burdekin and Siklos (2008), we delve into the suitability of the McCallum rule by estimating a money demand function (money as a function of prices, income, and an interest rate) to derive a money gap (money growth versus money growth predicted by money demand). In this setting, a positive money gap signals higher future inflation and lower future inflation when the money gap is negative. Tests (see Table A8 and Figure A8) identify a single cointegrating relationship between the log levels of the constituents of the money demand function (except for the interest rate which enters in levels) and suggest some predictive power of the money gap for future inflation.

Federal Reserve Bank of San Francisco's cyclical indicator for China.[15] The second proxy for the output gap is the arithmetic mean of (normalized) real GDP growth, with gaps that rely on the Hamilton and Ravn-Uhlig versions of the Hodrick-Prescott filter.[16] Our application to PBoC policy includes an augmented Taylor rule that allows for a time-varying neutral real interest rate. In Table 3(a), we assume the neutral real interest rate to be constant, in line with much existing empirical work recognizing the high uncertainty around estimates of what is commonly referred to as r* (or RSTAR). In Table 3(b), however, we enter a proxy for the neutral real interest rate (RSTAR) that varies over the sample period.[17] Both specifications include a lagged dependent variable to allow for inertia.

We can express the varieties of estimated Taylor rules as follows:

$$i_t = \delta_t + (1 - \delta_t)(\gamma_1 \tilde{\pi}_t + \gamma_2 \tilde{y}_t + \Gamma' Y_t) + \eta_t \tag{7}$$

$$i_t = \rho i_{t-1} + (1 - \rho) i_t^{\rho} \tag{8}$$

$\delta_t = 0, \Gamma' = 0$ no inertia case;
$\delta_t \neq 0, \Gamma' = 0$ inertia case;
$\delta_t \neq 0, \Gamma' \neq 0$ inertia and extended case.

Equation (7) contains the standard Taylor rule wherein the inflation and output gaps, respectively (i.e., $\bar{\pi}_t, \bar{y}_t$) dictate the policy rate level. The standard rule is augmented with the vector Y_t in recognition of extensions to the Taylor rule where we augment the original policy rule by alternatively adding credit growth, the US federal funds rate, and the rate of exchange rate appreciation or depreciation. As none of these additions altered the conclusions discussed below, nor resulted in substantive improvements to the Taylor rule estimates (see Figures A10 and A11 and Table A9), we do not discuss them further but results are available on request.

Both specifications yield the expected positive signs on the inflation and output gap variables. In specification (a), without RSTAR, both coefficients are significant at better than the 99 % confidence level. There is also strong evidence of inertia, and the lagged policy rate is also

[15] The data are available from https://www.frbsf.org/research-and-insights/data-and-indicators/china-cyclical-activity-tracker/.
[16] Calculation details are provided in Chen and Siklos (2023).
[17] RSTAR estimates are derived from a state space model, where $R_t = R^*_t + u_t$ and $R^*_t = R^*_{t-1} + v_t$ is latent (unobserved) and assumed to follow a random walk (only the immediate past value helps forecast its future value). The observed interest rate, R, fluctuates around R^*.

significant at the 99 % confidence level. In specification (b), the inflation gap's confidence level drops to 95 % and the coefficient is about half of its value in specification (a).[18] The output gap remains significant at the 99 % confidence level, however. Meanwhile, the RSTAR term is itself positive and significant at the 90 % confidence level. The fit of these two specifications over our sample period is represented in Figure 6. The only substantial deviation between the actual and fitted values for either specification is around the onset of the global financial crisis.

Finally, we note that the Taylor principle (a steady state inflation gap coefficient of one or above) holds when the neutral real rate is time-varying. The steady state output gap is also greater than one. In the constant RSTAR case, the steady state inflation gap is well below one – while the output gap has a coefficient of only 0.036 in this case.

4.3 Composite monetary policy rule

While the McCallum and Taylor rules both offer fairly good fits to actual PBoC policy, we also consider a composite rule incorporating elements of both.[19] As noted earlier, the fact that the PBoC simultaneously relies on several policy instruments renders it unlikely that a unique rule adequately explains the conduct of PBoC monetary policy over time.

Our composite rule develops an overall monetary conditions index using the range of inputs depicted in Figure 7. To estimate this composite rule, we proceed in the following manner: (1) assume that a monetary policy indicator (MPI) is constructed on the basis of *changes* in the level of the policy interest rate, M2 growth, changes in the required reserve ratio, the rate of change in the nominal exchange rate, and changes in the total private non-financial credit to GDP ratio, and (2) estimate a time-varying factor model and retrieve estimates (scores) from this model.[20] The

[18] Since the PBoC does not formally observe an inflation target we also considered an alternative estimate based on the mean under three methodologies. These are: a one-sided H-P filter, the Christiano-Fitzgerald asymmetric filter where the 8 to 20 quarters frequencies define business cycle frequencies, and a linear time trend with two structural breaks estimated at 2009Q1 and 2012Q1 according to the Bai-Perron multiple break tests. There were no meaningful changes in the conclusions when using this proxy for the inflation gap (see Figure A20 to A22).

[19] Encompassing tests based on head-to-head comparisons between the alternative policy rules yielded inconclusive results, that is, neither the McCallum nor Taylor type rules could encompass the other.

[20] We use the Bai-Ng (2002) estimation technique to obtain a single factor based on their IC_{p2} criterion as recommended by Stock and Watson (2016). Each factor model is estimated over a five-year period resulting in 11 sets of score estimates that are spliced together (overlapping observations are averaged). Using full sample estimates did not change the results in any meaningful fashion.

resulting estimates, which we call a monetary policy indicator (MPI), represent a data-driven linear combination of instruments. This composite or hybrid policy rule can then be written as:

$$MPI_t = \delta_t + (1 - \delta_t)(\gamma_1 \tilde{\pi}_t + \gamma_2 \tilde{y}_t + \Gamma' Y_t) + \eta_t \quad (9)$$

$$MPI = \rho MPI_{t-1} + (1 - \rho) MPI_t^{\rho} \quad (10)$$

$\delta_t = 0, \Gamma' = 0$ no inertia case;
$\delta_t \neq 0, \Gamma' = 0$ inertia case;
$\delta_t \neq 0, \Gamma' \neq 0$ inertia and extended case.

where MPI replaces the interest rate as our indicator of the PBoC's monetary policy stance.

The results in Table 4 show a response to inflation and output gaps comparable to those arising in the preceding separately estimated McCallum and Taylor policy rules.[21] Figure 8 displays this policy rule's variation over time. Figure 9 displays the associated changing probabilities of regime change. In addition to the 2011 and 2016 shifts seen in the earlier Markov-switching estimation, Figure 9 reveals an indicated break in the first half of 2009 (corresponding to the emergency expansionary policies adopted in response to the global financial crisis).

There is evidence that the return to the low-volatility regime in 2017 was interrupted by the onset of the pandemic in 2020. These additional indicated shifts in 2009 and 2020, coinciding as they do with major global events, add to our confidence in the performance of this composite rule. It is also worth noting the overall similarity of our MPI to the narrative-based policy indicator of Sun (2018), which relies on PBoC press releases and Monetary Policy Reports. Her indicator ranges from -2 (very easy) to +2 (very tight). When the two are plotted together (see Figure A23) both tend to find tightening or easing of PBoC policies at roughly the same time. That said, our continuous and smoother indicator reveals relatively tighter PBoC monetary policy from 2000 to 2003 and again from 2009 to 2010.

[21] As with the earlier case (see Table 1) the addition of the lagged CPI-PPI inflation gap and oil price inflation as common determinants did not alter the conclusions.

5. Conclusions

The setting of monetary policy in China today is much sophisticated than in the past, reflecting interest-rate liberalization and the PBoC's much broader array of policy tools. Nevertheless, the McCallum rule, which offered a fairly good fit to PBoC policymaking before the global financial crisis (Burdekin and Siklos, 2008), continues to capture the broad trajectory of Chinese money growth over the 2001–2023 period. We find this relationship is subject to a series of shifts, however, which we capture via Markov-switching analysis. We also modeled PBoC policymaking using an interest-rate-based version of the McCallum rule, a Taylor rule, and a composite rule. Our composite rule utilized an overall monetary conditions index based on interest rates and M2 money growth, as well as change in the required reserve ratio, currency depreciation against the US dollar, and the change in the ratio of total private non-financial credit to GDP. The closest fit between actual and predicted monetary policy is seen under this composite index.

Several extensions of this work deserve consideration. First, it would be interesting to report the out-of-sample forecast accuracy of the three policy rules.[22] Second, different strategies to combine PBOC policy instruments can be envisaged and potentially contrasted with the factor model approach employed here. Third, given the relative performance of the new monetary policy indicator proposed in this paper, it would be useful to see how it performs in models that typically use a Taylor rule to describe the conduct of PBoC monetary policy. We leave these suggestions for future research.

Finally, in view of the growing interest in central bank communication it is possible that the composite policy rule proposed here could be improved by quantifying not just what the PBoC does, but also what it says. Although we noted earlier that our monetary policy indicator overlaps very well with Sun's (2018) narrative indicator, recent developments in text and language analysis (e.g. Bailliu et al., 2021) provide additional avenues for future research.

[22] Extensive in-sample forecast accuracy tests confirm the superiority of the composite rule (see Figures A15 to A17).

References

Bai, Jushan and Pierre Perron (1998), "Estimating and Testing Linear Models with Multiple Structural Changes," *Econometrica* 66 (January): 47-78.

Bai, Jushan and Pierre Perron (2003a), "Computation and Analysis of Multiple Structural Change Models," *Journal of Applied Econometrics* 18 (January-February): 1-22.

Bai, Jushan and Pierre Perron (2003b), "Critical Values for Multiple Structural Change Tests," *Econometrics Journal* 6 (June): 72-78.

Bai, Jushan and Serena Ng (2002), "Determining the Number of Factors in Approximate Factor Models," *Econometrica* 70 (January): 191-221.

Bailliu, Jeannine, Xinfen Han, Barbara Sadaba and Mark Kruger (2021), "Chinese Monetary Policy and Text Analytics: Connecting Words and Deeds," Bank of Canada Staff Working Paper 2021-3, January.

Burdekin, Richard C. K. and Xinyi Hu (2018), "Deflationary Pressures Today: The Chinese, Japanese and Spanish Cases Compared," *Chinese Economy* 51 (November-December): 471-482.

Burdekin, Richard C. K. and Pierre L. Siklos (2008), "What Has Driven Chinese Monetary Policy Since 1990? Investigating the People's Bank's Policy Rule," *Journal of International Money and Finance* 27 (September): 847-859.

Burdekin, Richard C. K. and Marc D. Weidenmier (2015), "Assessing the Impact of the Chinese Stimulus Package at Home and Abroad: A Damp Squib?" *China Economic Review* 33 (April): 137-162.

Burdekin, Richard C. K. and Junjie Zhang (2019), "Macroeconomic Drivers of Chinese ADRs: Home Country vs. US Effects," *Chinese Economy* 52 (July-August): 342-357.

Chen, Hongyi and Pierre Siklos (2023), "Oceans Apart? China and Other Systemically Important Economies," *Emerging Markets Finance and Trade* 59 (5): 1349-1371.

Chen, Kaiji, Jue Ren and Tao Zha (2018), "The Nexus of Monetary Policy and Shadow Banking in China," *American Economic Review* 108 (December): 3891-3936.

Chen, Zhenzhu, Li Li and Changhua Yu (2023), "Monetary Policy Shocks and the Signaling Channel of Monetary Policy in China," *China Economic Quarterly International* 3 (March): 46-69.

Dai, Genyou (2002), "China's Monetary Policy: Too Tight?" *China & World Economy* 10 (September-October): 16-20.

Das, Sonali and Wentin Song (2022), "Monetary Policy Transmission and Policy Coordination in China," Working Paper 22/74, International Monetary Fund, April.

Fan, Longzhen, Yihong Yu and Chu Zhang (2011), "An Empirical Evaluation of China's Monetary Policies," *Journal of Macroeconomics* 33 (June): 358-371.

Federal Reserve Bank of Atlanta (2024), *China's Macroeconomy: Time Series Data*, July 2024 update [https://www.atlantafed.org/cqer/research/china-macroeconomy].

Federal Reserve Bank of San Francisco (nd), *The China Cyclical Activity Tracker* [https://www.frbsf.org/research-and-insights/data-and-indicators/china-cyclical-activity-tracker/].

Fernald, John G., Mark M. Spiegel and Eric T. Swanson (2014), "Monetary Policy Effectiveness in China: Evidence from a FAVAR Model," *Journal of International Money and Finance* 49 (December): 83-103.

Funke, Michael and Andrew Tsang (2020), "The People's Bank of China's Response to the Coronavirus Pandemic: A Quantitative Assessment," *Economic Modelling* 93 (December): 465-473.

Girardin, Eric, Sandrine Lunven and Guonan Ma (2017), "China's Evolving Monetary Policy Rule: From Inflation-Accommodating to Anti-Inflation Policy," Working Paper No. 641, Bank for International Settlements, May.

Gürkaynak, Refet S., Brian Sack and Eric Swanson (2005), "The Sensitivity of Long-Term Interest Rates to Economic News: Evidence and Implications for Macroeconomic Models," *American Economic Review* 95 (March): 425-436.

Hamilton, James D. (1988), "Rational-Expectations Econometric Analysis of Changes in Regime: An Investigation of the Term Structure of Interest Rates," *Journal of Economic Dynamics and Control* 12 (June-September): 385-423.

Jing, Yuan, Yan Peng, Zongwu Cai and Zhengyi Zhang (2022), "A Quantitative Evaluation of Interest Rate Liberalization Reform in China," *Annals of Economics and Finance* 23 (2): 197-221.

Kamber, Güneş and M. S. Mohanty (2018), "Do Interest Rates Play a Major Role in Monetary Policy Transmission in China?" Working Paper No. 714, Bank for International Settlements, April.

Kim, Soyoung and Hongyi Chen (2022), "From a Quantity to an Interest-Rate-Based Framework: Multiple Monetary Policy Instruments and Their Effects in China," *Journal of Money, Credit and Banking* 54 (October): 2103-2123.

Klingelhöfer, Jan and Rongrong Sun (2018), "China's Regime-Switching Monetary Policy," *Economic Modelling* 68 (January): 32-40.

Law of the People's Republic of China on The People's Bank of China (2003), revised in accordance with the Decision on Amending the Law of the People's Republic of China on the People's Bank of China adopted by the Standing Committee of the Tenth National People's Congress at its 6th Meeting on 27 December 2003. [http://www.pbc.gov.cn/english/130733/2941519/2015082610501049304.pdf]

Leahy, Joe, William Sandlund and Ian Smith (2024), "China Loosens Monetary Policy Stance for First Time in 14 Years," *Financial Times*, December 9.

Li, Bing and Qing Liu (2017), "On the Choice of Monetary Policy Rules for China: A Bayesian DSGE Approach," *China Economic Review* 44 (July): 166-185.

Liu, Dayu, Ning Xu and Tingting Zhao (2018), "Identifying the Nonlinear Correlation between Business Cycle and Monetary Policy Rule: Evidence from China and the US," *Economic Modelling* 73 (June): 45-54.

Lu, Dong, Tian Xia and Hang Zhou (2022), "Foreign Exchange Intervention and Monetary Policy Rules Under a Managed Floating Regime: Evidence from China," *Applied Economics* 54 (28): 3226-3245.

Maher, William (2024), "China's Monetary Policy Framework and Financial Market Transmission," *Reserve Bank of Australia Bulletin,* April: 85-94.

McCallum, Bennett T. (1999), "Recent Developments in the Analysis of Policy Rules," *Federal Reserve Bank of St. Louis Review,* 81 (November/December), 3-11.

Monetary Policy Analysis Group of the People's Bank of China (2012), *China Monetary Policy Report Quarter Four, 2011*, February 15.

Monetary Policy Analysis Group of the People's Bank of China (2016), *China Monetary Policy Report Quarter One, 2016*, May 6.

Monetary Policy Analysis Group of the People's Bank of China (2023), *China Monetary Policy Report Q1 2023*, May 15.

Pan Gongsheng (2024), "China's Current Monetary Policy Stance and Evolution of Monetary Policy Framework in the Future," Keynote speech by Governor Pan Gongsheng at 15th Lujiazui Forum, June 19 [http://www.pbc.gov.cn/en/3688110/3688175/5379439/index.html].

Razzak, W. A. (2003), "Is the Taylor Rule Really Different from the McCallum Rule?" *Contemporary Economic Policy* 21 (October): 445-457.

Shieh, Harrison (2024), “Can You Hear Me Now? Identifying the Effects of Chinese Monetary Policy Announcements,” *Journal of International Money and Finance* 144 (June): 103078.

Stock, James J., and Mark W. Watson (2016), “Dynamic Factor Models, Factor-Augmented Vector Autoregressions, and Structural Vector Autoregressions in Macroeconomics,” in John B. Taylor and Harald Uhlig (eds.), *Handbook of Macroeconomics*, Volume 2, pp. 415-525 (Amsterdam, Netherlands: North Holland).

Sun, Rongrong (2015), “What Measures Chinese Monetary Policy?” *Journal of International Money and Finance* 59 (December): 263-286.

Sun, Rongrong (2018), “A Narrative Indicator of Monetary Conditions in China”, *International Journal of Central Banking* 14 (September): 1-42

Sun, Shuzhang, Christopher Gan and Baidung Hu (2012), “Evaluating McCallum Rule as a Policy Guideline for China,” *Journal of the Asia Pacific Economy* 17 (August): 527-545.

Taylor, J. (1992), “Discretion Versus Policy Rules in Practice”, *Carnegoe-Rochester Conference Series on Public Policy* 39 (December): 195-214.

Wei, Shang-Jin and Yinxi Xie (2019), “The Wedge of the Century: Understanding a Divergence between CPI and PPI Inflation Measures,” NBER Working Paper No. 24319, May.

