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price-based policy?



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Contemporary monetary policy in China: A move towards price-based policy?

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Abstract

This paper focuses on monetary policy in China. A set of different specifications for the monetary policy reaction function are empirically evaluated using monthly data for 1999–2012. Variation is allowed both in the policy targets as well as in the monetary policy instrument itself. Overall, the performance of the estimated policy rules is surprisingly good. Chinese monetary policy displays countercyclical reactions to inflation and leaning-against-the-wind behaviour. The paper shows that there is a notable increase in the overall responsiveness of Chinese monetary policy over the course of the estimation period. The central bank interest rate is irresponsive to economic conditions during the earlier years of the sample but does respond in the later years. This finding supports the view that the monetary policy settings of the People's Bank of China have come to place more weight on price-based instruments. A time-varying estimation procedure suggests that the two monetary policy objectives are assigned to different instruments. The money supply instrument is utilised to control the price level and (after 2008) the interest rate instrument has been used to achieve the targeted output growth.

JEL Classification: E52, E58

Keywords: China, Monetary policy, Taylor rule, McCallum rule

1 Introduction

China's central bank, the People's Bank of China (PBC), states that the objective of its policy is 'to maintain stability of the value of the currency and thereby promote economic growth'¹. The central bank uses various instruments to achieve this objective. These include some unconventional instruments such as, the window guidance policy and the use of required reserve ratio as an active policy tool.

In conjunction with modernising and opening up a previously centrally planned economy, the conduct of monetary policy in China has experienced major changes. Interest rate liberalization is a fairly recent development in China. Therefore, one might assume that over time - with the emergence of the interest rate channel in the economy - the central bank interest rate will become a more effective policy instrument. The majority of the existing literature on Chinese monetary policy still finds the interest rate to be ineffective, and usually advocates the use of quantity-based instruments.

Typically, monetary policy reaction functions estimated for China take the form of traditional Taylor (1993) or McCallum (1988) rules. These rules are used to assess either the monetary policy stance over time or the effectiveness of the selected rule in achieving the ultimate goal of monetary policy. In this study, we address this issue from a different perspective. Rather than using a predetermined form of the policy rule, we concentrate on finding a specification of the central bank reaction function that is best supported by the data. This is done by empirically evaluating a variety of possible policy reaction functions with different policy instruments: price-based interest rate versus quantity-based money supply. We analyse the McCallum and Taylor rules as well as some hybrid rules combining their features. We estimate several different specifications in each of these categories taking into account the PBC's possible adherence to exchange rate stability.

Our study follows the approach of Patra and Kapur (2012) for India, Mehrotra and Sánchez-Fung (2011) for emerging market economies and Fan et al. (2011) for China. Our paper differs from Fan et al. (ibid.) in that we study a more recent period, include a wider variety of possible policy reaction functions, and utilize monthly data to obtain more observations. We focus mainly on the change in monetary policy responsiveness in China over time. The many market-based reforms successfully carried out during the recent decades afford presumptive evidence that central bank policy too has gone through a process of change. One question we are addressing is whether or not the economic progress in China has already reached a state where monetary policy can be credibly modelled using an interest rate as the policy instrument.

The paper proceeds as follows. The next section gives a theory review of monetary policy rules and a short summary of the most relevant recent empirical work. Section three briefly goes through the recent developments in China's monetary policy. The data are described in section four. Section five begins the empirical part of the paper by estimating the contemporaneous rules for China. In section six, we focus on changes in monetary policy reactions by estimating the policy rule parameters over time. The single-equation analysis is expanded in section seven to the analysis of vector autoregressive (VAR) models for the policy rules. Finally, section eight concludes.

2 Monetary policy rules

2.1 Theoretical review

The McCallum rule originates from the works of McCallum (1988, 2000) and is based on the idea that the central bank should adjust the nominal money supply in response to nominal output deviations from the desired path. In the event that nominal output grows at the desired target rate,

¹<http://www.pbc.gov.cn/publish/english/970/index.html>

money supply growth should equal the targeted nominal growth rate for the economy. The original rule (McCallum 1988, 2000) is

$$\Delta b_t = \Delta x^* - \Delta v_{t-1}^a + \lambda(\Delta x_{t-1}^* - \Delta x_{t-1}), \quad (1)$$

where Δb_t is the growth of monetary-base at time t and Δx_t and Δx_t^* are the log growth rates of actual and target nominal output, respectively. Δv_t^a denotes the average change in base-money velocity over the previous four years. This variable is included in the original rule to serve as a forecast for long-lasting regulatory and technological changes affecting the velocity of money over the foreseeable future. Parameter λ measures the strength of the feedback adjustment in response to departures of output from its target path. The value of λ should be positive if policy responses are countercyclical. For the U.S. economy, McCallum suggests a feedback parameter value of 0.5; for emerging economies, recent empirical studies find values of λ ranging from negative to higher than one (e.g. Mehrotra & Sánchez-Fung 2011; Patra & Kapur 2012).

Contrary to the McCallum rule, the Taylor rule (Taylor 1993) accounts separately for changes in real output and prices. The rule supposes that the central bank reacts to deviations of inflation from its target rate and real output from the long-run trend, using the steering rate i_t as the policy instrument. The original rule (Taylor 1993) was designed to reflect U.S. monetary policy of the late 1980s and early 1990s, and is specified as

$$i_t = (i^* + \pi_t) + 0.5\hat{y}_t + 0.5(\pi_t - \pi^*). \quad (2)$$

In (2), \hat{y}_t is the output gap at time t , measured as the log of real GDP less its trend, and $(\pi_t - \pi^*)$ is the excess of actual inflation over the target inflation rate. In the event that inflation and output are at their equilibrium values, the central bank steering rate *in real terms* corresponds to the equilibrium real interest rate i^* . Values other than 0.5 for the output and inflation gap coefficients have also been used frequently. The relative magnitudes of the coefficients reflect the tradeoff between central bank objectives: output versus inflation stabilization. For the 'Taylor principle' to hold, the overall coefficient for inflation should be larger than one. This assures the rule's stabilization properties: the steering rate should be increased in real terms in the event of rising prices.

One drawback in using the Taylor rule is that the current-period output gap cannot be observed. To overcome the measurement error problem in determining the trend or natural rate of output, some authors suggest that the original Taylor rule (2) should be specified in difference form. The estimated Taylor reactions in this paper are more in line with the following 'difference rule', proposed by Orphanides and Williams (2007):

$$i_t = (1 - \gamma_i)(i^* + \pi_t) + \gamma_i i_{t-1} + \gamma_y(\Delta y_t - \Delta y_t^*) + \gamma_\pi(\pi_t - \pi^*). \quad (3)$$

This formulation takes into account policy smoothing behavior in the lagged policy instrument with a weight $0 \leq \gamma_i < 1$.