Zheng, Tingguo, Xia Wang and Huiming Guo (2012), “Estimating Forward-Looking Rules for China's Monetary Policy: A Regime-Switching Perspective,” *China Economic Review* 23 (March): 47-59.

Zhong, Yi, Jiajun Lu and Yueteng Zhu (2022), “Does China’s Monetary Policy Framework Incorporate Financial Stability?” *Journal of the Asia Pacific Economy* 27 (1): 64-83.

Zhou, Lanxu (2024), “PBOC Injects $70b into System via New Outright Reverse Repos,” *China Daily*, November 1.

Zhou, Zhongfei, and Jingwei Li (2007), “Independence and Accountability of the People’s Bank of China: A Legal Perspective,” in James R. Barth, Zhongfei Zhou, Douglas W. Arner, Barry F. C. Hsu and Wei Wang (eds.), *Financial Restructuring and Reform in Post-WTO China* (Alphen aan den Rijn, Netherlands: Kluwer Law International).

TABLES

Table 1. Markov-switching estimates of an extended McCallum Rule

Dependent Variable: M2 growth rate
Sample (adjusted): 2001Q2-2023Q2

Variable	Coefficient	Std. error	z-Statistic	Prob.
Regime 1				
Constant	10.644	0.406	26.204	0.000
Nominal GDP gap	0.149	0.070	2.135	0.033
Real exchange rate growth	-0.018	0.053	-0.339	0.735
Growth in RMB foreign exchange reserves	0.168	0.021	7.877	0.000
Regime 2				
Constant	17.769	0.395	44.954	0.000
Nominal GDP gap	0.707	0.099	7.170	0.000
Real exchange rate growth	-0.040	0.047	-0.845	0.398
Growth in RMB foreign exchange reserves	0.336	0.019	17.932	0.000
Common				
LOG(SIGMA)	0.563	0.072	7.804	0.000
Transition Matrix Parameters				
P11 constant term	3.628	0.674	5.385	0.000
P21 constant term	-1.714	0.607	-2.821	0.005

Notes: P11 denotes the high volatility State 1 and P21 denotes the low volatility State 2; Huber-White standard errors are displayed under OPG-BHHH optimization with the Marquardt step method.

Table 2. Estimates of the modified interest-rate-based McCallum Rule

Dependent variable: First difference of the policy rate
Method: Least squares
Sample: 2001Q4-2021Q3
Number of observations: 80

Variable	Coefficient	Std. error	t-Statistic	Prob.
Moving average of M2 velocity/50	8.470	1.735	4.881	0.000
Nominal GDP gap/50	-0.783	0.196	-3.990	0.000
Adjusted R-squared	0.264			

Table 3. Taylor rule estimates

(a) Constant neutral real interest rate

Dependent variable: Policy rate
Method: Least squares
Sample: 2001Q1–2023Q1
Number of observations: 89 (after adjustment)

Variable	Coefficient	Std. error	t-Statistic	Prob.
C	0.586	0.136	4.305	0.000
CPI inflation gap	0.060	0.011	5.242	0.000
Output gap	0.038	0.008	4.988	0.000
Lagged policy rate	0.894	0.025	35.857	0.000

Adjusted R-squared 0.963

F-statistic 771.925 (.000)

Steady state inflation gap = 0.566 (.146); output gap = 0.036 (.073)[1]

(b) Time-varying neutral real interest rate

Dependent variable: Policy rate
Method: Least squares
Sample: 2001Q1-2023Q1
Number of observations: 89

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Neutral real interest rate (RSTAR)	0.043	0.024	1.810	0.074
CPI inflation gap	0.028	0.014	2.042	0.044
Output gap	0.024	0.008	3.125	0.002
Lagged policy rate	0.979	0.012	80.950	0.000

Adjusted R-squared 0.953
Log likelihood 12.973
Steady state inflation gap = 1.333 (1.091); output gap = 1.143 (.776).

Note: [1] standard errors in parenthesis.

Table 4. Markov-switching estimates for the composite monetary policy rule

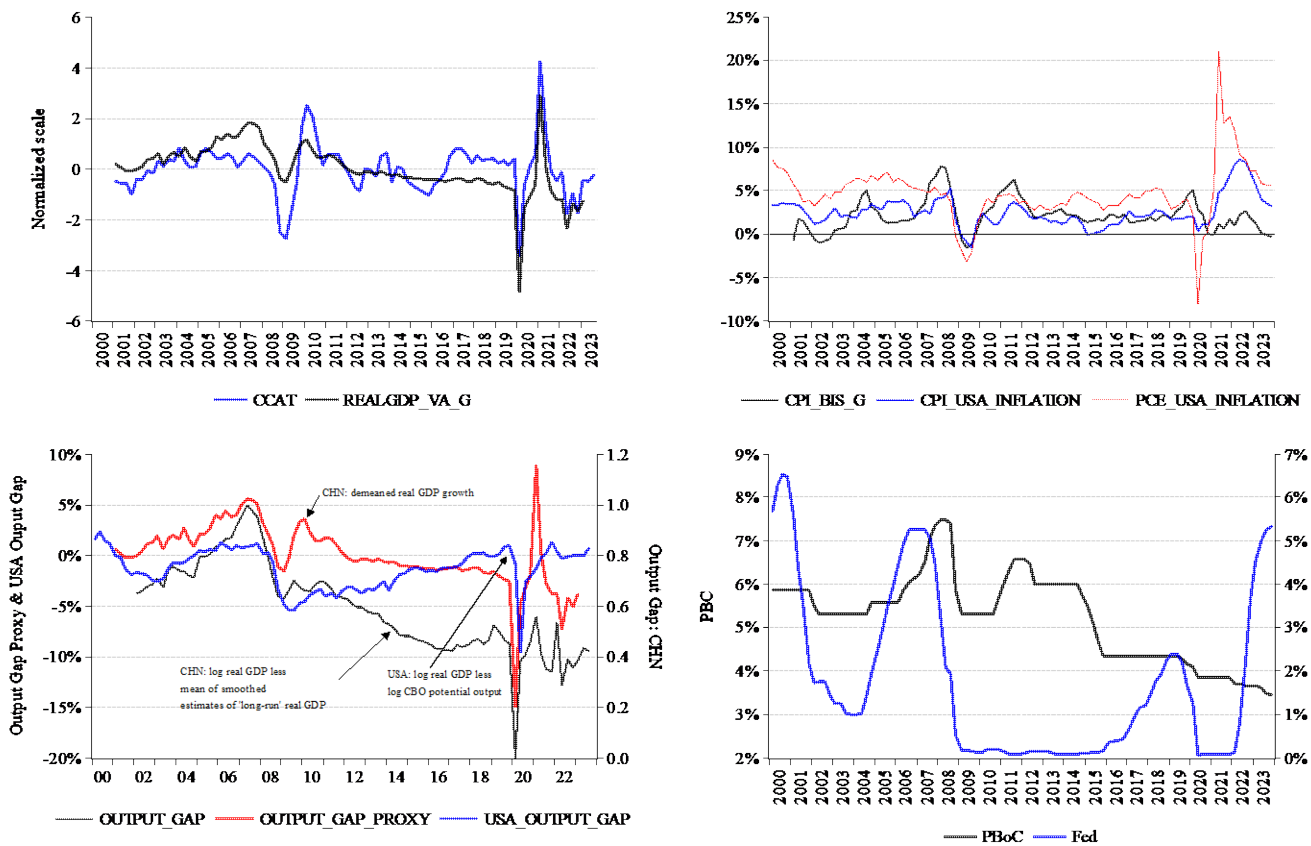
Dependent Variable: Monetary policy index (MPI)
Method: Markov-switching regression
Sample: 2001Q1 2023Q1
Number of observations: 89

Variable	Coefficient	Std. Error	z-Statistic	Prob.
	Regime 1			
Constant	0.054	0.142	0.378	0.705
CPI inflation gap	0.758	0.171	4.423	0.000
Output gap	0.235	0.089	2.634	0.008
	Regime 2			
Constant	0.192	0.069	2.794	0.005
CPI inflation gap	0.116	0.042	2.778	0.005
Output gap	0.141	0.023	6.141	0.000
	Common			
LOG(SIGMA)	-0.891	0.130	-6.844	0.000
	Transition matrix parameters			
P11-C	0.638	0.809	0.788	0.431
P21-C	-2.579	0.649	-3.975	0.000

Note: See notes to Table 1. CPI is the Consumer Price Index.

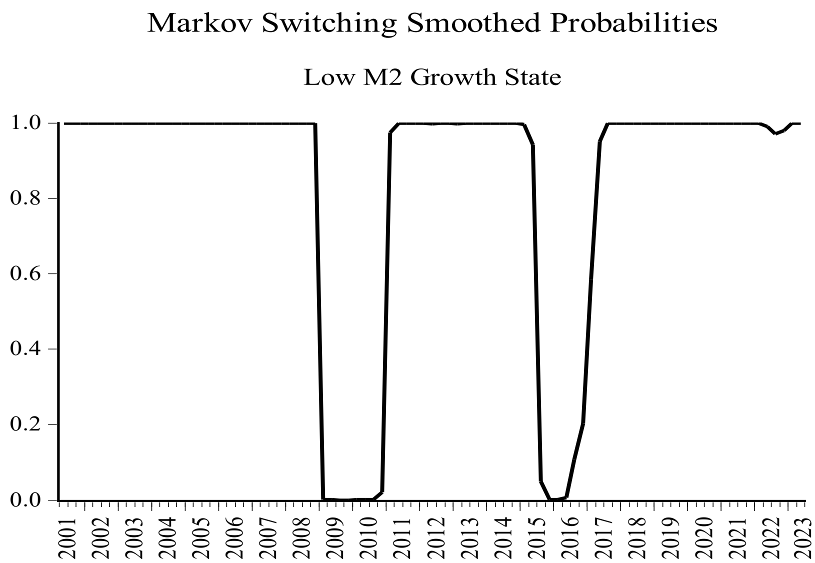
FIGURES

Figure 1. Selected China and US macroeconomic indicators, 2001–2023.



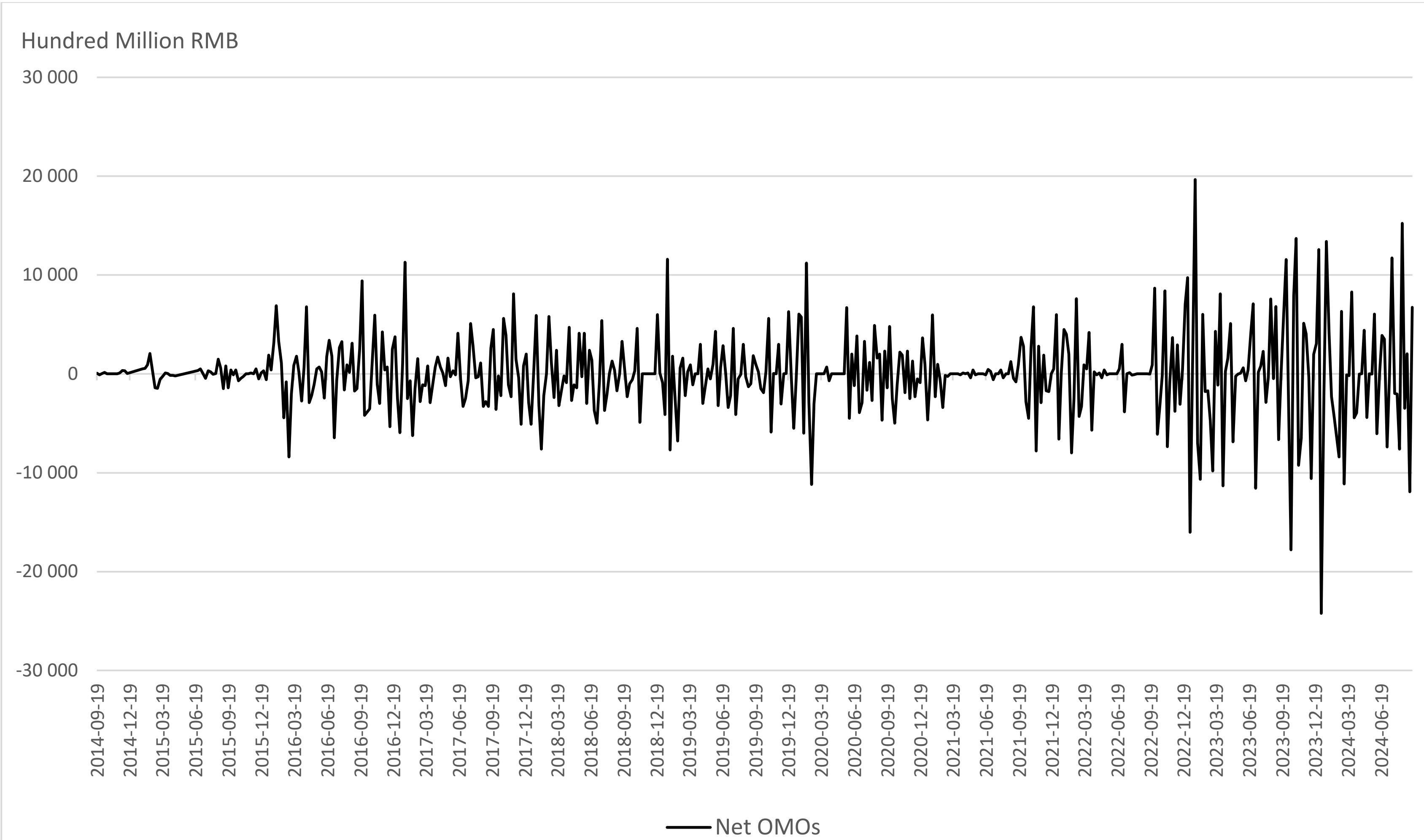
Notes: CCAT is the Federal Reserve Bank of San Francisco Cyclical Activity tracker. BIS indicates the source for China's inflation rate. US data are from St. Louis Federal Reserve Economic Data (FRED) for headline CPI (CPI) and the Personal Consumption Expenditures Deflator (PCE). PBoC and Fed refer to the policy rates of the two respective central banks (7-day repo rate and federal funds rate). See text for details about estimation of output gaps.

Figure 2. Regime probabilities in the Markov-switching model for the McCallum Rule.



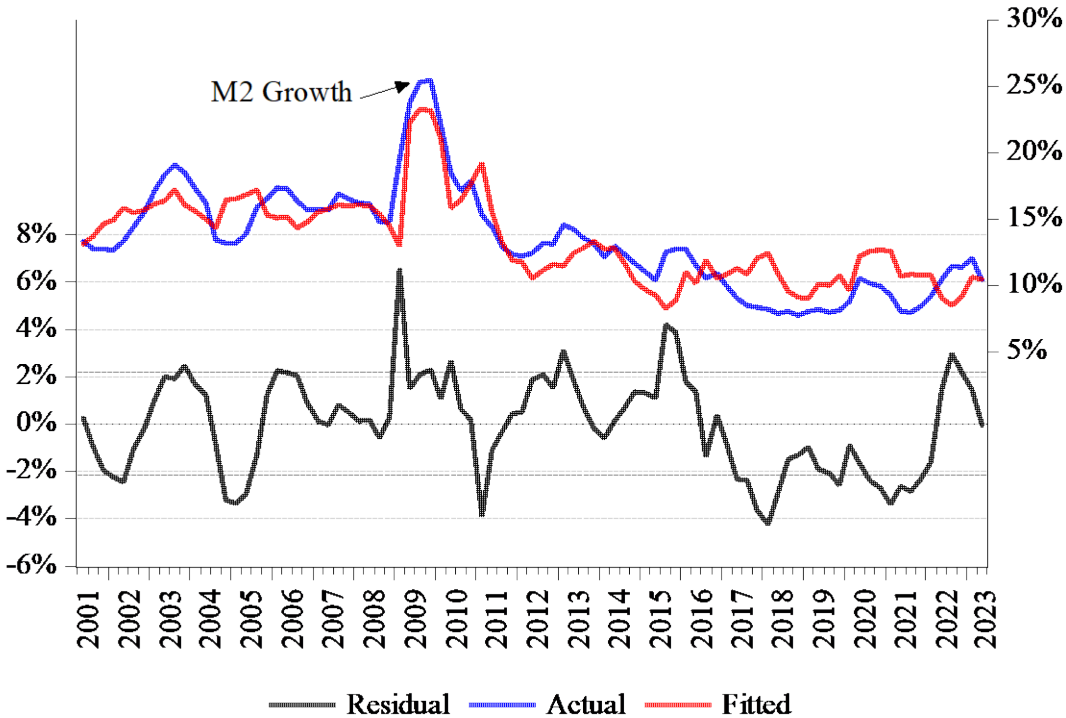
Note: Based on the estimates shown in Table 1.

Figure 3. Extent of PBoC's open market operations, 2014–2024.



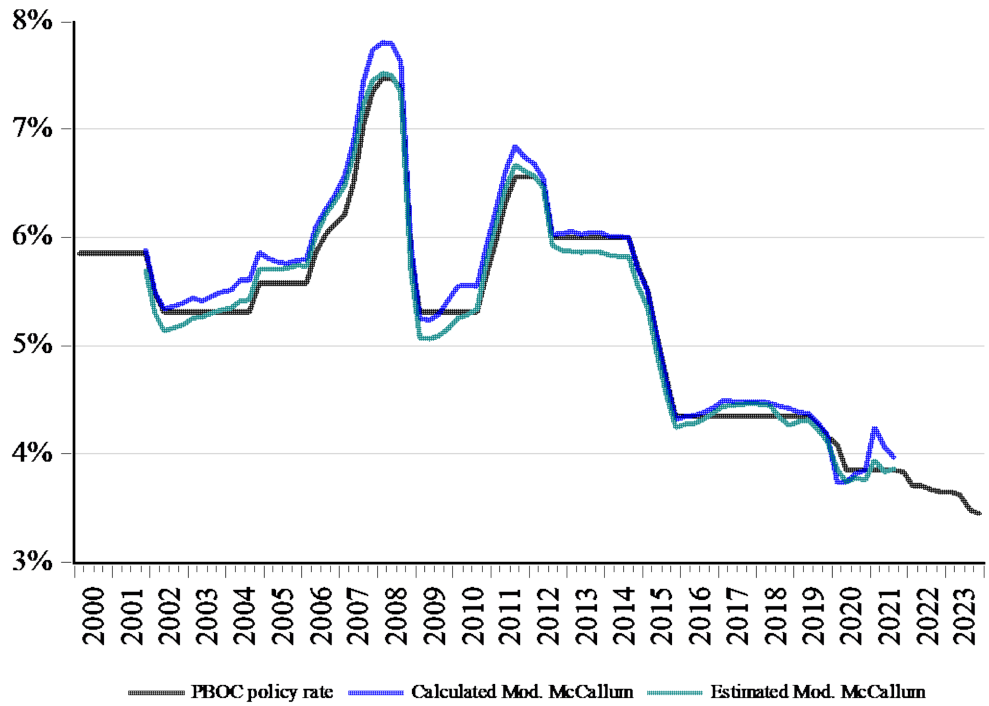
Note: Data reflect net money delivery by the People's Bank of China and are drawn from the Wind Terminal.

Figure 4. Performance of the McCallum rule over time.



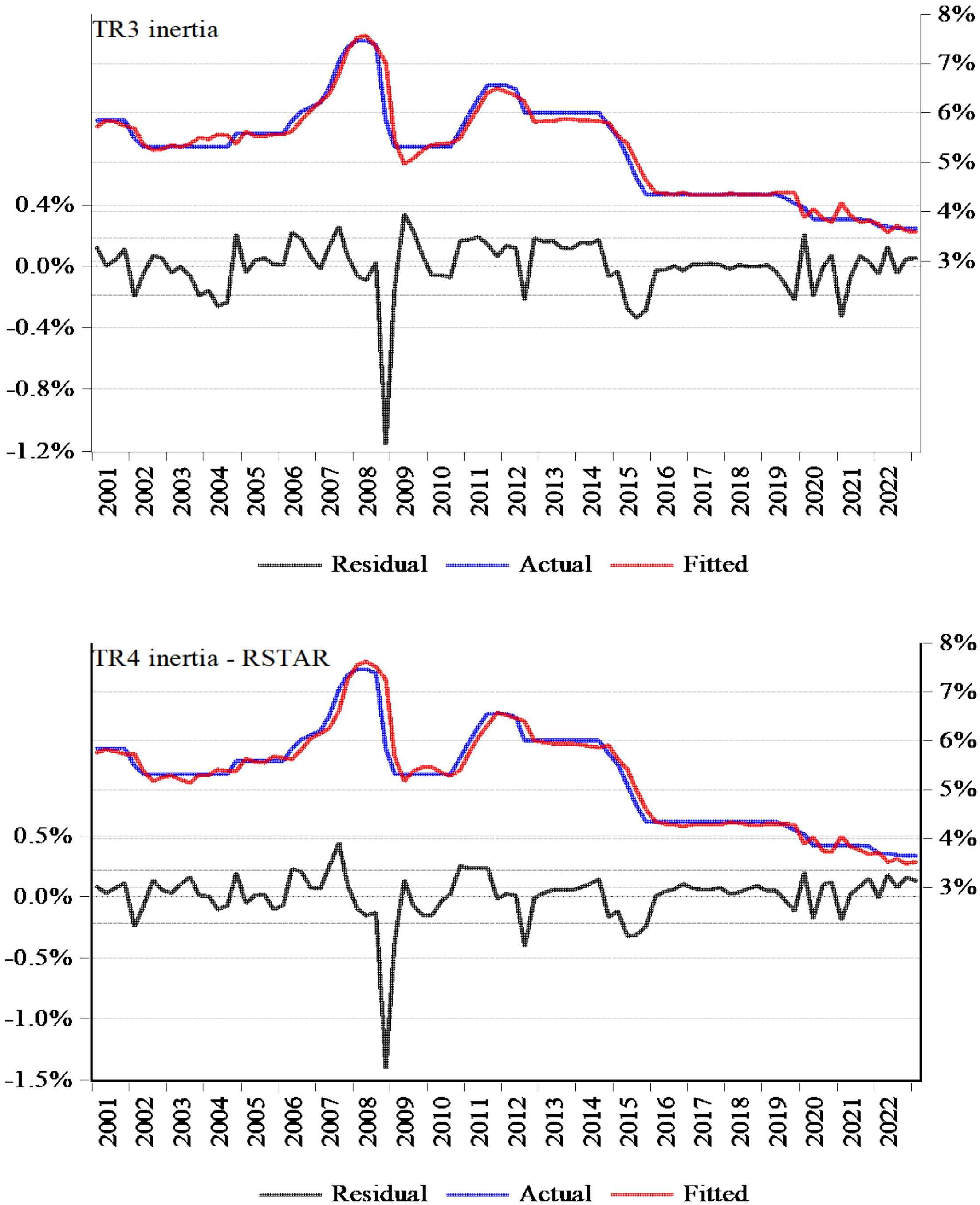
Note: Based on the estimates from Table 1.

Figure 5. Overall fit of modified McCallum rule.



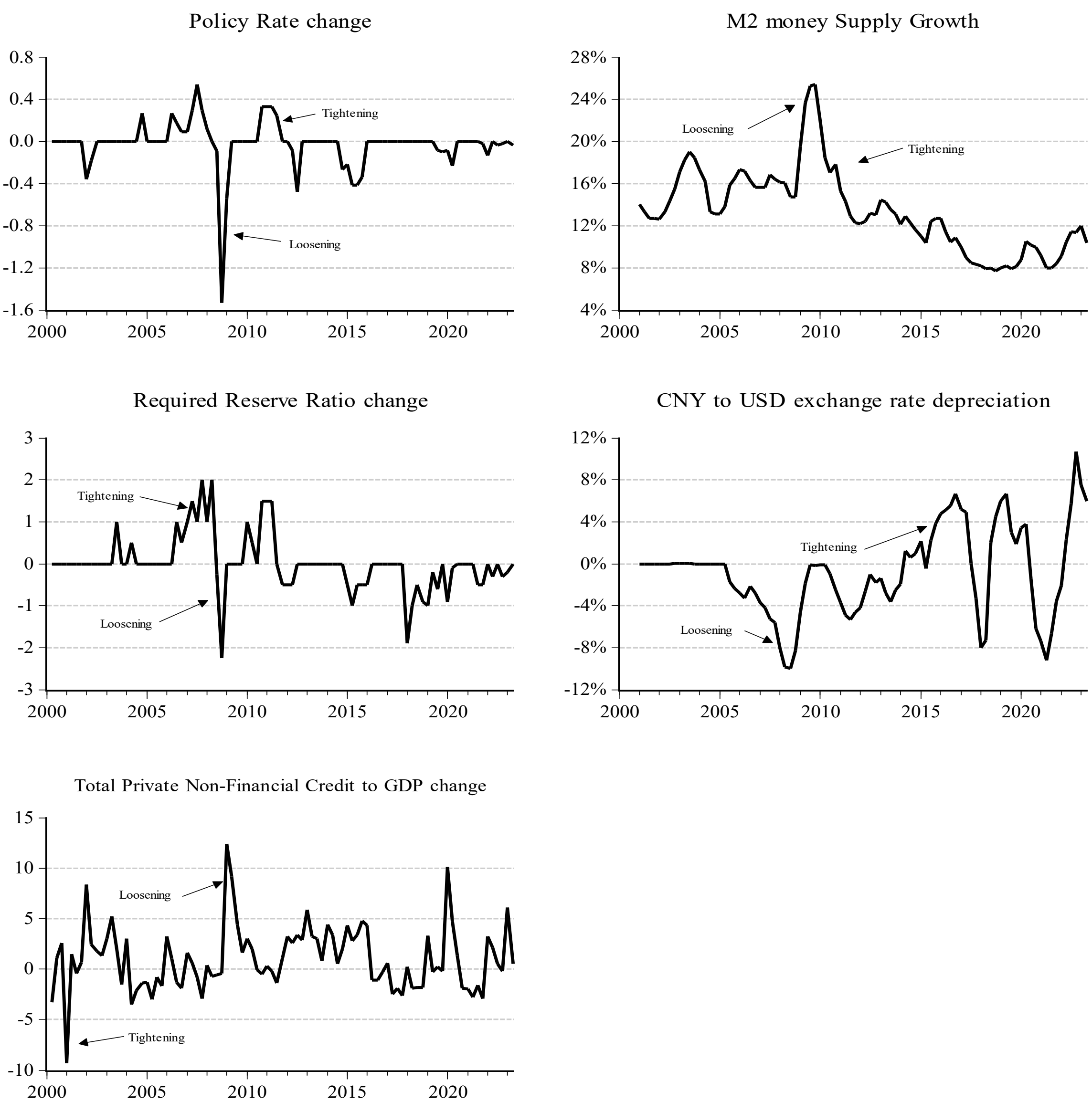
Note: Mod. McCallum refers to the calibrated and estimated McCallum rules (see equation (6)). The dependent variable is $\Delta i_t = i_t - i_{t-1}$, where i_t is the PBOC policy rate.

Figure 6. Performance of estimated Taylor rules over time.



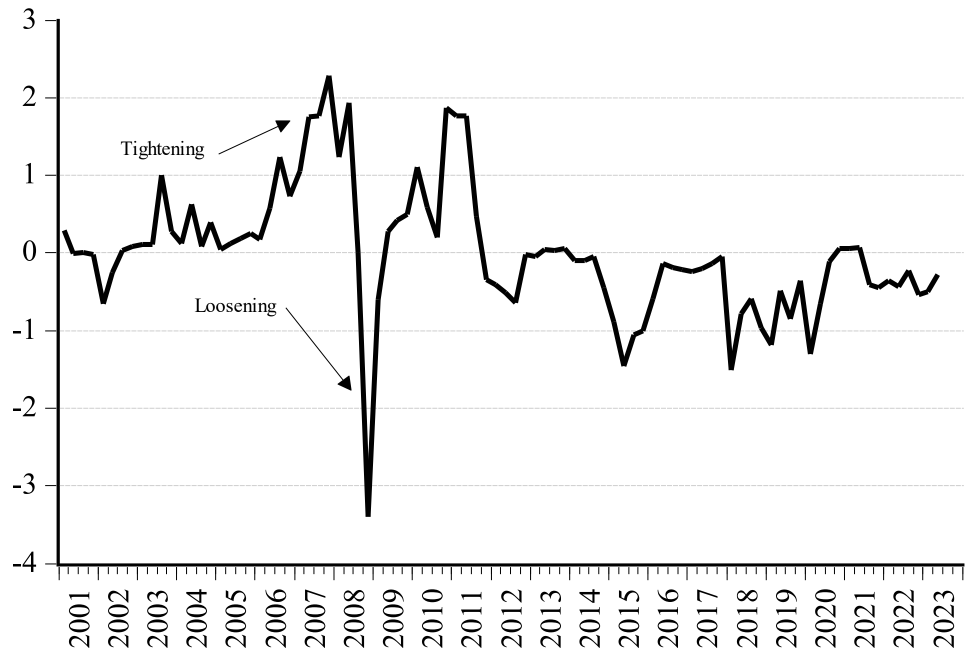
Note: Obtained from the results shown in Table 3. RSTAR is the neutral real interest rate obtained from calculations detailed in the text (note 14).

Figure 7. Inputs for composite monetary policy rule.



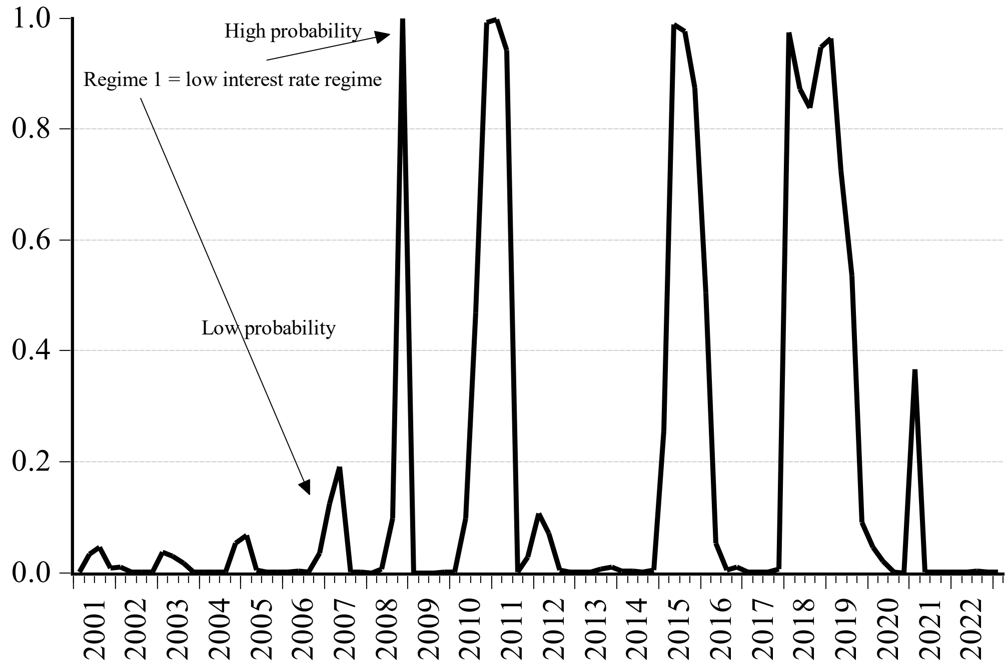
Note: Data sources provided in the text.

Figure 8. Time series behavior of composite monetary policy rule



Note: Predicted values for MPI derived from the results in Table 4.

Figure 9. Regime probabilities for the composite monetary policy rule.



Note: Derived from the results shown in Table 4.

ONLINE APPENDIX

Combating Crises and Deflation in China's Central Bank: Modeling Post-pandemic Monetary Policymaking

Richard C. K. Burdekin and Pierre L. Siklos

Table A1

OLS Estimation of the McCallum Rule with Structural Breaks

Dependent Variable: M2_G
Method: Least Squares with Breaks
Sample (adjusted): 2001Q2 2023Q2
Number of observations: 89
Estimated Break dates: 2011Q3, 2016Q3

Variable		Coefficient	Std. Error	t-Statistic	Prob.
2001Q2 - 2011Q2					
Constant		18.647	2.501	7.457	0.000
Nominal GDP Gap		0.320	0.276	1.158	0.250
2011Q3 - 2016Q2					
Constant		12.446	0.431	28.891	0.000
Nominal GDP Gap		-0.040	0.061	-0.664	0.509
2016Q3 - 2023Q2					
Constant		9.566	0.414	23.123	0.000
Nominal GDP Gap		0.176	0.054	3.268	0.002
Adjusted R-squared	0.703				
F-statistic	42.663				
Prob(F-statistic)	0.000				

Note: Breaks obtained from Bai-Perron test with a maximum of 2 breaks, 10% trimming, Newey-West standard errors. A 1% threshold was used to decide whether a break is statistically significant.

Table A2

OLS McCallum Rule Estimates

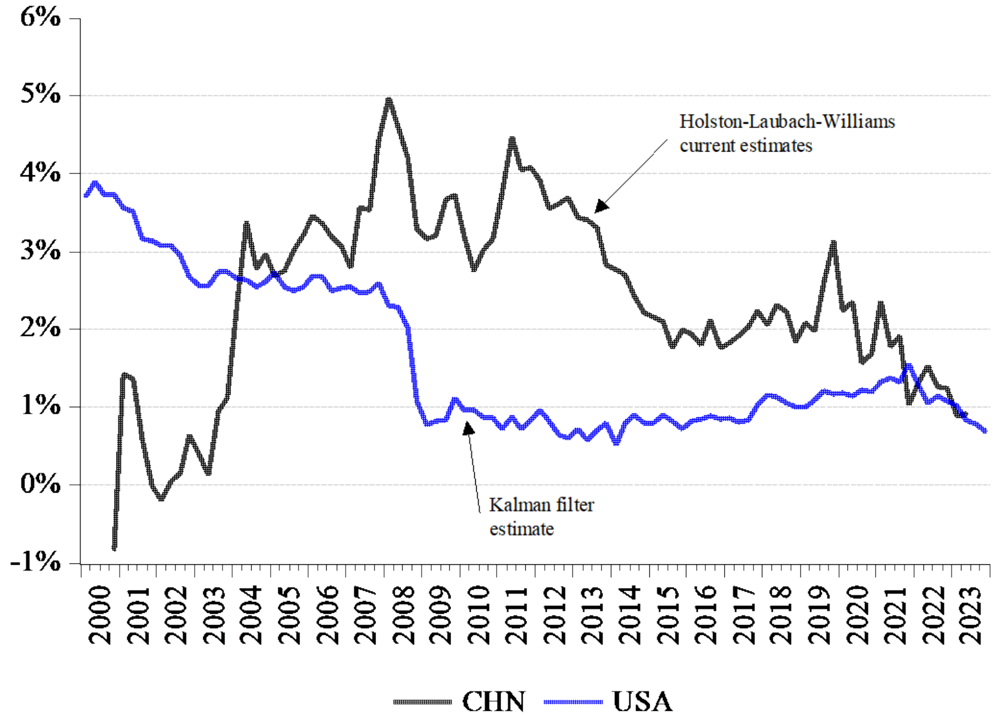
Dependent Variable: M2_G
Method: Least Squares
Sample (adjusted): 2001Q2 2023Q2
Included observations: 89 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	12.069	0.462	26.130	0.000
Nominal GDP Gap	0.265	0.101	2.621	0.010
Real Exchange Rate Growth	0.002	0.064	0.026	0.979
Growth in RMB Foreign Exchange Reserves	0.170	0.024	7.039	0.000