McCallum (2000) argues that there is no apparent reason for the policy instruments and target variables to be paired in any particular combinations. The hybrid rules, then, can be expressed as

$$\Delta b_t = \Delta x^* - \Delta v_t^a - 0.5[\hat{y}_t + (\pi_t - \pi^*)] \quad \text{and} \quad (4)$$

$$i_t = (i^* + \pi_t) - \delta(\Delta x_{t-1}^* - \Delta x_{t-1}). \quad (5)$$

In (5), the parameter $\delta > 0$ is the policy feedback parameter, similar to λ in (1) but now measuring the strength of adjustment in the interest rate. Already Taylor (1979) specified an optimal policy rule in terms of responses to the inflation and output gaps in the nominal money supply similar to (4). Hall and Mankiw (1994) introduced the concept of 'hybrid target' for monetary

policy. In equation (4) this is the last term in square brackets. McCallum and Nelson (1999) find that for U.S. data from the mid-1950s to the mid-1990s nominal income targeting with a type of hybrid McCallum and Taylor rule (5) performs reasonably well.

While the Taylor rule has gained prominence in contemporary macroeconomics, quantity-based rules have been shown to be successful in describing monetary policy in certain environments. These include emerging markets, where the market environment is less developed (see Taylor 2001), as well as in situations where the interest rate rule is problematic because of its zero lower bound limit (see McCallum 2003).

2.2 Previous results on emerging markets

Patra and Kapur (2012) evaluate the empirical performance of McCallum and Taylor rules, as well as the two hybrid rules for India. The authors also estimate forward-looking formulations of the rules and find that the forward-looking versions do outperform contemporaneous and backward-looking rules in the Indian context.

Mehrotra and Sánchez-Fung (2011) estimate the Taylor and McCallum rules as well as hybrid rules for 20 emerging economies. Their country set, however, does not include China. For the 14 inflation-targeting economies, the authors find that the hybrid McCallum-Taylor specification is superior to the traditional Taylor rule, whereas the results are mixed for the six monetary or exchange rate targeting economies.

In a preceding paper Mehrotra and Sánchez-Fung (2010) estimate a hybrid McCallum-Taylor policy reaction function for China for 1994–2008. Using vector autoregressions, the study finds a stabilizing monetary policy reaction to the output gap, but in terms of the inflation gap the policy reaction is procyclical. The analysis is also extended to allow reactions to expected future inflation by adding a survey-based inflation-expectations metric to the estimation. This results in a restrictive policy response to increases in inflation expectations, while responses to both the inflation and output gaps are procyclical.

Following a similar method, Fan et al. (2011) estimate a Taylor rule and a ‘generalized McCallum rule’ (similar to the hybrid McCallum-Hall-Mankiw rule in our analysis) for China. The overall finding is that the rules are able to capture monetary policy responses to the inflation gap and output gap, but the magnitude of responses is much smaller than the ones observed for market economies. In addition to fixed coefficient models, time varying coefficients are also estimated. The time-varying models are found to better describe the behaviour of policy instruments in 1992–2009. The time varying coefficients for the inflation gap in the Taylor rule, however, show no permanent change over the estimation period.

Our paper extends the study of Fan et al. (2011) by analysing also the nominal policy rules sometimes claimed to be more appropriate for emerging economies. We also study a more recent time period in which the monetary policy environment has become more market-oriented. In addition, our study utilizes monthly data frequency, allowing for more observations.

There are few other papers exploiting monetary policy rules to study the recent monetary policy in China. Burdekin and Siklos (2008) study whether Chinese monetary policy can be modelled using a McCallum-type rule. Also Koivu et al. (2009) estimate a McCallum rule for China and find it to contain information that is useful in inflation forecasting. Taking a somewhat different approach, Zhang (2009) compares the performance of quantity- and price-based rules for China in a New Keynesian DSGE model framework. His findings indicate the Taylor rule to be more effective for managing the Chinese economy and to lead to a reduction in inflation and output fluctuations.

3 Monetary policy in China

Unlike the central banks in many advanced economies, the PBC does not operate in a single-instrument environment, nor in an inflation-targeting framework. Instead, the PBC uses a variety of policy instruments including both price-based as well as quantity-based and administrative policy measures. The policy is formally aimed at two main objectives: economic growth and stable prices. In addition to domestic price stability, the PBC also deals with exchange rate stability. Monetary policy in China also has fiscal goals, such as job creation and providing financial support for different sectors or areas.

Monetary policy is implemented in conjunction with the annual economic development targets set by the National Development and Reform Commission. Explicit targets are set for inflation and GDP growth. In addition, an annual target for the broad money (M2) growth is set as the predominant intermediate policy target. The PBC claims that by controlling money growth it can ‘promote economic growth positively and contribute to preventing both inflation and deflation’ (PBC 2005).

Deepening of the economic and financial reforms in China in recent years has created a need for a more market-oriented monetary policy framework. Until 1997, the PBC controlled credit and money directly, and monetary policy was mainly implemented through credit plans. An indirect policy management framework was adopted in 1998, and a reserve requirement ratio, open market operations and central bank lending have been introduced as the main policy tools.

The PBC has gradually developed price-based monetary tools such as interest rates. The central bank sets a series of benchmark interest rates, including rates on required and excess reserves, rediscounting rate and benchmark deposit and lending rates of different maturities. Interest rate policy is still under development in China and, for example, there is no short-term rate to anchor policy expectations. The PBC benchmark deposit and loan rates are currently considered the main policy interest rates in China.

The financial system liberalization has also added to the demand for a more price-based policy. The market-based interest rate reform started with money and bond market rates, which were largely liberalized in 1996–1998. The banking sector retail rate liberalization, however, has proceeded more gradually. Banks have been allowed to adjust interest rates offered to their customers within a limited band around the PBC benchmark deposit and lending rates. The ceiling for commercial bank lending rates and the floor for deposit rates were abolished in 2004. The floating bands within which banks can set their retail lending and deposit rates have also been gradually widened.