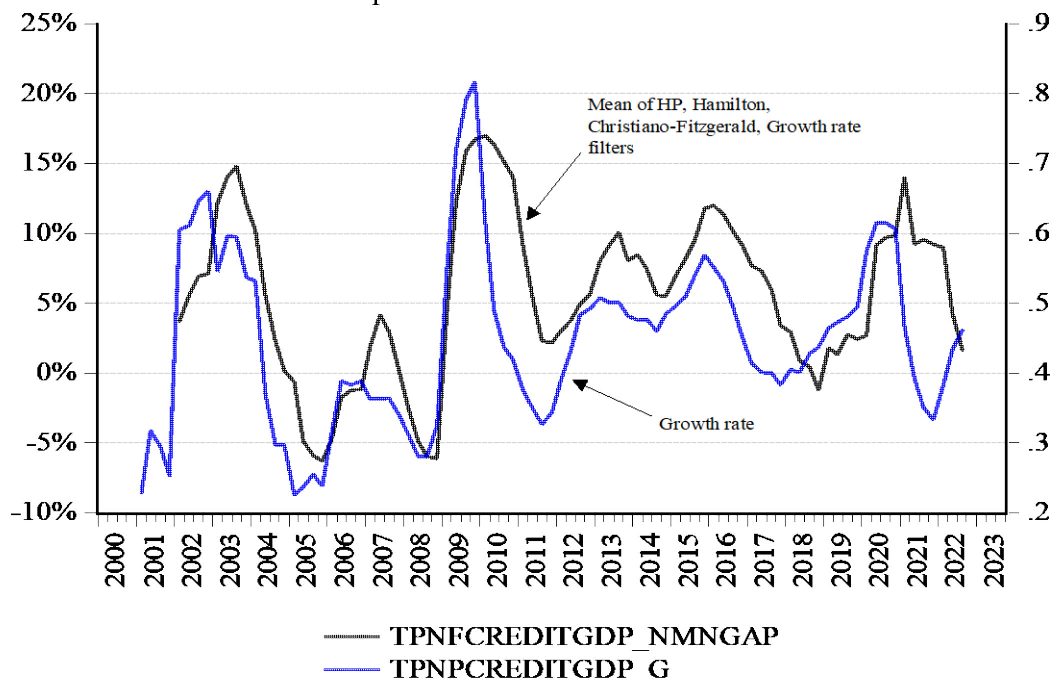
R-squared	0.401	Mean dependent var	13.346
Adjusted R-squared	0.380	S.D. dependent var	3.942
S.E. of regression	3.104	Akaike info criterion	5.147
Sum squared resid	818.990	Schwarz criterion	5.259
Log likelihood	-225.050	Hannan-Quinn criterion	5.192
F-statistic	18.964	Durbin-Watson stat	0.208
Prob(F-statistic)	0.000		

Figure A1 Neutral Real Interest Rates and Credit Gaps

China's and the USA Neutral Real Interest Rates



Two Estimates of China's Credit Gap



Selected Estimates: McCallum Rule: $\Delta m_t = \Delta x^* - \Delta v_t + 0.5(\Delta x^* - \Delta x_{t-1}) + \Gamma Y_t + \varepsilon_t$

Replace 0.5 value used by McCallum in his calibrated version of his rule with a coefficient estimate as in Burdekin and Siklos (2008) and add a constant to replace the first two terms. Alternatives are considered that relax some of these assumptions and I also consider a structural break test which was not considered in our JIMF paper and we now also consider a structural Break test which was not considered in our earlier paper.

Table A3 McCallum's Rule for China with Structural Breaks

Dependent Variable: M2_G
Method: Least Squares with Breaks
Sample (adjusted): 2001Q2 2023Q2
Included observations: 89 after adjustments
Break type: Bai-Perron tests of L+1 vs. L sequentially determined breaks
Breaks: 2011Q3, 2016Q3
Selection: Trimming 0.10, Max. breaks 2, Sig. level 0.01
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
2001Q2 - 2011Q2 -- 41 obs				
C	18.647	2.501	7.457	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	0.320	0.276	1.158	0.250
2011Q3 - 2016Q2 -- 20 obs				
C	12.446	0.431	28.891	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	-0.040	0.061	-0.664	0.509
2016Q3 - 2023Q2 -- 28 obs				
C	9.566	0.414	23.123	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	0.176	0.054	3.268	0.002
R-squared	0.720	Mean dependent var		13.346
Adjusted R-squared	0.703	S.D. dependent var		3.942
S.E. of regression	2.148	Akaike info criterion		4.432
Sum squared resid	382.955	Schwarz criterion		4.600
Log likelihood	-191.224	Hannan-Quinn criter.		4.500
F-statistic	42.663	Durbin-Watson stat		0.243
Prob(F-statistic)	0.000			

Figure A2 Fitted and Residuals from McCallum's Rule for China with Structural Breaks

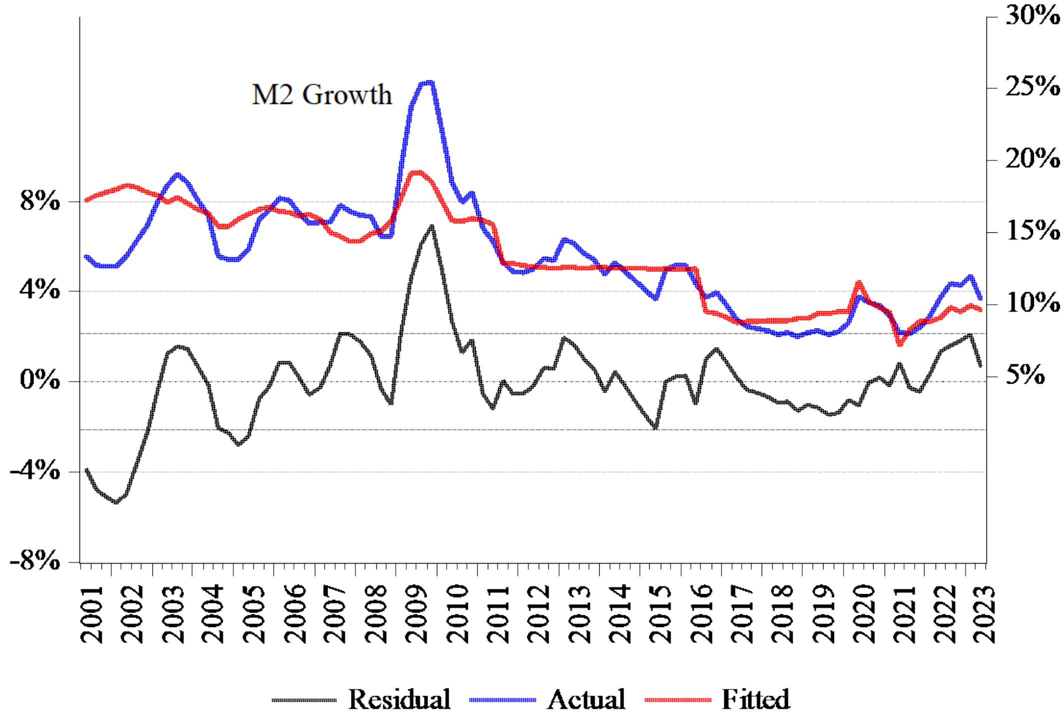


Table A4 Additional McCallum's Rule Estimates with Structural Breaks

Dependent Variable: M0_G
Method: Least Squares with Breaks
Sample (adjusted): 2001Q2 2023Q1
Included observations: 88 after adjustments
Break type: Bai-Perron tests of L+1 vs. L sequentially determined breaks
Breaks: 2014Q2, 2021Q2
Selection: Trimming 0.10, Max. breaks 2, Sig. level 0.01
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
2001Q2 - 2014Q1 -- 52 obs				
C	9.043	0.924	9.784	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	-0.310	0.123	-2.509	0.014
2014Q2 - 2021Q1 -- 28 obs				
C	5.451	0.653	8.347	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	0.308	0.129	2.384	0.019
2021Q2 - 2023Q1 -- 8 obs				
C	11.423	0.771	14.815	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	0.492	0.075	6.589	0.000

R-squared	0.611	Mean dependent var	8.957
Adjusted R-squared	0.587	S.D. dependent var	3.761
S.E. of regression	2.416	Akaike info criterion	4.668
Sum squared resid	478.715	Schwarz criterion	4.837
Log likelihood	-199.392	Hannan-Quinn criter.	4.736
F-statistic	25.764	Durbin-Watson stat	1.041
Prob(F-statistic)	0.000		

Figure A3 Fitted and Residuals from Additional McCallum's Rule with Structural Breaks

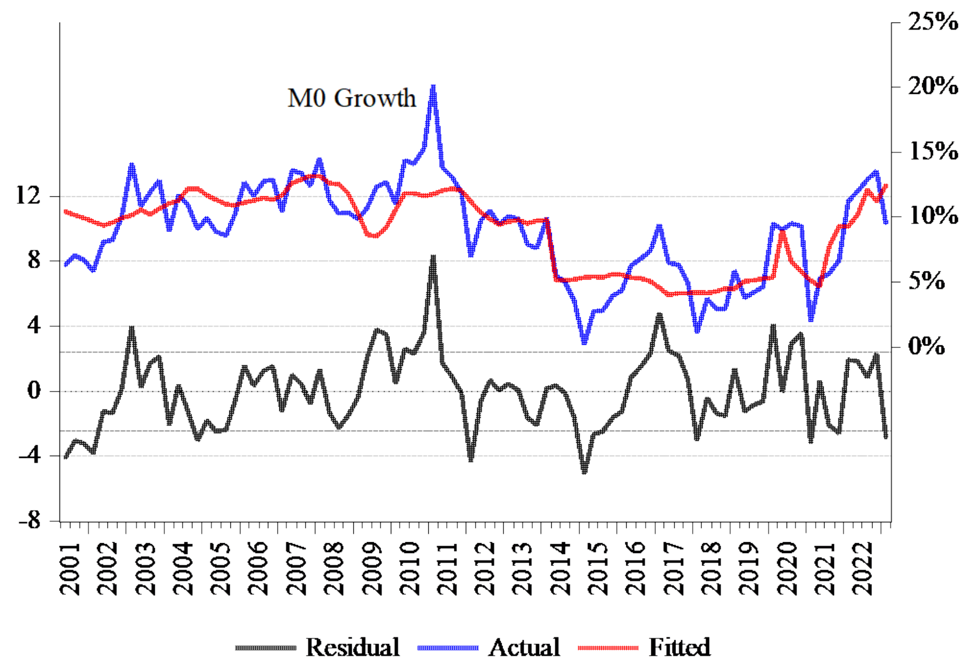


Table A5 Extended McCallum's Rule

Dependent Variable: M2_G
Method: Least Squares
Sample (adjusted): 2001Q2 2023Q2
Included observations: 89 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	12.069	0.462	26.130	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	0.265	0.101	2.621	0.010
REER_G	0.002	0.064	0.026	0.979
FOREXRES_RMB_ALT_G	0.170	0.024	7.039	0.000
R-squared	0.401	Mean dependent var		13.346
Adjusted R-squared	0.380	S.D. dependent var		3.942
S.E. of regression	3.104	Akaike info criterion		5.147
Sum squared resid	818.990	Schwarz criterion		5.259
Log likelihood	-225.050	Hannan-Quinn criter.		5.192
F-statistic	18.964	Durbin-Watson stat		0.208
Prob(F-statistic)	0.000			

Figure A4 Fitted and Residuals from Extended McCallum's Rule

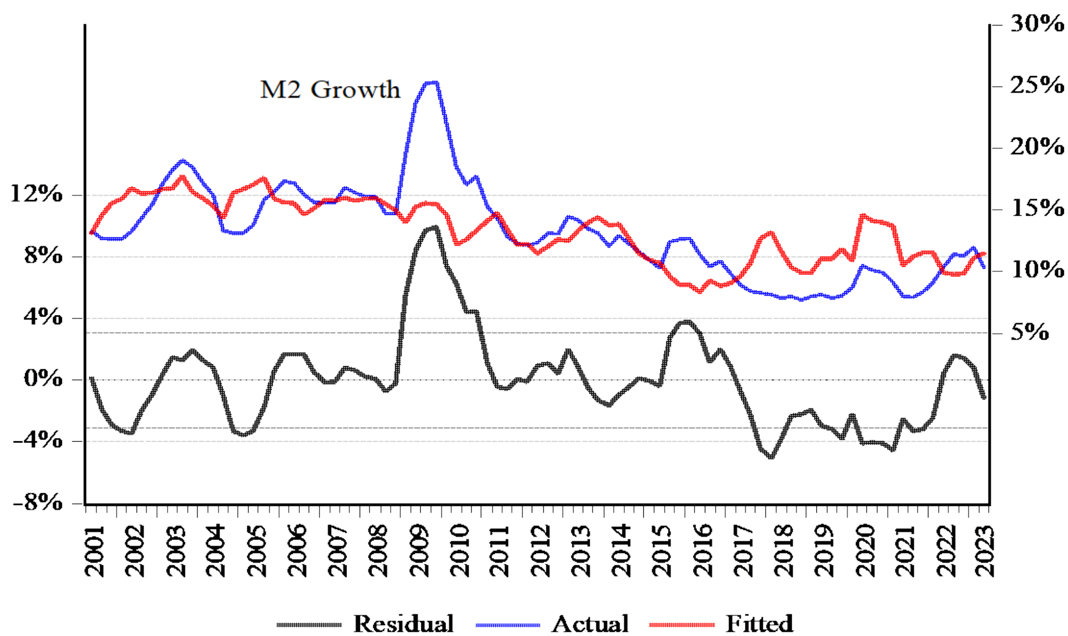


Table A6 GMM Estimates of McCallum's Extended Rule

Dependent Variable: M2_G
Method: Generalized Method of Moments
Sample (adjusted): 2002Q2 2022Q4
Included observations: 83 after adjustments
Linear estimation with 1 weight update
Estimation weighting matrix: HAC (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)
Standard errors & covariance computed using estimation weighting matrix
Instrument specification: M2_G(-1) FOREXRES_RMB_ALT_G(-1) OIL_INFLATION(-1) CCAT(-1) EPU_D(-1) TPNFCREDITGDP_N MNGAP(-1) CNYUSD_XRATE_G(-1) M2_G(-2)
Constant added to instrument list

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	12.17814	0.969821	12.55710	0.0000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	0.482855	0.275212	1.754485	0.0832
REER_G	0.083818	0.099286	0.844206	0.4011
FOREXRES_RMB_ALT_G	0.198134	0.048375	4.095801	0.0001
R-squared	0.372264	Mean dependent var		13.42308
Adjusted R-squared	0.348426	S.D. dependent var		4.064474
S.E. of regression	3.280848	Sum squared resid		850.3532
Durbin-Watson stat	0.242561	J-statistic		6.912579
Instrument rank	9	Prob(J-statistic)		0.227224

Figure A5 Fitted and Residuals from GMM Estimates of McCallum's Rule

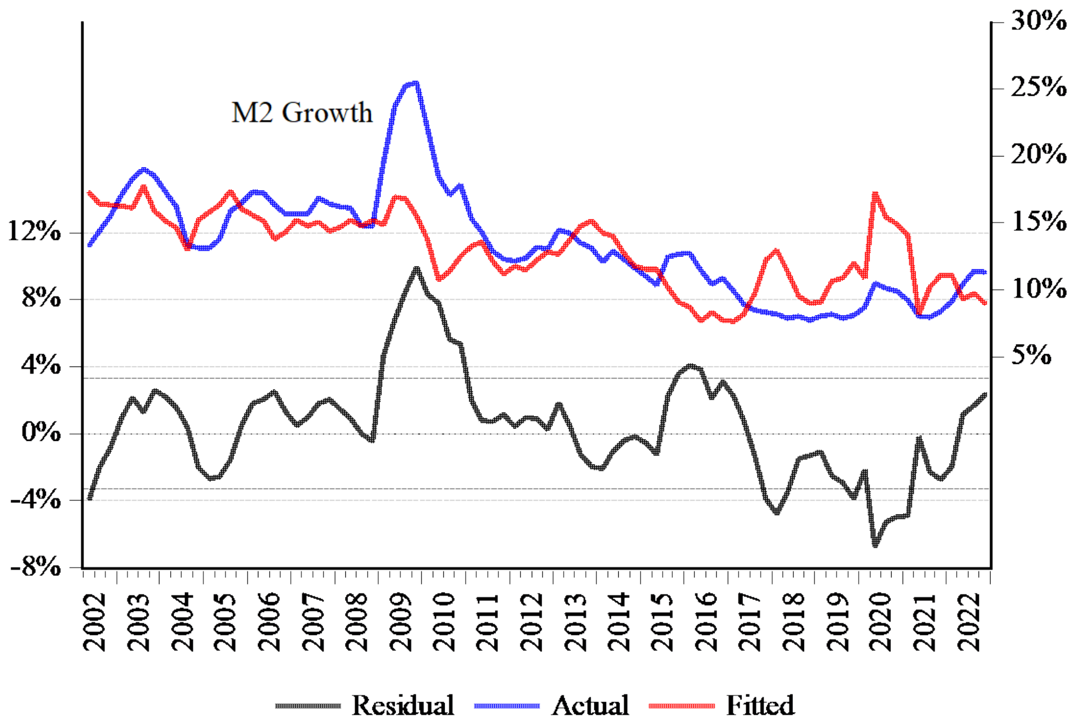


Table A7 Additional Markov Switching Estimates of McCallum's Rule

Dependent Variable: M2_G
Method: Markov Switching Regression (OPG - BHHH / Marquardt steps)
Sample (adjusted): 2001Q2 2023Q2
Included observations: 89 after adjustments
Number of states: 2
Initial probabilities obtained from ergodic solution
Huber-White robust standard errors & covariance
Random search: 25 starting values with 10 iterations using 1 standard deviation (rng=kn, seed=1935181338)
Failure to improve objective (non-zero gradients) after 7 iterations

Variable	Coefficient	Std. Error	z-Statistic	Prob.
	Regime 1			
C	21.683	1.089	19.906	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	0.630	0.133	4.725	0.000
	Regime 2			
C	11.115	0.319	34.828	0.000
NOMGDPG_TARGET-NOMGDP_VA_G(-1)	0.100	0.095	1.048	0.295
	Common			
LOG(SIGMA)	0.714	0.063	11.278	0.000
	Transition Matrix Parameters			
P11-C	3.283	0.569	5.771	0.000
P21-C	-4.266	0.903	-4.725	0.000

Mean dependent var	13.346	S.D. dependent var	3.942
S.E. of regression	2.220	Sum squared resid	413.865
Durbin-Watson stat	0.258	Log likelihood	-197.689
Akaike info criterion	4.600	Schwarz criterion	4.795
Hannan-Quinn criter.	4.679		

Figure A6 Regime Probabilities in Additional Markov Switching McCallum Rule Estimates

Markov Switching Smoothed Probabilities

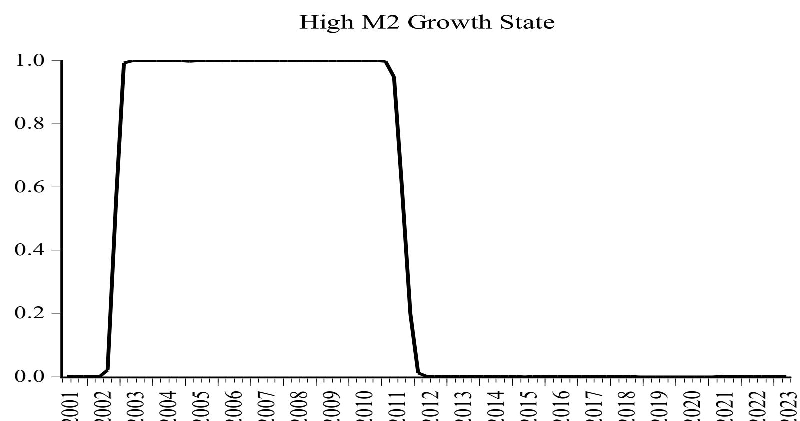
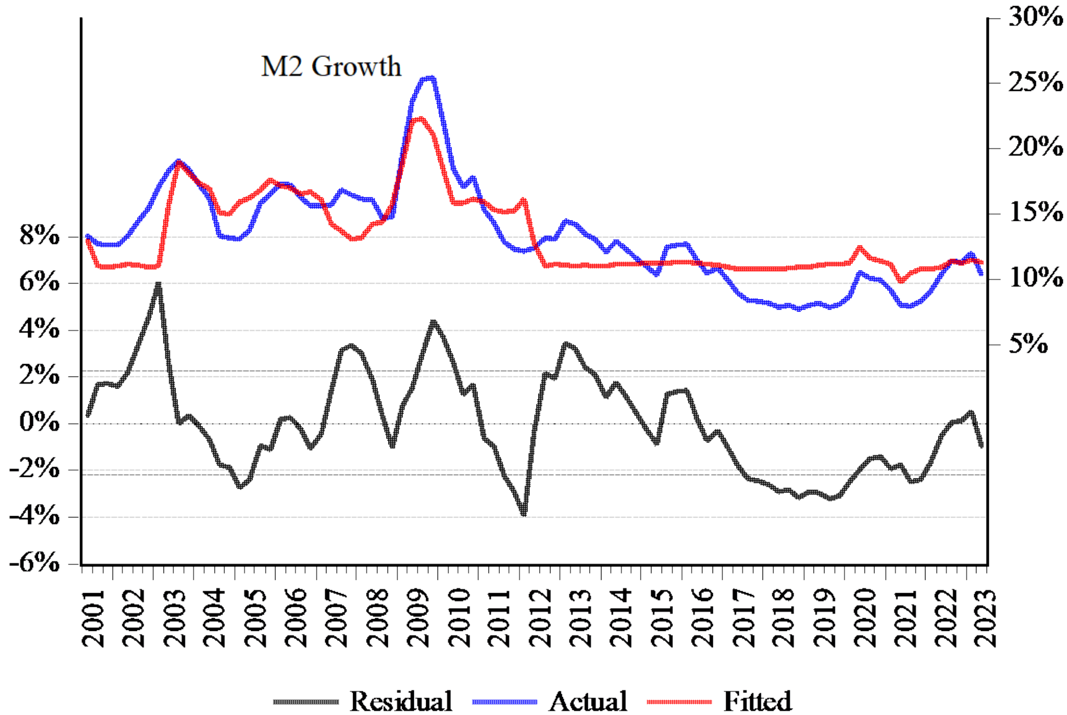


Figure A7 The Performance Over Time of Additional Markov Switching McCallum's Rule Estimates



Cointegration Equation Testing: Long-Run estimates of the money gap (a measure of inflationary pressure; see Adam and Hendry, 1999). First step in a two-step process.

$$m_t = \gamma_0 + \gamma_1 p_t + \gamma_2 y_t - \gamma_3 i_t$$

Table A8 Cointegration Tests

Dependent Variable: LM0
Method: Fully Modified Least Squares (FMOLS)
Sample (adjusted): 2000Q2 2023Q1
Included observations: 92 after adjustments
Cointegrating equation deterministics: C
Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LCPI_BIS	0.567146	0.342947	1.653743	0.1017
LOGREALGDP_NIPA	0.949591	0.100539	9.444997	0.0000
PR	0.023469	0.009328	2.516065	0.0137
C	-3.222173	0.705692	-4.565975	0.0000
R-squared	0.996285	Mean dependent var		8.320685
Adjusted R-squared	0.996159	S.D. dependent var		0.613874
S.E. of regression	0.038046	Sum squared resid		0.127382
Long-run variance	0.004567			

Dependent Variable: LM2
Method: Fully Modified Least Squares (FMOLS)
Sample (adjusted): 2000Q2 2023Q2
Included observations: 93 after adjustments
Cointegrating equation deterministics: C
Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LCPI_BIS	0.291	0.295	0.987	0.327
LOGREALGDP_NIPA	1.544	0.086	17.857	0.000
PR	-0.019	0.008	-2.357	0.021
C	-4.374	0.607	-7.204	0.000
R-squared	0.999	Mean dependent var		11.183
Adjusted R-squared	0.999	S.D. dependent var		0.934
S.E. of regression	0.032	Sum squared resid		0.093
Long-run variance	0.003			

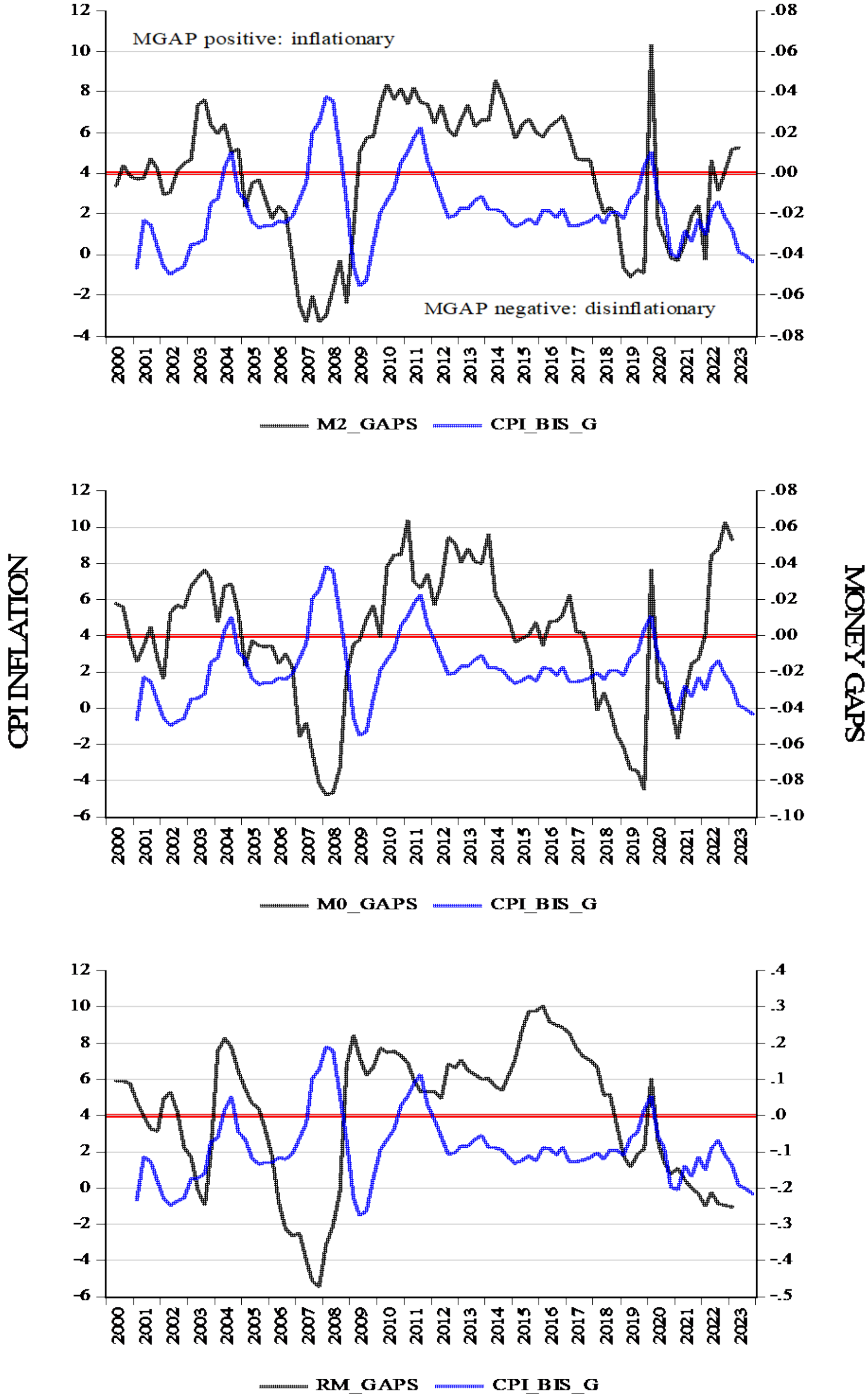
Dependent Variable: LRESERVEMONEY
Method: Fully Modified Least Squares (FMOLS)
Sample (adjusted): 2000Q2 2023Q1
Included observations: 92 after adjustments
Cointegrating equation deterministics: C
Long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LCPI_BIS	-1.809	1.709	-1.058	0.293
LOGREALGDP_NIPA	2.512	0.501	5.012	0.000
PR	0.262	0.046	5.645	0.000
C	-7.135	3.517	-2.029	0.046

R-squared	0.965	Mean dependent var	9.107
Adjusted R-squared	0.964	S.D. dependent var	1.003
S.E. of regression	0.191	Sum squared resid	3.208
Long-run variance	0.113		

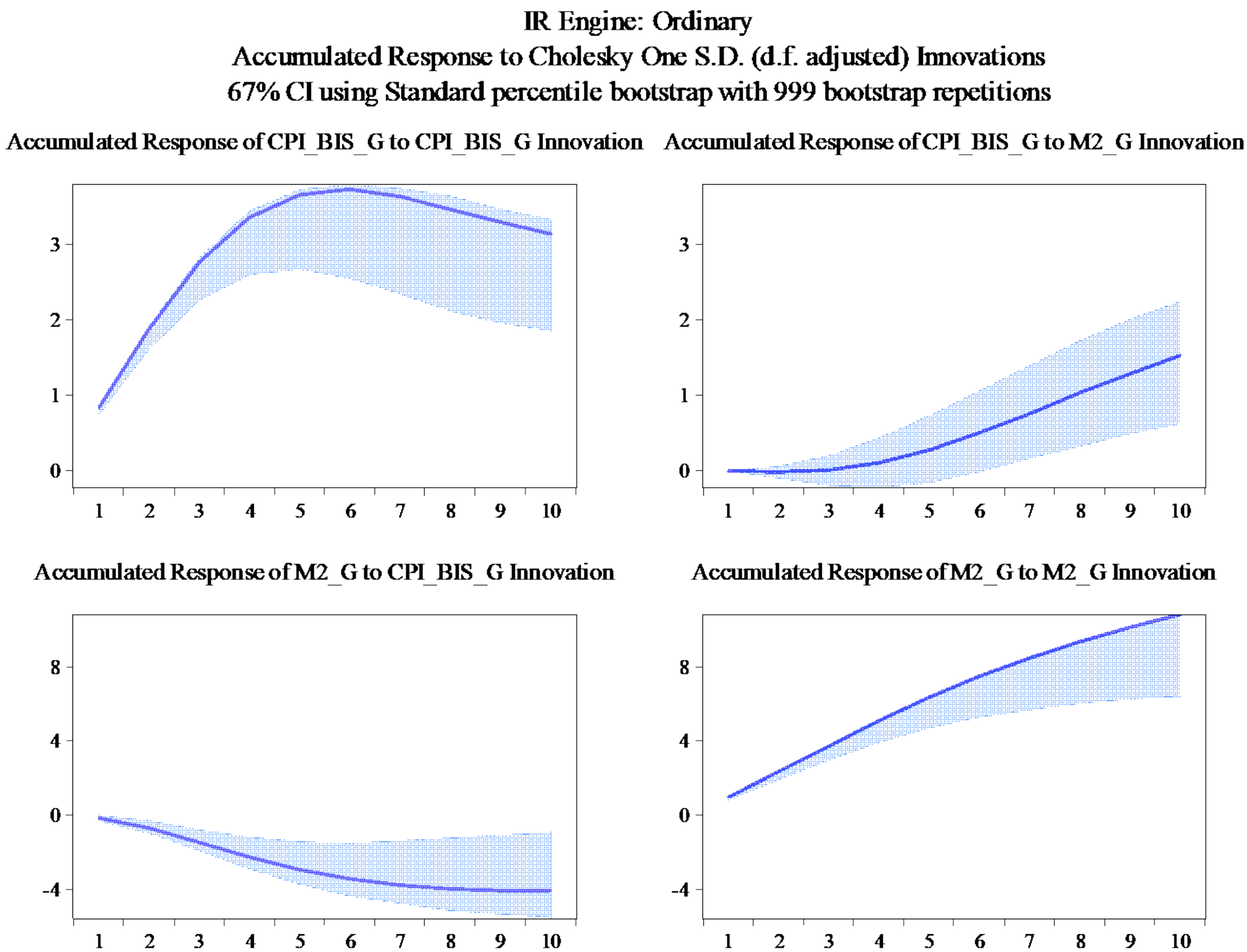
Error Correction Terms (when lagged one period). Money Gaps when considered in the current period. Inflation should rise when the money gap is positive and falls when it is negative.

Figure A8 Estimates of Money Gaps Versus Inflation



VECM estimation: (1) No exogenous variables (except constant and EC term); (2) adding 2 lags of REER growth.
Shown below are impulse responses.

Figure A9 Impulse Response Functions Derived from VECM Estimates



Taylor rules: three versions. (1) no inertia; (2) with inertia; (3) extended rule with additional determinants

$$i_t = \delta_t + (1-\delta_t)(\gamma_1\tilde{\pi}_t + \gamma_2\tilde{y}_t + \Gamma' Y_t) + \eta_t$$
$$i_t = \rho i_{t-1} + (1-\rho) i_t^{\rho}$$

$$\delta_t = 0, \Gamma' = 0;\ \text{no inertia case;}$$
$$\delta_t \neq 0, \Gamma' = 0\ \text{inertia case ;}$$
$$\delta_t \neq 0, \Gamma' \neq 0\ \text{inertia and extended case.}$$

Table A9 Additional Taylor Rule Estimates

Dependent Variable: PR **TR3 NO INERTIA**
Method: Least Squares
Sample (adjusted): 2001Q1 2023Q1
Included observations: 89 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	5.404	0.088	61.736	0.000
CPI_BIS_G-INFLATION_TARGET	0.174	0.044	3.962	0.000
OUTPUT_GAP_PROXY	0.174	0.026	6.702	0.000
R-squared	0.429	Mean dependent var		5.260
Adjusted R-squared	0.416	S.D. dependent var		0.982
S.E. of regression	0.751	Akaike info criterion		2.297
Sum squared resid	48.452	Schwarz criterion		2.381
Log likelihood	-99.227	Hannan-Quinn criter.		2.331
F-statistic	32.313	Durbin-Watson stat		0.366
Prob(F-statistic)	0.000			

Dependent Variable: PR **TR4 INERTIA**
Method: Least Squares
Date: 07/03/24 Time: 15:15
Included observations: 89 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.351	0.144	2.441	0.017
CPI_BIS_G-LPBOCPRICEEXPINDEX	0.029	0.014	2.107	0.038
OUTPUT_GAP_PROXY	0.036	0.008	4.294	0.000
PR(-1)	0.934	0.027	34.696	0.000
R-squared	0.955	Mean dependent var		5.260
Adjusted R-squared	0.954	S.D. dependent var		0.982
S.E. of regression	0.211	Akaike info criterion		-0.232
Sum squared resid	3.778	Schwarz criterion		-0.120
Log likelihood	14.304	Hannan-Quinn criter.		-0.186
F-statistic	608.025	Durbin-Watson stat		1.379
Prob(F-statistic)	0.000			

Table A9 Cont'd

Dependent Variable: PR **TR5 INERTIA**
Method: Least Squares
Date: 07/03/24 Time: 15:15
Sample (adjusted): 2001Q1 2023Q4
Included observations: 92 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.191	0.115	1.661	0.100
CPI_BIS_G-INFLATION_TARGET	0.049	0.011	4.322	0.000
CCAT	0.094	0.020	4.680	0.000
PR(-1)	0.967	0.021	46.127	0.000

R-squared	0.967	Mean dependent var	5.203
Adjusted R-squared	0.966	S.D. dependent var	1.015
S.E. of regression	0.188	Akaike info criterion	-0.461
Sum squared resid	3.116	Schwarz criterion	-0.351
Log likelihood	25.183	Hannan-Quinn criter.	-0.416
F-statistic	852.791	Durbin-Watson stat	1.507
Prob(F-statistic)	0.000		

Dependent Variable: PR **TR4 RSTAR INERTIA**
Method: Least Squares
Sample (adjusted): 2001Q1 2023Q1
Included observations: 89 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RSTAR_PROXY	0.043	0.024	1.810	0.074
CPI_BIS_G-LPBOCPRICEEXPINDEX	0.028	0.014	2.042	0.044
OUTPUT_GAP_PROXY	0.024	0.008	3.125	0.002
PR(-1)	0.979	0.012	80.950	0.000

R-squared	0.954	Mean dependent var	5.260
Adjusted R-squared	0.953	S.D. dependent var	0.982
S.E. of regression	0.214	Akaike info criterion	-0.202
Sum squared resid	3.893	Schwarz criterion	-0.090
Log likelihood	12.973	Hannan-Quinn criter.	-0.157
Durbin-Watson stat	1.301		

Selected Extended Taylor Rule Estimates:

Dependent Variable: PR **TR4a inertia**
Method: Least Squares
Sample (adjusted): 2001Q1 2023Q1
Included observations: 89 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.157	0.160	0.981	0.330
CPI_BIS_G-LPBOCPRICEEXPINDEX	0.019	0.014	1.408	0.163
OUTPUT_GAP_PROXY	0.029	0.009	3.239	0.002
REER_G	-0.013	0.005	-2.487	0.015
PR(-1)	0.972	0.030	32.073	0.000

R-squared	0.959	Mean dependent var	5.260
Adjusted R-squared	0.957	S.D. dependent var	0.982
S.E. of regression	0.205	Akaike info criterion	-0.280
Sum squared resid	3.519	Schwarz criterion	-0.140
Log likelihood	17.465	Hannan-Quinn criter.	-0.224
F-statistic	485.375	Durbin-Watson stat	1.342
Prob(F-statistic)	0.000		

Note that I also tried a measure of credit or the US fed funds rate (both observed and an estimate of the shadow rate (Wu-Xia estimate) and these either produced estimates that are not terribly plausible (wrong sign, coefficients that are too small or too large) or do not add to what is shown above. In any case I would expect an exchange rate indicator to be a more meaningful addition to the TR than any of the others considered.