A prominent feature of the PBC’s monetary policy over the estimation period has been the exchange rate controls. The Chinese yuan has been more or less directly pegged to the U.S. dollar from 1995 to 2005 and again during the financial crisis in 2008–2010. Capital controls, however, are considered to have been largely binding during the period of controlled exchange rates, which renders the monetary policy to be utilized at domestic purposes. After 2010, the PBC has reduced the volume of forex interventions and increased exchange rate flexibility.

4 Data

We use monthly data for the period 1998m1–2012m10. Sample selection is based on the timing of the market-based reforms in China. Year 1998 marks the start of the fifth phase of economic reforms, in which monetary policy underwent significant changes. These include the abolishment of credit plans and adoption of open market operations. The dual-track exchange rate system had been abandoned in 1994. In addition, our sample period leaves out the most volatile periods of Asian financial crises. All the data are from Thomson Datastream, Bloomberg or People’s Bank of China websites (www.pbc.gov.cn). A list of utilized data series and their original sources is given

in Appendix 1.

The policy instruments considered are nominal interest rate and annual growth rates of the monetary aggregates: base money (reserve money) and broad money (M2). The interest rate variable is the official PBC one-year benchmark lending rate.² For a measure of base money, we use the data series 'reserve money' from IMF International Financial Statistics.³

We use a number of different formulations for the monetary policy target variables. Two inflation measures are used: consumer price index (CPI) and corporate goods price index (CGPI). Inflation rates are percentage changes in the corresponding price indices from the same month of the previous year. Inflation gaps are calculated by removing the Hodrick-Prescott-filtered trend from the inflation series. In addition, the official target CPI growth rate, annually set by the Central Economic Working Conference, is used in calculating inflation deviation from targeted rate. Mehrotra and Sánchez-Fung (2010) also use official CPI targets to derive the inflation gap. Consumer price inflation deviation is the actual inflation less the official target rate. For CGPI inflation, the target growth rate is calculated from the official CPI growth target, and the deviation from target is derived accordingly.⁴

In calculating the output gap in China, we use the monthly industrial production index. Annual output growth is based on the industrial production index, adjusted for the Chinese New Year.⁵ Following Mehrotra & Sánchez-Fung (2010), the output gap is defined by applying the Hodrick-Prescott filter to annual growth rates of industrial production. Output growth deviation from the target rate, obtained from the official GDP growth target announced by the Central Economic Working Conference, is used as an alternative measure of the output gap.⁶ Nominal output gap, which is needed in an analysis of McCallum-type rules, is derived similarly to the real output gap. The nominal annual output growth is the sum of real annual output growth and annual corporate goods price inflation. In the derivation of nominal output deviation from target, the target rate for nominal output growth is the sum of the targets for real output growth and CGPI inflation. The measures of the output and inflation gaps are compared in figure A2 in Appendix 2.

Broad money growth is the most prominent intermediate target for monetary policy in China. Therefore, the official target growth rate is added to the set of explanatory variables in the money growth instrument rules.⁷

The last group of monetary policy target variables includes the alternative metrics of the exchange rate. We utilize the trade-weighted real effective exchange rate (REER) and the nominal effective exchange rate (NEER). The exchange rate measure is the log change in the REER/NEER index from the same month previous year. We also account for the possibility that monetary policy reacts to exchange rate variations from the trend path itself. The exchange rate gaps are again

²PBC benchmark lending rates of other maturities, benchmark deposit rates and deposit and loan rates of personal housing provident funds are adjusted correspondingly together with the one-year benchmark lending rate.

³IMF's reserve money series represents currency in circulation as well as central-bank deposits of banks and other residents, excluding the central government.

⁴Target for CGPI inflation is derived from CPI growth target: $\pi^{*cgpi} = 1.65 \times \pi^{*cpi} - 1.40$. The constant and coefficient values are obtained by regressing actual CGPI inflation on actual CPI inflation.

⁵The January and February figures for industrial production are affected by the Chinese New Year, and since 2007 the Chinese National Bureau of Statistics has stopped publishing the industrial production figures for January. Throughout the sample, we adjust the data by using the average values for January and February in both of these months.

⁶The Central Economic Working Conference sets targets only for GDP growth. To obtain a target for industrial production growth, we first regress annual industrial production growth on GDP growth (using quarterly data for 1998q1 – 2012 q2). The results give: $\Delta IP = 1.33 \times \Delta GDP$. Target growth rate for industrial production is set to 1.33 times the official GDP growth target.

⁷For reserve money, no official growth target is announced. Broad money supply, by definition, equals the money multiplier (mm) times base money supply. To derive the target growth rate for reserve money, we utilize this relationship and express the reserve money growth target as $\Delta b_t^{*rm} = \Delta b_t^{*M2} - \Delta mm_t^{trend}$, where the last term is the Hodrick-Prescott trend growth rate in the money multiplier. This approach can be justified by the fact that the PBC states that regulating the base money supply enables it to meet its broad money target (PBC 2008).

calculated by removing the HP-filtered trend from the exchange rate series.

All the growth rates are calculated as year-on-year bases and are not seasonally adjusted. The utilized data series are depicted in figures A1 and A2 in Appendix 2. The summary statistics and unit root test statistics are given in table A2.

Lastly, we take into account the possibility that the responsiveness of the policy interest rate and money supply may be different in periods when reserve requirement ratio changes are actively used as a policy tool. We create a dummy variable to account for these periods. Detailed information about the dummy variable for reserve requirement ratio increases is given in Appendix 3.

5 Empirical estimation of the contemporaneous models

To provide a first glance at the performance of the different policy rules, we estimate the following set of contemporaneous policy reaction functions.⁸ These model formulations nest the original policy rules as presented in section 2.1.⁹

McCallum:

$$\Delta b_t^i = \alpha_0 + \alpha_* \Delta b_t^* + \alpha_x (\Delta x^* - \Delta x)_{t-1} + \alpha_e \Delta e_{t-1}^{neer} + \alpha_d d_t^{rrr} + \alpha_b \Delta b_{t-1}^i, \quad (6)$$

Hybrid McCallum-Hall-Mankiw:

$$\Delta b_t^i = \beta_0 + \beta_* \Delta b_t^* + \beta_\pi (\pi^* - \pi)_t + \beta_y (\Delta y^* - \Delta y)_t + \beta_e \Delta e_t^{reer} + \beta_d d_t^{rrr} + \beta_b \Delta b_{t-1}^i, \quad (7)$$

Taylor:

$$i_t = \gamma_0 + \gamma_\pi (\pi - \pi^*)_t + \gamma_y (\Delta y - \Delta y^*)_t + \gamma_e \Delta e_t^{reer} + \gamma_d d_t^{rrr} + \gamma_i i_{t-1}, \quad (8)$$

Hybrid McCallum-Taylor:

$$i_t = \delta_0 + \delta_x (\Delta x - \Delta x^*)_{t-1} + \delta_e \Delta e_{t-1}^{neer} + \alpha_d d_t^{rrr} + \delta_i i_{t-1}. \quad (9)$$

In the original literature, McCallum (1988) specified the model to react to variables that prevailed in the previous period, whereas in Taylor's work the policy reactions are specified taking into account the current period variables. Therefore the lag structure differs somewhat as between the model specifications.