Figure A10 The Performance of the Estimated Taylor Rule Over Time

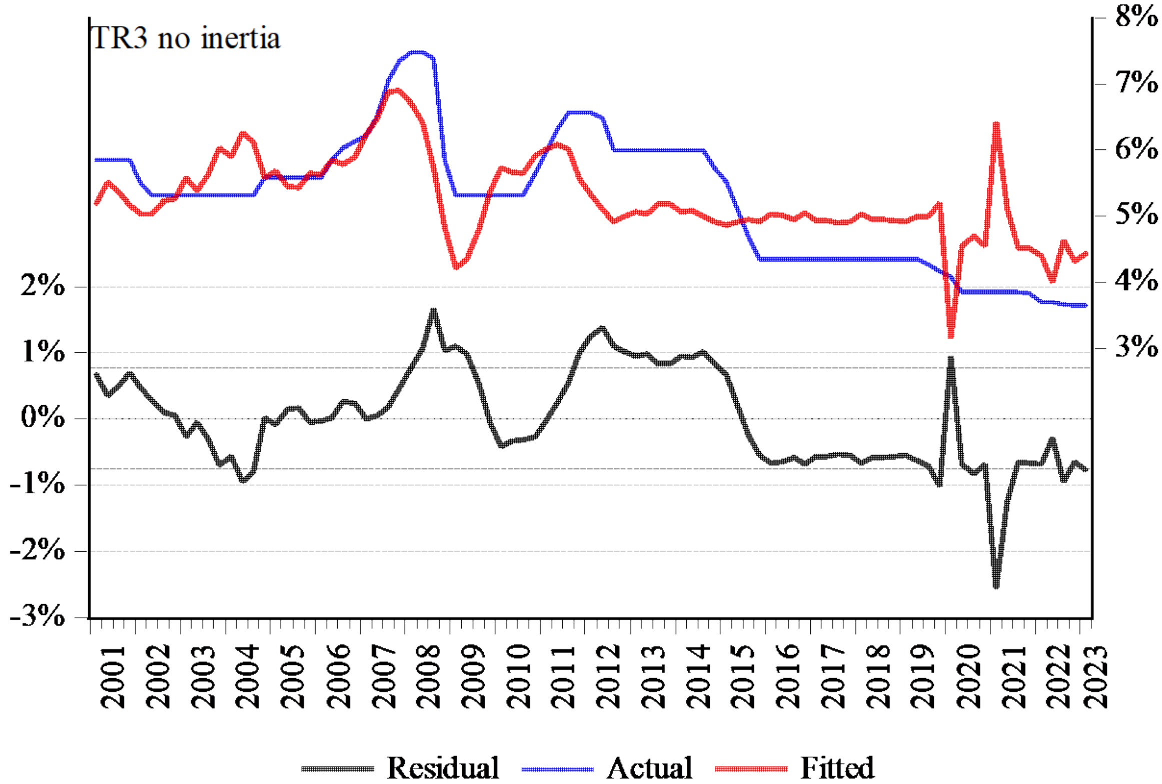
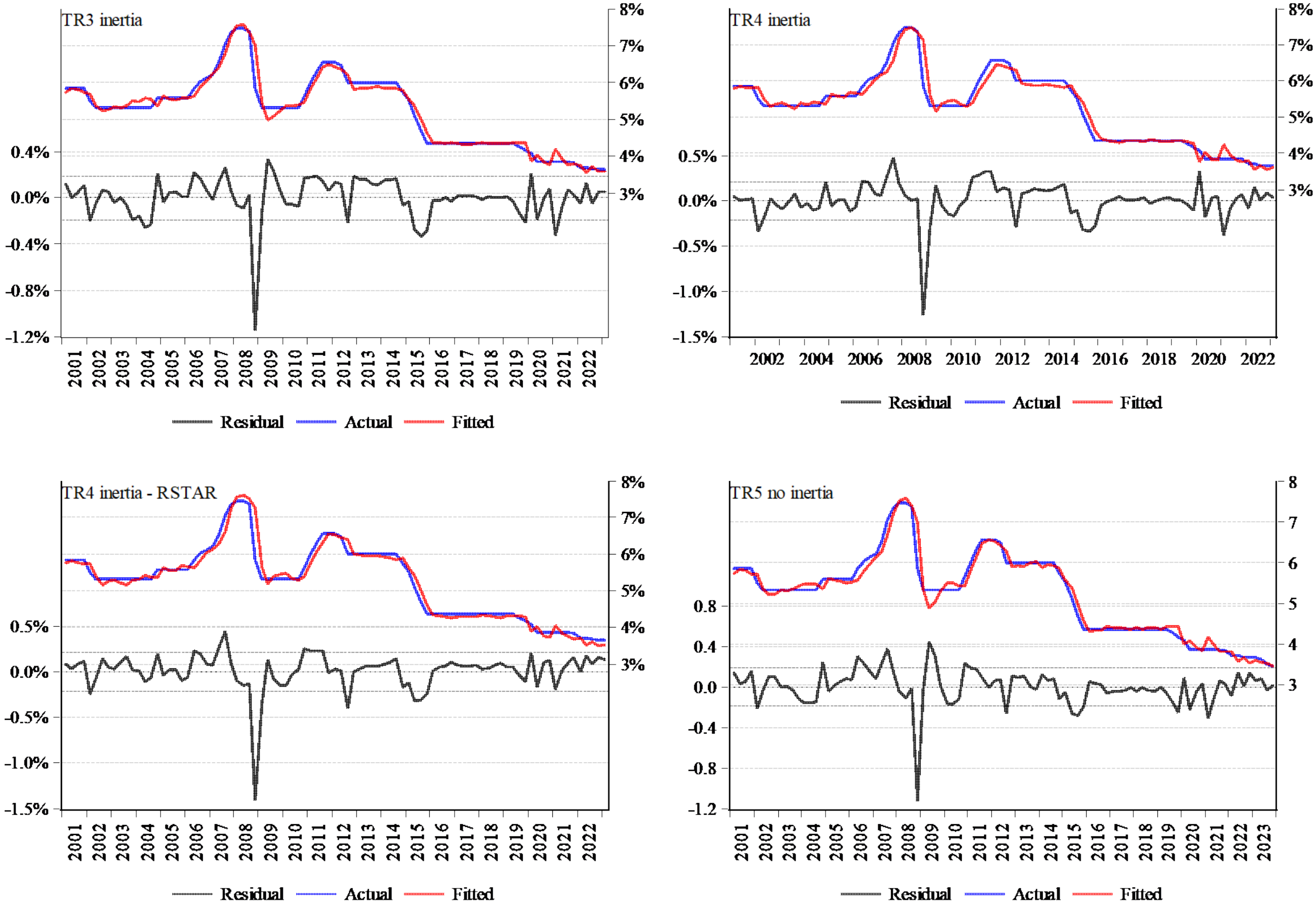


Figure A11 The Performance of Estimated Taylor Rules Compared

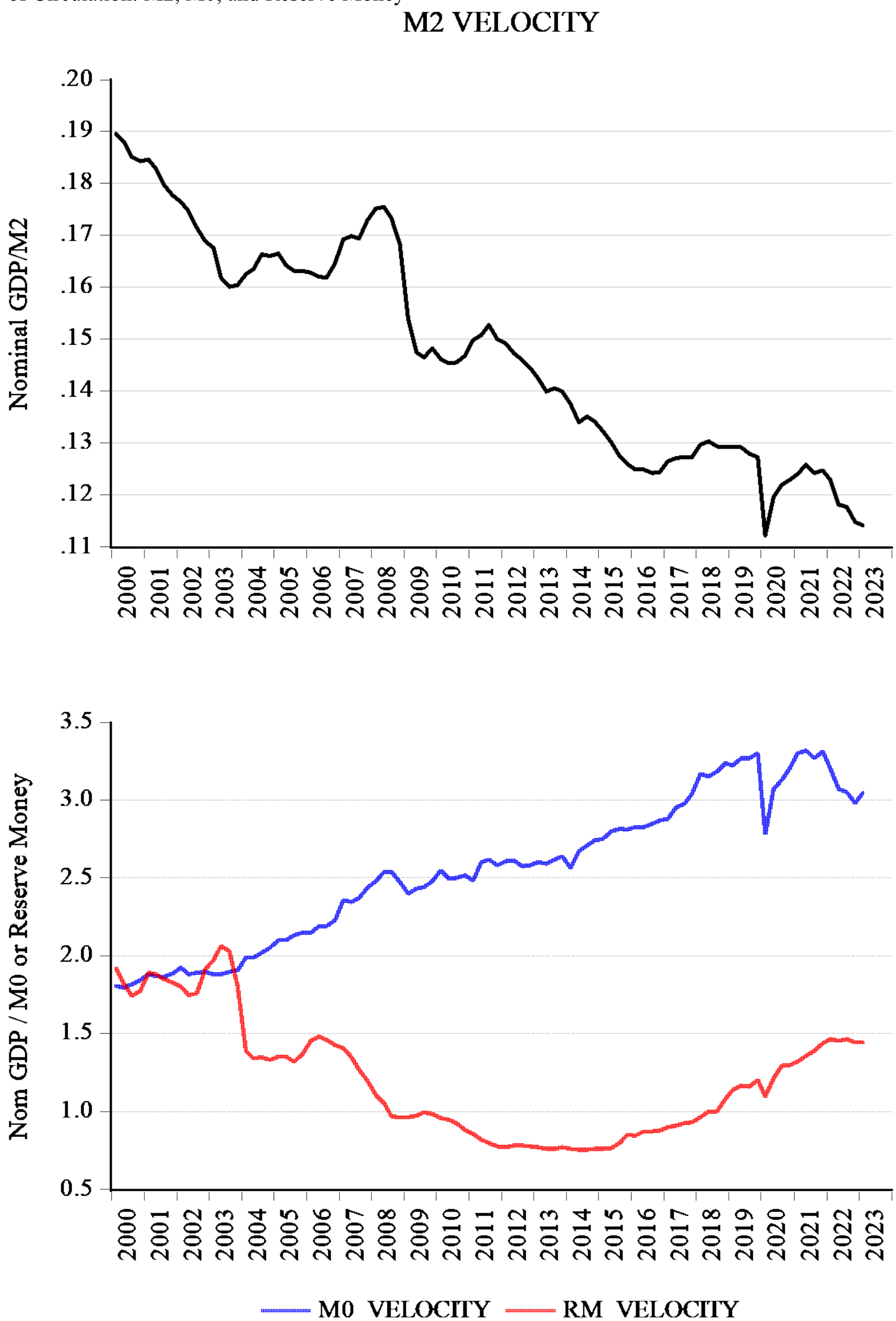


Difference Taylor Rule

$$\Delta i_t = \beta_0(\pi_t - \pi_t^{IT}) + \beta_1 \Delta y_t^{gap} + \zeta_t$$

None of the estimates improved on the above, whether or not a structural break was allowed, nor when Markov Switching versions were estimated. Accordingly, none are shown.

Figure A12 Varieties of Estimates of the Velocity of Money
Velocity of Circulation: M2, M0, and Reserve Money



Modified McCallum Rule (Razzak, 2003; Meltzer, 1998; Lucas, 1988; Stock and Watson, 1993).
Step 1: Establishing stability of Velocity

$$\Delta V_t = f(\Delta i_t) + \varphi_t$$

Step 2: Calculating or Estimating Modified McCallum rule.

$$\Delta i_t = (\overline{\Delta V}_t - (1 + \lambda_{\Delta x})(\overline{\Delta x} - \Delta x))/k \text{ (calibrated)}$$

$$\Delta i_t = \varphi_0 + \varphi_1 \overline{(\Delta V/k)}_t - \varphi_1(\overline{\Delta x} - \Delta x)/k \text{ (estimated)}$$

Table A10 Estimates of the Velocity Equation in McCallum's Modified Rule

Step 1:

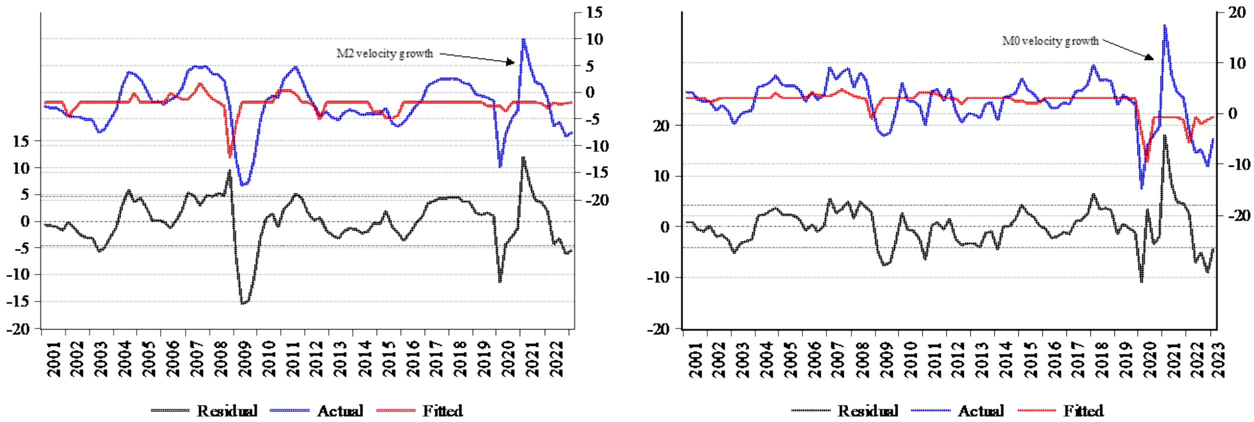
Dependent Variable: DLM2X_VELOCITY
Method: Least Squares with Breaks
Sample (adjusted): 2001Q1 2023Q1
Included observations: 89 after adjustments
Break type: Bai-Perron tests of L+1 vs. L sequentially determined breaks
No breakpoints selected
Selection: Trimming 0.10, Max. breaks 1, Sig. level 0.05
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.970	0.766	-2.573	0.012
DPR	6.754	2.897	2.332	0.022

R-squared	0.106	Mean dependent var	-2.137
Adjusted R-squared	0.096	S.D. dependent var	4.807
S.E. of regression	4.571	Akaike info criterion	5.900
Sum squared resid	1817.815	Schwarz criterion	5.955
Log likelihood	-260.531	Hannan-Quinn criter.	5.922
F-statistic	10.334	Durbin-Watson stat	0.612
Prob(F-statistic)	0.002		

Neither M0 (2019Q4) nor Reserve Money (2015Q1) were stable (structural break timing shown in parenthesis. It is interesting to contrast the residuals for the M2 and M0 cases (note that the M0 version incorporates the correction for a break in 2019Q4):

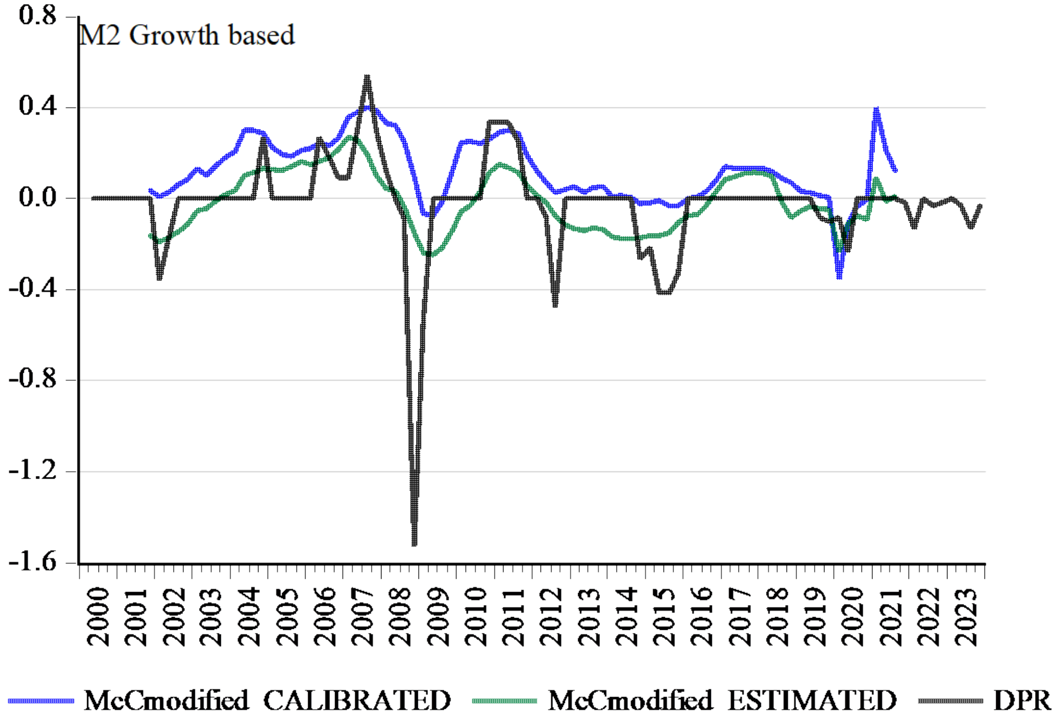
Figure A13 The Performance of the Velocity Equation in McCallum's Modified Rule



Step 2: The estimated regression, assuming k=50 (as in Razzak, 2003) and a three year moving average of velocity (McCallum and Razzak used 4 years but the results don't change even if I use a 2 year moving average. The consequence is, of course, a loss of observations/degrees of freedom) is shown although the cases where k=1 (-.01), 10 (-.16), and 25 (-0.39) were also estimated (with the estimated coefficient on the deviation from target growth GDP shown in parenthesis; all were highly significant as in the case used and shown below).