In (6) and (7), index i refers to the two monetary aggregates considered: reserve money (rm) and broad money ($M2$). Throughout the estimations, the two measures of nominal and real output gaps, $(\Delta x - \Delta x^*)$ and $(\Delta y - \Delta y^*)$, respectively, are considered: HP-filtered series and output growth deviation from the target rate. Similarly, the same measures of the CPI and CGPI inflation gaps $(\pi - \pi^*)$ are taken into account. Note that all the models are specified so that the parameters for output and inflation gaps are assumed to be positive. In other words, one would expect expansionary monetary policy at such times when growth falls behind the long run target value. The nominal (real) exchange rate measure is used in the policy rules specified for nominal (real) variables. As an alternative measure for exchange rate change (Δe) , the exchange rate gap term (\hat{e}) is tested in all the estimations. Policy smoothing behavior is accounted for by the lagged value of the policy instrument. All reactions are estimated using ordinary least squares estimation.

Tables 1–4 present the estimation results of 'contemporaneous' formulations. This means that in the McCallum (table 1) and hybrid McCallum-Taylor (table 4) rules, the estimations are conducted

⁸The robustness of the results is also examined by estimating backward-looking versions of equations (6)–(9). In the backward-looking specifications a maximum of 12 lags is allowed for all dependent variables. The results are in line with the contemporaneous estimation results presented. Detailed analysis of the backward-looking models are available from the author.

⁹McCallum (2002) finds that the performance of the rule does not depend on the velocity correction term. Therefore, and following other empirical studies on estimating monetary policy responses, the variable Δv^a is omitted in the empirical estimations of equations (1) and (4).

by using the previous-period values of the policy variables. In the Taylor rule (table 3) and the hybrid McCallum-Hall-Mankiw (table 2) reactions, monetary policy settings are assumed to take into account the current period variables. The exchange rate measure is included in the estimation if it is statistically significant. Similarly, the dummy variable indicating periods of rapid RRR increase (discussed in Appendix 3) is included, if it appears to be statistically significant. Interaction between the dummy variable and other target variables was also tested, but these effects were statistically insignificant in all the specifications.

In addition, the sample is divided into two sub-periods. The 'best' contemporaneous specifications are estimated also for the sub-periods. The data are divided into periods before and after 2007. The division is based on the CUSUM of squares test, which points to possible parameter instability during the period from end of 2006 to start of 2007 for money supply rules estimated on the whole sample period. To be able to compare the different rules, interest rate rules are also divided into the same sub-periods. The next section presents the rolling estimations of policy parameters and analyses of changes in the responsiveness of policy in more detail.

Turning to the estimation results, the contemporaneous McCallum rule reactions (table 1) clearly indicate the problematic nature of the reserve money measure. The reserve requirement ratio (RRR) increases that occur in times of policy tightening cause the reserve money aggregate to increase, contrary to its role as a stabilizing policy instrument (see Appendix 3 for details). Therefore, reserve money growth reacts negatively to nominal output deviation. Figures A3 and A4 in Appendix 3 confirm that RRR hikes have accelerated the reserve money growth at times when M2 growth has been slowing down. Not surprisingly, the dummy variable is also significant in the McCallum estimations for reserve money, but not for M2. Nonetheless, the dummy variable does not adequately account for the RRR's influence on reserve money.

Broad money, then, seems to be a more appropriate monetary aggregate for policy analysis, although it is not directly controllable by the monetary authority. The M2 aggregate is also the predominant intermediate target for the Chinese central bank. Indeed, the estimated McCallum rules for M2 perform remarkably well. The estimated reactions to nominal output deviation get the expected sign in all specifications. The long-run coefficient of nominal output deviation from trend is 0.40 – 0.60 for models 3 and 4 (table 1). These are close to the parameter values suggested in McCallum's work (0.25 to 0.50). It is interesting that in all specifications the target growth rate for money Δb^* is strongly significant, replacing the constant term in the estimated functions. The numerical value, nonetheless, is clearly less than one.

The hybrid McCallum-Hall-Mankiw rule is the other policy rule studied here, in which the money supply serves as the policy instrument. The estimation results presented in table 2 suffer again from the same problem as the McCallum rule results with the reserve money aggregate. In all the estimates of equation (7) for reserve money the coefficients of inflation are negative. On the contrary, in the models, where M2 is the policy instrument, the reactions to inflation gap are statistically significant and correctly signed. The magnitudes of the responses are also rather high. The long-run coefficients are around 1.40 for models 7 and 8. The second notable feature is that even with the broad money measure, the money supply seems not to react to the output gap. In the single occasion, where the output gap is statistically significant (model 9), the parameter estimate has a negative sign.

In Mehrotra & Sánchez-Fung (2010) the monetary base is used as the only money supply measure in estimating similar kinds of hybrid McCallum-Hall-Mankiw reactions. The findings are consistent with ours when reserve money is used as the policy instrument. Our results indicate, however, that broad money would be a preferable aggregate and, contrary to base money, the results for M2 are largely in line with theoretical assumptions. Our results are also broadly similar to those of Fan et al. (2011), who use the inflation rate, instead of the inflation gap, in their policy simulations. Taking into account the policy smoothing behavior, however, our estimations produce larger policy responses to inflation. This provides further evidence that the money supply has actually become

more responsive to inflation during the more recent estimation period.

The Taylor rule reactions are reported in table 3. The rules perform well in terms of the signs of the inflation deviation and output deviation terms. Both are positive, as expected. The parameter coefficients, however, are smaller than Taylor's suggested ones and thus violate the 'Taylor principle'. The long-run coefficients of the inflation gap are around 0.10 – 0.30 and for the output gap around 0.20 – 0.40. When the exchange rate gap is added to the contemporaneous equations, reactions to the inflation and output gaps become smaller and statistically less significant (see models 11 and 14). An interesting observation in the Taylor rule estimations is that the interest rate has become much more responsive to the inflation and output gaps in recent times (models 10 and 13). At the same time, the past interest rate level has become less important.

Mehrotra and Sánchez-Fung (2010) also investigate the possibility of using the interest rate as a policy instrument. They find that the Taylor rule does not provide an adequate description of monetary policy behavior in China during the sample period 1994–2008. In their estimated VAR model, the Taylor rule coefficient for the output gap is statistically insignificant, and the parameter estimate for the inflation gap is small in magnitude, although the sign suggests a countercyclical policy response. Comparing our Taylor rule estimation results to Mehrotra and Sánchez-Fung (*ibid.*) is interesting. For the latter sub-period, our results are quite different, suggesting a possible change in policy conduct. Moreover, our results for the inflation responses in the Taylor rule are in line with Fan et al. (2011), who also generally find a positive reaction to the inflation gap, but its magnitude is always less than one. Contrary to our findings, the output gap coefficient in Fan et al. (*ibid.*) is often not statistically significant. Our results show clear positive and significant reactions of the policy interest rate to the output gap, especially for the more recent time period.

Finally, table 4 presents the results of hybrid McCallum-Taylor rule estimations. The interest rate is here again the policy instrument, but policy reacts to nominal variables, as in to the McCallum rule. Generally, this specification of the Taylor rule also seems to fit the Chinese data well. Reactions to the nominal output gap are correctly signed and statistically significant at the 99% level, although the numerical values are again quite small. Comparison between sub-periods shows that the interest rate has started to react statistically significantly to nominal output deviations only in the more recent period. Also the magnitude of the response has increased. The long-run coefficients, accounting for the policy smoothing in models 16 and 17 are 2–3 times higher in the latter sub-period (0.14 and 0.12, respectively) compared to the previous period (0.05 and 0.06). Comparing the results from the two sub-samples in models 16–18, the same conclusion as for the Taylor rule can be drawn: The central bank interest rate has become more responsive to macroeconomic variables after 2006. These results indicate that Chinese monetary policy implementation is moving towards placing more weight on price-based policy tools. The next section further studies the behavior of policy reactions over time.

In line with the empirical policy rules literature, policy smoothing behavior is evident in all the specifications. The estimated interest rate reactions, however, show much stronger policy smoothing than the money supply reactions. In interpreting the results for interest rate rules, it should be borne in mind that the interest rate is rarely altered (the policy interest rate is depicted in figure A4 in Appendix 3), which may affect the results. Especially in some Taylor rule specifications, the AR-coefficient for the previous period value of interest rate is close to unity. In addition, the estimation results show that, overall, the inclusion of an exchange rate measure does not notably affect the results. This finding is in line with the previous literature.

Based on the estimated model specifications (not all presented), it can be concluded that, overall, there seems to be very little difference in whether the HP-filter or the official target rate is utilized in calculating the inflation and output gap measures. Further, the estimation results remain largely robust to the use of CPI or CGPI inflation measures. We rely on these findings in the remaining of this paper, and focus only on the HP-filtered gap series, when estimating policy rule parameters in a rolling window.

Table 1. Estimation results of contemporaneous McCallum rules.

Model	Model 1			Model 2			Model 3			Model 4		
	Whole sample	2000m7 -2006m12	2007m1 -2012m10	Whole sample	2000m7 -2006m12	2007m1 -2012m10	Whole sample	1999m1 -2006m12	2007m1 -2012m10	Whole sample	1999m1 -2006m12	2007m1 -2012m10
Δb_t^*	0.318*** [5.47]	0.163** [2.36]	0.468*** [4.71]	0.319*** [5.41]	0.174*** [2.43]	0.587*** [5.46]	0.165*** [4.79]	0.146*** [3.00]	0.222*** [3.87]	0.165*** [4.82]	0.167*** [3.24]	0.201*** [3.20]
$-\hat{x}_{t-1}$	-0.150** [-2.45]	0.024 [0.26]	-0.269*** [-2.98]	-0.153** [-2.06]	0.047 [0.46]	-0.515*** [-3.87]	0.093*** [5.10]	0.094*** [2.60]	0.102*** [4.26]	0.068*** [2.98]	0.082** [2.19]	0.075* [1.83]
Δe_{t-1}^{neer}	-	-	-	0.004 [0.06]	-0.042 [-0.61]	0.310** [2.44]	-	-	-	-	-	-
\hat{e}_{t-1}^{neer}	-	-	-	-	-	-	-	-	-	0.067* [1.80]	0.054 [1.20]	0.062 [0.84]
d_t^{rrr}	2.895*** [3.57]	4.380** [2.36]	2.776** [2.34]	2.893*** [3.54]	4.264** [2.28]	3.270*** [2.81]	-	-	-	-	-	-
Δb_{t-1}^i	0.648*** [11.61]	0.814*** [11.44]	0.516*** [5.73]	0.647*** [11.29]	0.801*** [10.73]	0.358*** [3.31]	0.841*** [25.51]	0.852*** [17.39]	0.798*** [15.47]	0.841*** [25.70]	0.832*** [16.13]	0.817*** [14.50]
\bar{R}^2	0.836	0.440	0.790	0.835	0.435	0.805	0.877	0.794	0.883	0.879	0.795	0.888
SIC.	5.250	4.850	5.624	5.284	4.900	5.597	3.017	2.781	3.359	3.028	2.813	3.409
LM-test	5.989*** (0.00)	2.421** (0.01)	3.264*** (0.00)	6.689*** (0.00)	2.922*** (0.00)	2.400** (0.01)	2.003** (0.03)	1.207 (0.29)	1.222 (0.29)	2.177** (0.02)	1.319 (0.22)	1.263 (0.27)

Notes: Table reports OLS estimates. t -values are given in square brackets. ***, ** and * denote 1%, 5% and 10% level of significance, respectively. Whole sample refers to period 1999m1-2012m10 for estimations using M2 and 2000m7-2012m10 for estimations using reserve money (RM). Variable description is given in table A1 in appendix. Variable Δb_{t-1}^i in the table denotes the lagged value of the dependent variable and Δb_t^* is the target growth rate for the corresponding monetary aggregate. The goodness of fit statistics are the adjusted R-squared, Schwarz information criterion (SIC) as well as Breusch-Godfrey Lagrange multiplier test for no serial correlation in residuals up to order twelve (p-value given in parenthesis).

Table 2. Estimation results of contemporaneous Hybrid McCallum-Hall-Mankiw rules.