The first graph shows the various estimates of the change in the policy rate using the modified McCallum rule. The second graph shows the same results but now in terms of the levels of the policy rate which is obviously easier to interpret. Note that taking moving averages for velocity shortens the sample. Nevertheless, we have results for the early part of the pandemic. If I reduce the span of the moving average calculations to 8 quarters, both McC modified rules approach the observed policy rate more closely.
I also tested for a structural break (maximum of 2) and found that there are no breaks.

Figure A14 Fitted Values for Alternative Versions of McCallum's Modified Rule



Does the modified McCallum rule encompass the Taylor rule?

We use a version of the Chong and Hendry (1986) and Fair and Shiller (1990) test written as:

$$i_t = \psi_0 + \psi_1 i_t^{Mc} + \psi_2 i_t^{TR}$$

Where Mc is a modified McCallum rule (either the calibrated or estimated versions shown above) and TR is one of the Taylor rule results shown above.

Estimates of this equation suggest that, in none of the variations considered, does the McC rule encompass TR and the same is true in reverse except for TR3 inertia versus both versions of the McCallum modified rule and TR5inertia for the calibrated McCallum rule. All p-values for the tests are low so the rejection is clear. In general, the estimated modified McCallum rule performs better based on the encompassing metric than the calibrated McCallum rule. This implies that a hybrid policy rule may improve our understanding of PBOC monetary policy.

The Table below gives the p-values for whether the TR encompasses the McC rule, and vice-versa. A low p-value means that one rule does *not* encompass the other. If we use a threshold of 0.10 then there is some evidence that TR encompasses the McC rule but there are only 3 of 24 cases where tis happens. Hence, there is no strong evidence that one MP rule encompasses the other.

Hybrid policy rule

As I am sure you know there have been attempts to measure hybrid rules. As with all such rules there is some ad hoc element. Generally, there are ordered probit models that are used. I have specified a different formulation. First, I assume there are 4 different instruments, namely the policy rate, the real exchange rate, required reserve ratio, and a measure of aggregate credit. Next, I assume that a monetary policy indicator (MPI) is constructed on the basis of *changes* in the level of the policy interest rate, M2 growth, changes in the required reserve ratio, the rate of change in the nominal exchange rate, and changes in the total private non-financial credit to GDP ratio. The plot below shows the series as they are used to create the MPI (see below) while the next plot shows the newly constructed MPI.

To generate the MPI I followed the following steps:

(1) Estimate a factor model.[1]
(2) Finally, I re-estimated policy rules like the ones above using the newly constructed MPI as a replacement for the TR or McC rules.

The factor loadings were estimated using the Bai-Ng (average of their criteria, there are 6 of them) method to estimate the number of factors. Since the series (see above plot) are stationary no additional transformations (i.e., no demeaning only time-standardization was carried out). In all cases considered one factor was sufficient implying that a single linear combination of the 4 instruments is adequate to define an MPI.

Interpretation of the factor loadings is as follows:

(a) A rise in PR_D raises the MPI. This ought to make sense since this indicates that a rise in the policy rate (i.e., PR_D is positive) is equivalent, ceteris paribus, to a tightening of monetary policy. Note that the sign appears counter-intuitive for the 2015-2019 period. Between 2015Q4 and 2019Q2 the PR does not change.
(b) The same interpretation holds for a rise in the RRR. See also the NOTE made in part (a).
(c) A depreciation in the exchange rate or, here, a positive growth in the real exchange rate implies a loss of competitiveness. The PBoC might respond by *loosening* monetary policy which would translate into a decline in the MPI and, therefore, a negative loading.
(d) Given the definition of the credit variable a rise signals *looser* credit conditions which is also consistent with a *looser* MP.
(e) A rise in M2 growth ought to signal a loosening of MP.

When the full sample is considered, the signs are correct for all the factor loadings except for M2 growth and credit growth. However, the size of these two loadings is considerably smaller than for the PR and RRR.

[1] I also thought of estimating the factor model by converting the instrument series shown above into normalized form (i.e., min = 0, max = 1) thinking that the results would be easier to interpret. There is the implicit assumption made that all instruments are equally important at all times, and this is likely an implausible assumption. Accordingly, I dropped this approach though I have kept the results. I also tried a time-varying factor model but this did not improve the results nor did they appear more plausible.

What matters most is whether the episodes of tightening and loosening shown in the plot above make sense given what we know about the stance taken by the PBoC over time.

What follows are selected estimates of the policy rules of the form:

$$MPI_t = \delta_t + (1-\delta_t)(\gamma_1\tilde{\pi}_t + \gamma_2\tilde{y}_t + \Gamma' Y_t) + \eta_t$$
$$MPI = \rho MPI_{t-1} + (1-\rho)MPI_t^{\rho}$$

$\delta_t = 0, \Gamma' = 0$; no inertia case;
$\delta_t \neq 0, \Gamma' = 0$ inertia case ;
$\delta_t \neq 0, \Gamma' \neq 0$ inertia and extended case.

The foregoing rules are identical to the earlier estimated TR except that; (1) *MPI* replaces *i* as the dependent variables, and (2) *Y* only consists of the shadow fed funds rate since the other variables previously considered are now used to create the MPI.

Rather than show a large number of results I have selected 2 results because they seem plausible and fit the MPI data best. The first allows for a structural break, the second one is a Markov switching model together with the estimated probabilities of being in the first regime.

Table A11 Estimates of China's Hybrid Monetary Policy Rule with Structural Breaks

Dependent Variable: MPI_20012023
Method: Least Squares with Breaks
Sample (adjusted): 2001Q2 2023Q1
Included observations: 88 after adjustments
Break type: Bai-Perron tests of L+1 vs. L sequentially determined breaks
Break: 2009Q2
Selection: Trimming 0.10, Max. breaks 1, Sig. level 0.01
HAC standard errors & covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0000)

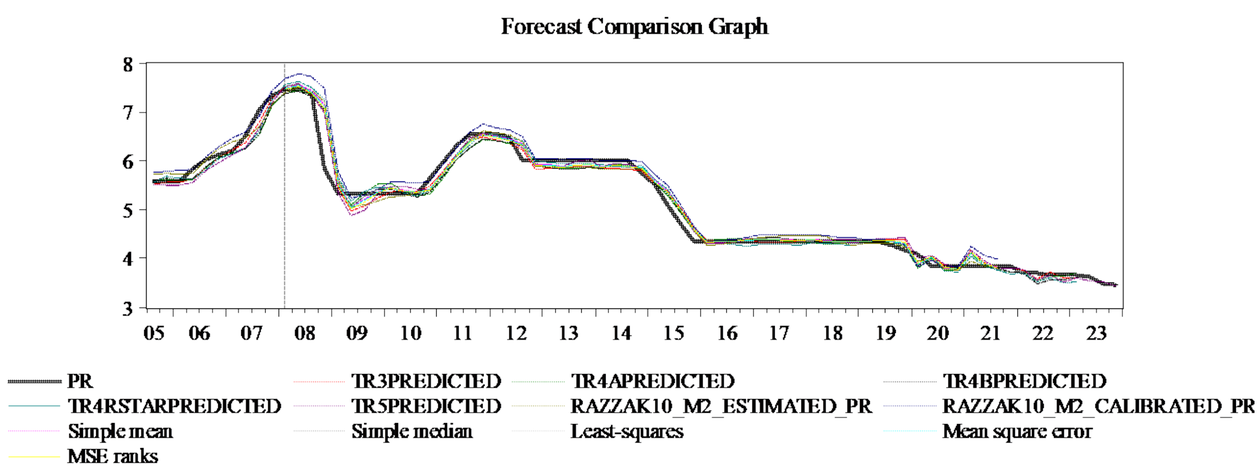
Variable	Coefficient	Std. Error	t-Statistic	Prob.
2001Q2 - 2009Q1 -- 32 obs				
C	-0.215	0.192	-1.118	0.267
CPI_BIS_G-INFLATION_TARGET	0.263	0.113	2.319	0.023
OUTPUT_GAP_PROXY	0.386	0.092	4.180	0.000
MPI_20012023(-1)	-0.385	0.257	-1.497	0.138
2009Q2 - 2023Q1 -- 56 obs				
C	0.022	0.137	0.162	0.871
CPI_BIS_G-INFLATION_TARGET	0.023	0.074	0.306	0.760
OUTPUT_GAP_PROXY	0.063	0.027	2.378	0.020
MPI_20012023(-1)	0.605	0.082	7.371	0.000
R-squared	0.677	Mean dependent var		-0.000
Adjusted R-squared	0.649	S.D. dependent var		0.853
S.E. of regression	0.505	Akaike info criterion		1.559
Sum squared resid	20.424	Schwarz criterion		1.784
Log likelihood	-60.599	Hannan-Quinn criter.		1.650
F-statistic	24.000	Durbin-Watson stat		1.869
Prob(F-statistic)	0.000			

The last exercise I conducted is to make a selection of TR, McC, and hybrid rules and conduct some "forecast" comparisons. Although I could have selected a very large number of them, I've restricted my attention to a total of 9 for various reasons (i.e., they are all shown above).
The selected forecasts are: TR3, TR4a, TR4b, TR4r*, TR5, McC estimated and calibrated, MPI3, MPI5, MPI5a. All are shown earlier in detail. One difficulty is that it seems impossible to 'convert' MPI into PR equivalents (i.e., we can't really say that, for example, a 0.10 change in MPI translates into a 25bp change in the PR. This is not surprising since MPI combines the effects of 4 different variables and, just as is true in the US and elsewhere, a change in the PR does not give a full indication of the change in a central bank's policy stance).
I also sub-divided the "forecast" test into 2 parts, namely to ask how well the selected policy rules forecast actual PR before and since the GFC (before is defined as 2001Q1-2007Q4; after is the remainder of the sample beginning with 2008Q1).

Post-GFC results

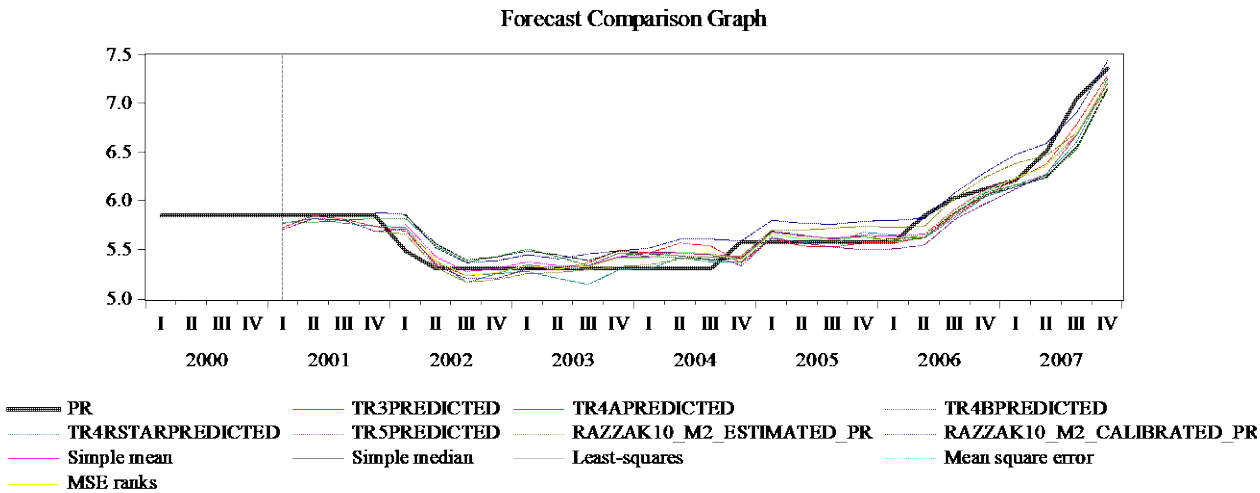
I will spare you the detailed statistics (see, however, the plot below) but TR5 performs best according to RMSE and MAE. The thick line is the variable to be forecast.

Figure A15 Forecast Comparisons of Alternative Policy Rule: Full Sample



Pre-Crisis TR3 performs best (RMSE=0.132; MAE 0.103). However, differences across models are not large).

Figure A16 Forecast Comparisons of Alternative Policy Rule: Pre-Crisis Sample



Below are the results for the MPI series.

It is not clear that one can compare the RMSE and MAE between the TR, McC and Hybrid models.
The plots are below. The variable being forecasted is the thick line.