Model	Model 5		Model 6		Model 7		Model 8		Model 9		
	Whole	2000m7	2007m1	Whole	Whole	1999m1	2007m1	Whole	1999m1	Whole	
time period	sample	-2006m12	-2012m10	sample	-2006m12	-2012m10	-2012m10	sample	-2006m12	sample	-2012m10
	Δb_t^{rm}	Δb_t^{rm}	Δb_t^{rm}	Δb_t^{rm}	Δb_t^{M2}	Δb_t^{M2}	Δb_t^{M2}	Δb_t^{M2}	Δb_t^{M2}	Δb_t^{M2}	Δb_t^{M2}
Δb_t^i	0.369*** [5.88]	0.177** [2.51]	0.739*** [6.26]	0.341*** [5.78]	0.185*** [4.75]	0.203*** [3.02]	0.264*** [3.42]	0.128*** [3.68]	0.163*** [4.77]	0.232*** [4.06]	
$-\hat{\pi}_t^{cpi}$	-0.601*** [-3.14]	-0.130 [-0.59]	-1.668*** [-4.82]	-	0.242*** [4.09]	0.255*** [2.83]	0.325*** [3.16]	-	-	-	
$-\hat{\pi}_t^{cgpi}$	-	-	-	-0.277*** [-2.98]	-	-	-	-	-	-	
$(\pi^* - \pi)_t^{cpi}$	-	-	-	-	-	-	-	0.210*** [4.08]	-	-	
$(\pi^* - \pi)_t^{cgpi}$	-	-	-	-	-	-	-	-	0.108** [2.59]	0.152*** [4.11]	
$-\hat{y}_t$	0.027 [0.25]	-0.051 [-0.28]	0.244 [1.66]	0.047 [0.42]	-0.029 [-0.68]	-0.048 [-0.76]	-0.023 [-0.37]	-	-	-	
$(\Delta y^* - \Delta y)_t$	-	-	-	-	-	-	-	-0.044 [-1.41]	-0.063** [-2.00]	-0.078* [-1.90]	
Δe_t^{reer}	-	-	-	-	-	-	-	0.038** [2.21]	-	-	
e_t^{reer}	-	-	-	-	0.063** [1.91]	0.078** [1.89]	0.011 [0.17]	-	-	-	
d_t^{rrr}	2.737*** [3.39]	4.525** [2.41]	2.022* [1.80]	2.66*** [3.24]	-	-	-	-	-	-	
Δb_{t-1}^i	0.600*** [10.02]	0.799*** [10.90]	0.277** [2.63]	0.629*** [11.17]	0.823*** [22.14]	0.798*** [14.29]	0.762*** [11.01]	0.855*** [24.44]	0.820*** [23.24]	0.765*** [13.63]	
\bar{R}	0.840	0.435	0.822	0.839	0.876	0.797	0.878	0.872	0.878	0.886	
SIC	5.26	4.90	5.504	5.263	3.08	2.84	3.49	3.107	3.038	3.381	
LM-test	5.485*** (0.00)	2.147** (0.03)	2.034** (0.04)	5.968*** (0.00)	2.081** (0.02)	1.243 (0.27)	0.988 (0.47)	2.045** (0.02)	2.262** (0.01)	1.502 (0.14)	0.763 (0.68)

Notes: Table reports OLS estimates. t -values are given in square brackets. ***, ** and * denote 1%, 5% and 10% level of significance, respectively. Whole sample refers to period 1999m1-2012m10 for estimations using M2 and 2000m7-2012m10 for estimations using reserve money (RM). Variable description is given in table A1 in appendix. Variable Δb_{t-1}^i in the table denotes the lagged value of the dependent variable and Δb_t^i is the target growth rate for the corresponding monetary aggregate. The goodness of fit statistics are the adjusted R-squared, Schwarz information criterion (SIC) as well as Breusch-Godfrey Lagrange multiplier test for no serial correlation in residuals up to order twelve (p-value given in parenthesis).

Table 3. Estimation results of contemporaneous Taylor rules.

Model	Model 10		Model 11		Model 12		Model 13		Model 14		Model 15	
	Whole sample	1999m1-2006m12	2007m1-2012m10	Whole sample	Whole sample	Whole sample	1999m1-2006m12	2007m1-2012m10	Whole sample	Whole sample	Whole sample	Whole sample
time period	i_t	i_t	i_t	i_t	i_t	i_t	i_t	i_t	i_t	i_t	i_t	i_t
constant	0.294*** [2.62]	0.333* [1.91]	0.589** [2.60]	0.345*** [3.36]	0.260** [2.50]	0.242* [1.97]	0.190 [0.77]	0.603*** [2.98]	0.218* [1.89]	0.126 [1.21]		
$\hat{\pi}_t^{cpi}$	0.011 [1.63]	0.000 [0.05]	0.023* [1.77]	0.011 [1.51]								
$\hat{\pi}_t^{cgpi}$	-	-	-	0.005 [1.50]								
$(\pi - \pi^*)^{cpi}_t$	-	-	-	-	-	0.015** [2.34]	0.004 [0.58]	0.025** [2.40]	0.011* [1.90]	-	-	-
$(\pi - \pi^*)^{cgpi}_t$	-	-	-	-	-	-	-	-	-	0.005* [1.66]	-	-
\hat{y}_t	0.020*** [4.57]	0.000 [0.07]	0.025*** [3.63]	0.011* [1.89]	0.020*** [4.46]	-	-	-	-	-	-	-
$(\Delta y - \Delta y^*)_t$	-	-	-	-	-	0.009*** [2.68]	0.002 [0.55]	0.021*** [3.43]	0.007*** [1.98]	0.010*** [2.88]	-	-
\hat{c}_t^{reer}	-	-	-	-0.013*** [-2.88]	-	-	-	-	-0.016*** [-4.65]	-	-	-
i_{t-1}	0.950*** [50.08]	0.941*** [30.69]	0.904*** [24.54]	0.940*** [55.33]	0.955*** [54.35]	0.955*** [49.10]	0.966*** [22.87]	0.892*** [28.25]	0.960*** [52.30]	0.973*** [57.35]	-	-
\bar{R}^2	0.957	0.912	0.960	0.957	0.957	0.956	0.913	0.961	0.961	0.955	-	-
SIC	-1.185	-1.801	-0.660	-0.851	-1.183	-1.169	-1.810	-0.745	-1.264	-1.153	-	-
LM-test (12)	1.764* (0.06)	0.078 (1.00)	1.225 (0.29)	1.250 (0.25)	1.653* (0.08)	1.810* (0.05)	0.060 (1.00)	1.181 (0.32)	1.253 (0.25)	1.800* (0.05)	-	-

Notes: Table reports OLS estimates. t -values are given in square brackets. ***, ** and * denote 1%, 5% and 10% level of significance, respectively. Whole sample refers to period 1999m1-2012m10. Variable description is given in table A1 in appendix. The goodness of fit statistics are the adjusted R-squared, Schwarz information criterion (SIC) as well as Breusch-Godfrey Lagrange multiplier test for no serial correlation in residuals up to order twelve (p-value given in parenthesis).

6 Rolling estimations

The estimation results in the previous section suggest that there is likely to be a change in the responsiveness of the monetary policy instruments over time. In this section, this change is studied in more detail. We estimate the different contemporaneous monetary policy response functions in a rolling window. We choose a four-year window (48 observations) to be able to timely detect any changes in policy conduct.¹⁰

In the rolling estimations we only consider the broad money (M2) aggregate, because of the problems with the reserve money aggregate (base money) discussed in the previous section. In order to make the results based on different monetary policy rules more comparable with each other, this section uses the HP-detrended consumer price inflation as the inflation measure¹¹ and real and nominal HP-detrended industrial production as the measure for output deviation. Similarly, the exchange rate measure is the HP-detrended nominal or real effective exchange rate gap. The equations estimated are as follows:

$$\text{McCallum} : \Delta b_t^{M2} = \alpha_*^l \Delta b_t^{M2*} - \alpha_x^l \hat{x}_{t-1} + \alpha_e^l \hat{e}_{t-1}^{neer} + \alpha_b^l \Delta b_{t-1}^{M2}, \quad (10)$$

$$\text{Hybrid McCallum-Hall-Mankiw} : \Delta b_t^{M2} = \beta_*^l \Delta b_t^{M2*} - \beta_\pi^l \hat{\pi}_t - \beta_y^l \hat{y}_t + \beta_e^l \hat{e}_t^{reer} + \beta_b^l \Delta b_{t-1}^{M2}, \quad (11)$$

$$\text{Taylor} : i_t = \gamma_0^l + \gamma_\pi^l \hat{\pi}_t + \gamma_y^l \hat{y}_t + \gamma_e^l \hat{e}_t^{reer} + \gamma_i^l i_{t-1}, \quad (12)$$

$$\text{Hybrid McCallum-Taylor} : i_t = \delta_0^l + \delta_x^l \hat{x}_{t-1} + \delta_e^l \hat{e}_{t-1}^{neer} + \delta_i^l i_{t-1}. \quad (13)$$

Parameter superscripts l refer to the different sub-periods. The first lag of the policy instrument is added to the right-hand-side to account for the policy smoothing behavior. Note that because of the original design of these rules (see section 2) the ‘Taylor-type’ rules (equations 11 and 12) employ the contemporaneous policy target variables, whereas the ‘McCallum-type’ rules (equations 10 and 13) use the first lags of these variables.¹²

The data for the rolling estimations start at 1998m1 and the first parameter estimate using the previous four-year data is for 2002m12. At each step of the estimation, the rolling window is moved one month forward and the parameter estimates, their standard errors, and other test statistics are re-estimated. Proceeding in this way to the end of the data sample, 2012m10, we get 119 different four-year windows for which the policy parameters are estimated.

In the rolling estimations, only data that are available at the time of the estimation are utilized in calculating the parameter estimates. This means that the Hodrick- Prescott-filtered gap series are recalculated at each estimation step. The HP-filtering is performed at each step using data starting from 1998m1 up to the end of the estimation period in question.¹³

Figure 1 presents the rolling McCallum rule (eq. 10) parameter estimates and their 90% confidence intervals. The broad money supply has reacted statistically significantly to the nominal output gap roughly during the period mid-2005 – 2007 and again from mid-2010 to the end of the

¹⁰ Also a five-year (60-month) rolling window is tested, and the results are in line with those for a four-year window.

¹¹ In addition, the robustness of the results is tested by selecting the corporate goods prices as the price measure. These results proved to be largely similar to those for the consumer price measure (see Appendix 4).

¹² The estimation results show that the dummy variable for frequent RRR hikes is not relevant in the rolling estimations. This is likely due to the fact that broad money (M2) supply is only moderately affected by the reserve requirement ratio changes. For further analysis between the relationship of RRR and broad money supply see Ma et al. (2013).

¹³ To study the robustness of this method, we have also carried out the rolling parameter estimations with data where the HP-filtering is conducted for the entire data sample prior to the rolling estimations. These estimation results (not presented here) are very similar to the ones with the rolling HP-filtering.

Table 4. Estimation results of contemporaneous Hybrid McCallum-Taylor rules.

Model	Model 16		Model 17		Model 18		
	Whole sample	1999m1–2006m12 i_t	Whole sample	1999m1–2006m12 i_t	Whole sample	1999m1–2006m12 i_t	2007m1–2012m10 i_t
constant	0.307*** [2.81]	0.319* [1.89]	0.193* [1.92]	0.165 [0.73]	0.465*** [3.83]	0.180 [0.75]	0.611*** [3.27]
\hat{x}_{t-1}	0.008*** [3.49]	0.003 [0.83]	0.011*** [2.89]	0.002 [1.14]	0.002** [2.04]	0.002 [0.30]	0.006* [1.87]
$(\Delta x - \Delta x^*)_{t-1}$	–	–	0.006*** [3.85]	0.002 [1.14]	0.010*** [4.00]	0.013 [0.19]	0.140** [2.43]
d_t^{rrr}	0.947*** [51.38]	0.943*** [31.66]	0.965*** [56.81]	0.969*** [24.80]	0.915*** [43.08]	0.968*** [23.22]	0.889*** [28.03]
i_{t-1}	–	–	–	–	–	–	–
\bar{R}^2	0.952	0.914	0.953	0.915	0.956	0.914	0.955
SIC	-1.108	-1.856	-1.123	-1.862	-1.173	-1.814	-0.581
LM-test (12)	2.484** (0.01)	0.087 (1.00)	2.135** (0.02)	0.070 (1.00)	1.727* (0.07)	0.066 (1.00)	1.175 (0.32)

Notes: Table reports OLS estimates. t -values are given in square brackets. ***, ** and * denote 1%, 5% and 10% level of significance, respectively. Whole sample refers to period 1999m1–2012m10. Variable description is given in table A1 in appendix. The goodness of fit statistics are the adjusted R-squared, Schwarz information criterion (SIC) as well as Breusch-Godfrey Lagrange multiplier test for no serial correlation in residuals up to order twelve (p-value given in parenthesis).

sample period. The nominal effective exchange rate (NEER) gap is not significant for the McCallum rule in any of the sub-samples. The probability of the hypothesis that the NEER gap variable is omitted from the estimated equations is never below 10%.