Figure A17 Forecast Comparisons of Alternative Policy Rule: Pre-Crisis Sample

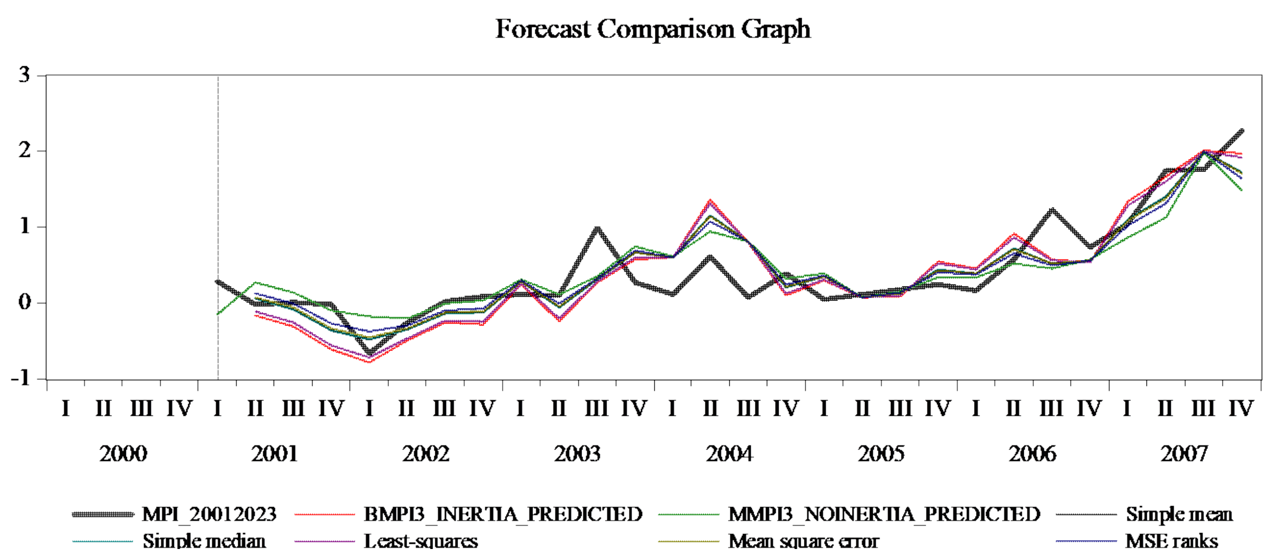


Figure A18 More Forecast Comparisons of Policy Rules: Post-Crisis

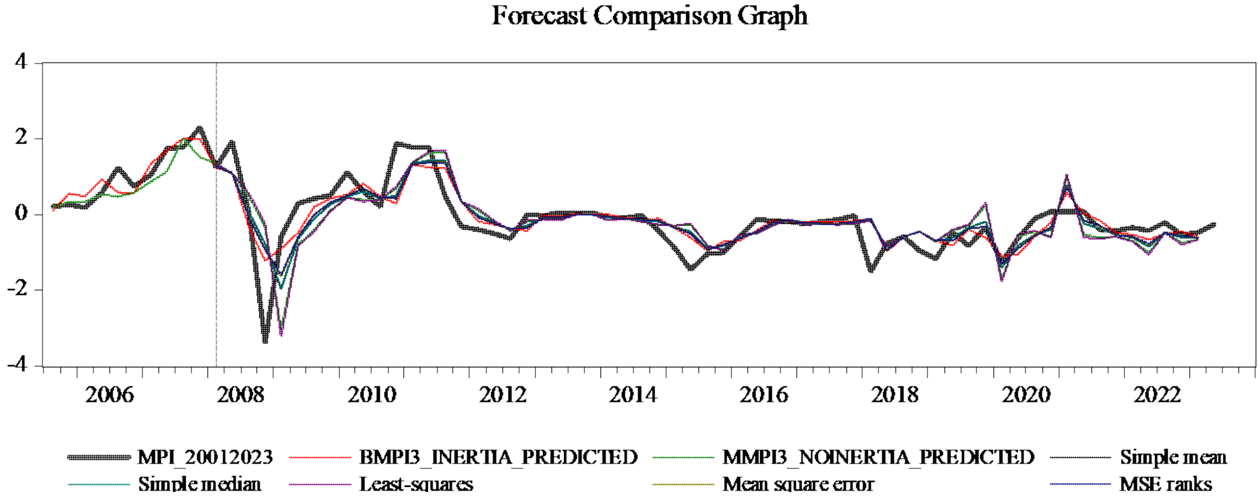
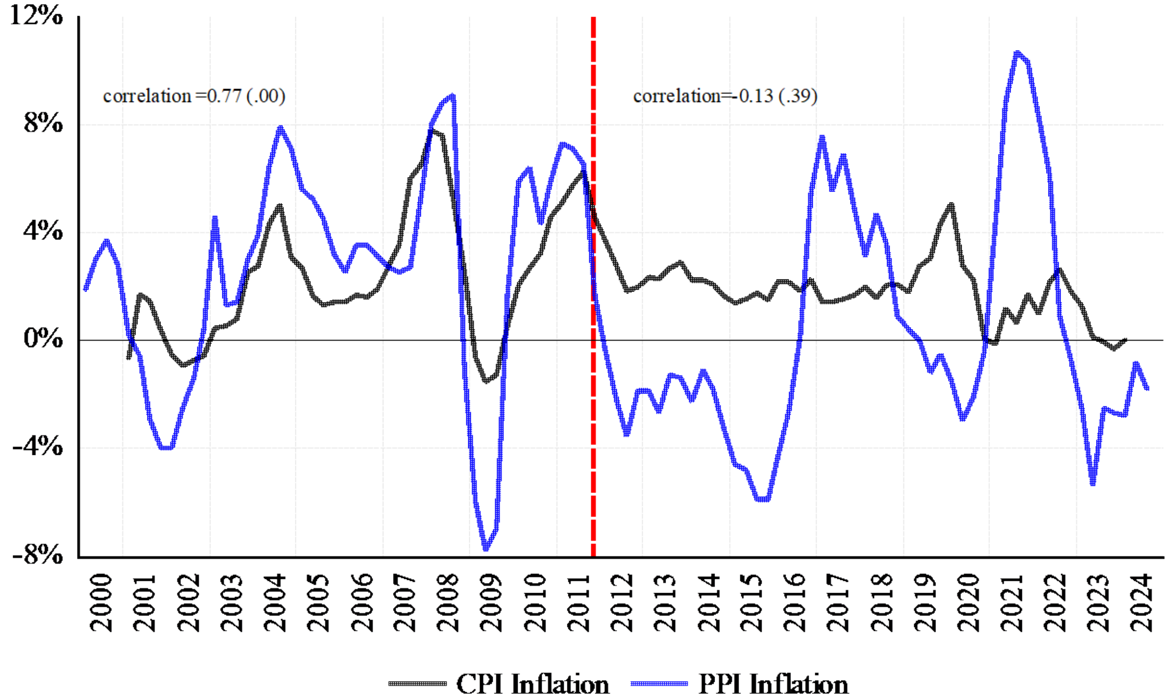
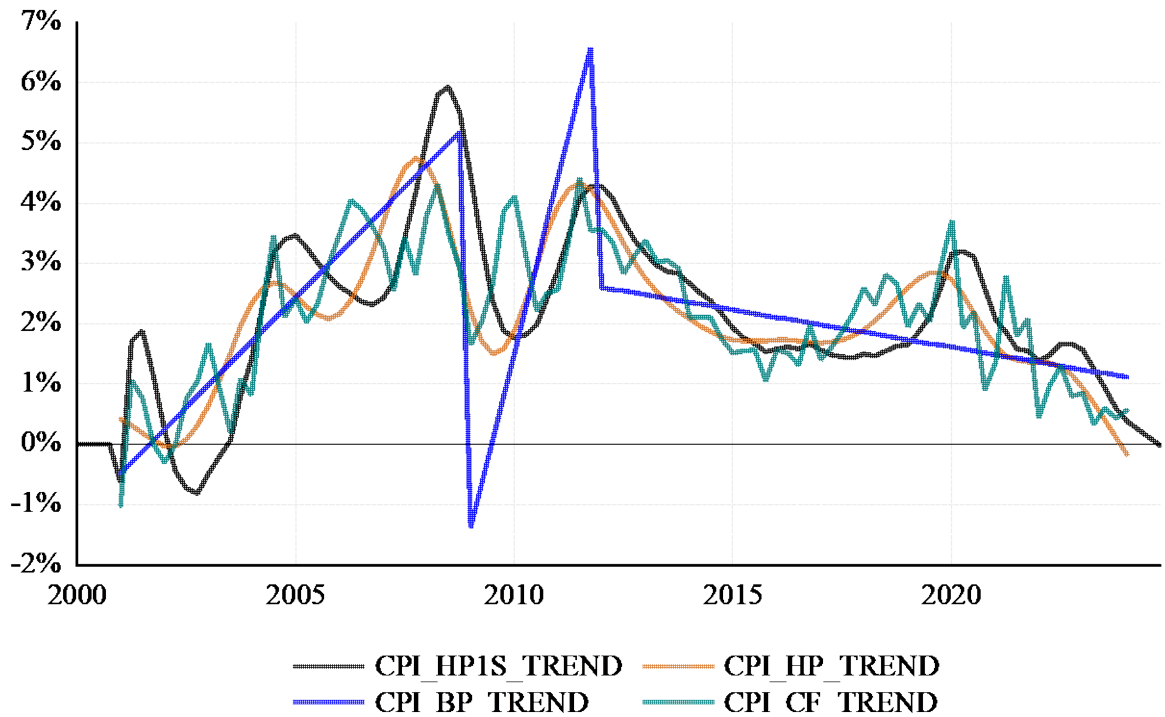


Figure A19 PPI vs CPI Inflation



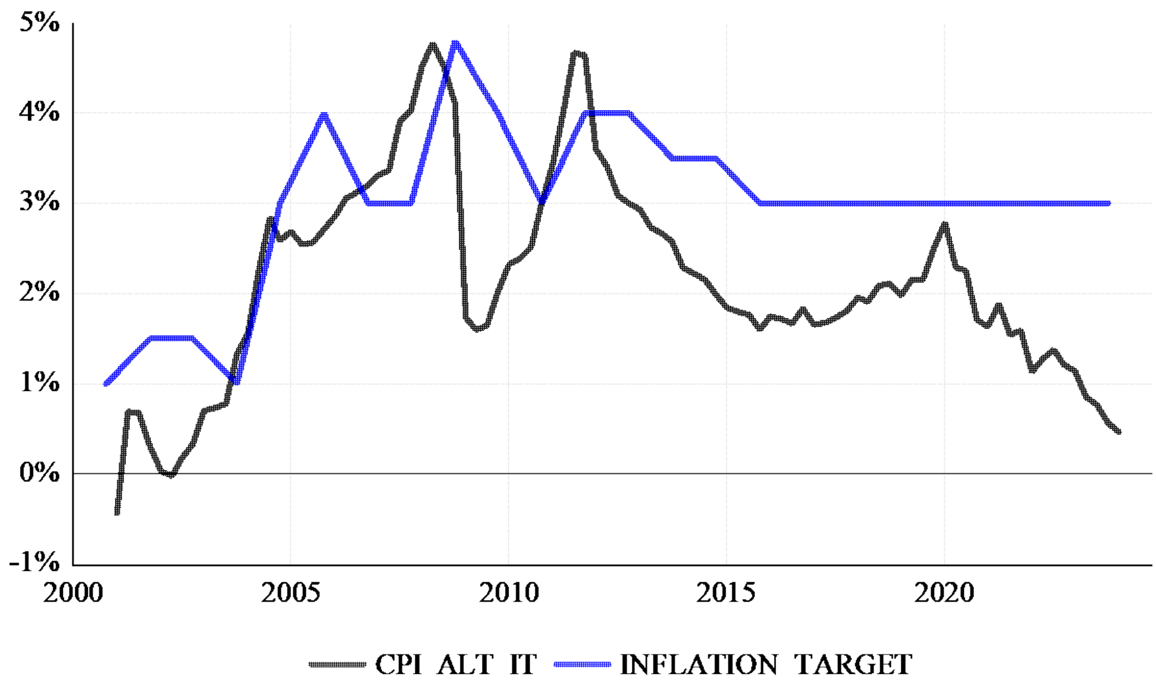
ADF test (1 lag, SIC)= -4.02 (.00), ADF Breakpoint test (5 lag, SIC) = -4.05 (.07). Unconditional correlation = 0.46 (full sample).

Figure A20 Alternative Estimates of China's Inflation Target



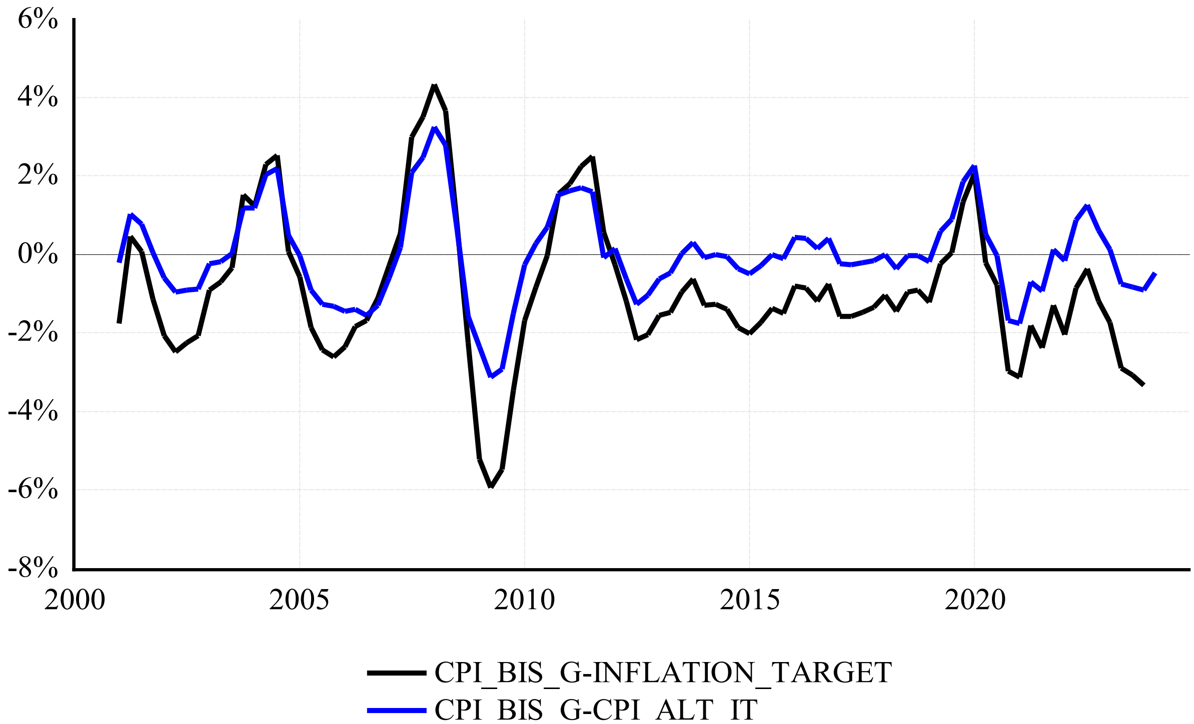
Note: HP1S is one sided HP filter; HP is HP filter; BP is Bai-Perron derived estimate; CF is Christiano-Fitzgerald filter. HP filter: Ravn-Uhlig, power =2, smoothing parameter = 1600, boosted using information criteria. HP1S is the one sided-filter, same specification as HP filter. CF is the full sample asymmetric filter where 8Q-20Q defines the business cycle frequencies. BP is the fitted value of a regression of inflation on a constant and a linear trend augmented with 2 structural breaks estimated with the Bai-Perron specification (Newey-West standard errors). Trimming was 5% and a p=0.01 us used to determine the location of structural breaks. The null of K+1 vs K breaks is specified.

Figure A21 More Alternative Inflation Target Estimates for China



Note: Inflation target: China's government sets an annual target for CPI YoY%, typically released in the Premier's Work Report at the National People's Congress in March. CPI_ALT_IT is the mean of estimates shown in the previous figure.

Figure A22 Alternative Estimates of the Inflation Gap for China



Note: Calculation details explained in previous two figures and in the main body of the paper.

Additional Markov Switching Estimates: Table A12

Dependent Variable: M2 growth rate
Sample (adjusted): 2001Q2 2023Q2

Variable	Coefficient		Std. Error		z-Statistic		Prob.	
Regime 1								
Constant	10.644	10.166	0.406	0.403	26.204	25.220	0.000	.000
Nominal GDP Gap	0.149	0.114	0.070	0.082	2.135	1.396	0.033	.163
Real Exchange Rate Growth	-0.018	-0.047	0.053	0.049	-0.339	-0.971	0.735	.331
Growth in RMB Foreign Exchange Reserves	0.168	0.164	0.021	0.021	7.877	7.874	0.000	.000
Regime 2								
Constant	17.769	13.632	0.395	0.710	44.954	24.907	0.000	.000
Nominal GDP Gap	0.707	0.760	0.099	0.146	7.170	5.211	0.000	.000
Real Exchange Rate Growth	-0.040	-0.005	0.047	0.048	-0.845	-0.094	0.398	.925
Growth in RMB Foreign Exchange Reserves	0.336	0.351	0.019	0.016	17.932	21.455	0.000	.000
Common								
CPI-PPI inflation gap		0.304		0.077		3.950		.000
Oil price inflation		0.032		0.014		2.320		.020
LOG(SIGMA)	0.563	0.484	0.072	0.066	7.804	7.395	0.000	.000
Transition Matrix Parameters								
P11 constant term	3.628	3.615	0.674	0.740	5.385	4.887	0.000	.000
P21 constant term	-1.714	-1.759	0.607	0.634	-2.821	-2.775	0.005	.001

Note: The black numbers are the original ones found in Table 1. The red numbers are for the case where the CPI-PPI inflation gap and oil inflation (both lagged one period) are added.

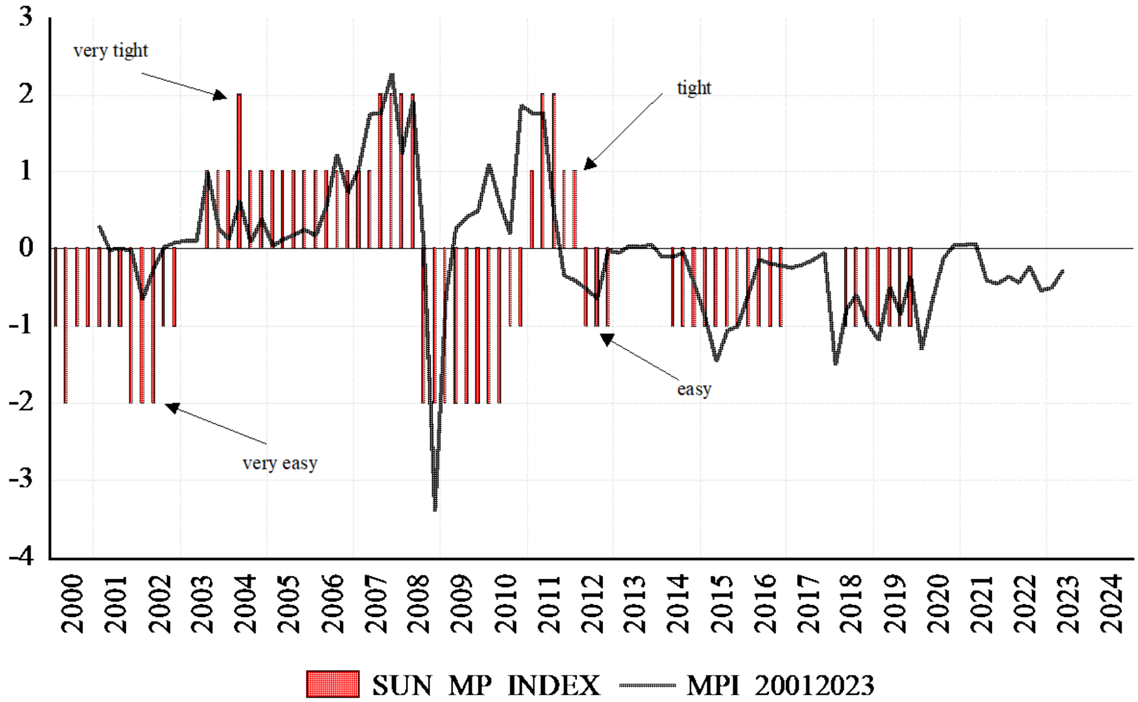
Additional Markov Switching Estimates: Table A13

Dependent Variable: Monetary policy index (MPI)
Method: Markov Switching Regression
Sample: 2001Q1 2023Q1
Number of Observations: 89

Variable	Coefficient	Std. Error	z-Statistic	Prob.
	Regime 1			
Constant	-0.055	0.183	-0.303	0.762
CPI Inflation Gap	0.666	0.129	5.154	0.000
Output Gap	0.214	0.064	3.353	0.001
	Regime 2			
Constant	0.260	0.080	3.241	0.001
CP Inflation Gap	0.121	0.041	2.952	0.003
Output Gap	0.144	0.020	7.101	0.000
	Common			
CPI-PPI inflation gap	-0.034	0.017	-1.976	0.048
Oil price inflation	-0.001	0.003	-1.907	0.057
LOG(SIGMA)	-0.944	0.122	-7.762	0.000
	Transition Matrix Parameters			
P11-C	0.705	0.801	0.881	0.378
P21-C	-2.348	0.537	-4.372	0.000

Note: This is the same set of estimates as Table 4 except that two common variables are added as determinants.

Figure A23 Comparison of Hybrid MP Stance (Figure 7) and Sun's (2018) Narrative Indicator



Sources: See main paper Figure 7 and Sun (2018).

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