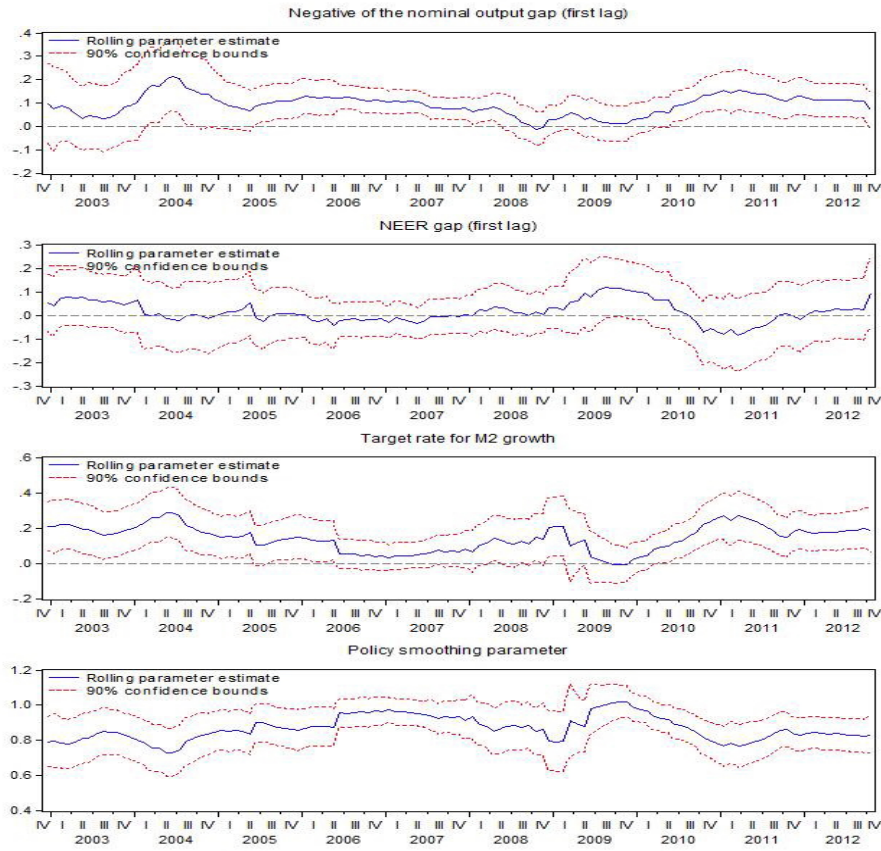


Figure 1: Rolling McCallum rule (eq. 10) parameter estimates using a 48-month rolling window.

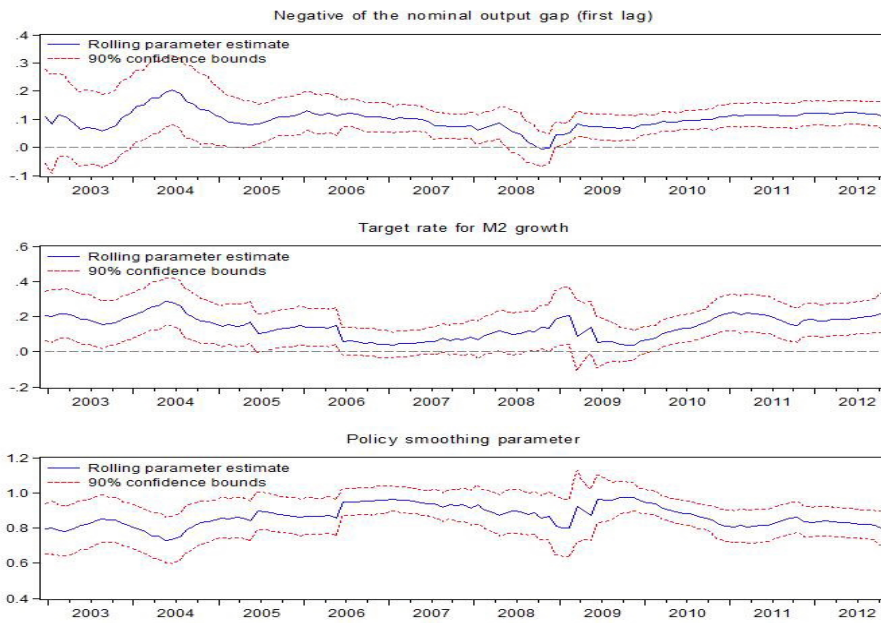


Figure 2: Rolling McCallum rule (eq. 10) parameter estimates, excluding the exchange rate term, using a 48-month rolling window.

Therefore, the rolling McCallum rule parameters are estimated also by assuming that the policy does not react to the exchange rate. The McCallum rule estimation results without the NEER gap are presented in figure 2. Again, the broad money supply has been responsive to the nominal output gap at 90% level of confidence in almost all the sub-samples, apart from the first year of estimation and a short period in late 2008. The reactions for the negative output gap are positive. This is in line with the theory: at times when the nominal output falls behind its trend, the broad money supply is increased. The policy smoothing behavior has been persistent over time.

Figure 3 shows the rolling estimation results for the second money supply rule, the Hybrid McCallum-Hall-Mankiw rule (eq. 11). The results offer interesting insights into the previous McCallum-rule estimates. First of all, as the broad money supply does not seem to be responsive to the output gap, the reactions to the nominal output gap in the McCallum rule are mainly driven by reactions to the inflation gap. Reactions to the inflation gap in the Hybrid McCallum-Hall-Mankiw rule are similar to the reactions to nominal output gap in the McCallum rule.

The real effective exchange rate (REER) shows not to be significant at the 90% level in the majority of the sub-samples. The Hybrid McCallum-Hall-Mankiw estimation results without the exchange rate are presented in figure 4. The output gap remains largely insignificant, except for a short period in early 2006, where the reaction to the negative output gap is strangely negative, which is at odds with the theory. The policy smoothing in the central bank broad money supply is strong, but appears to recede towards the end of the estimation sample, along with a rising significance of the official target for the broad money growth in the central bank broad money supply.

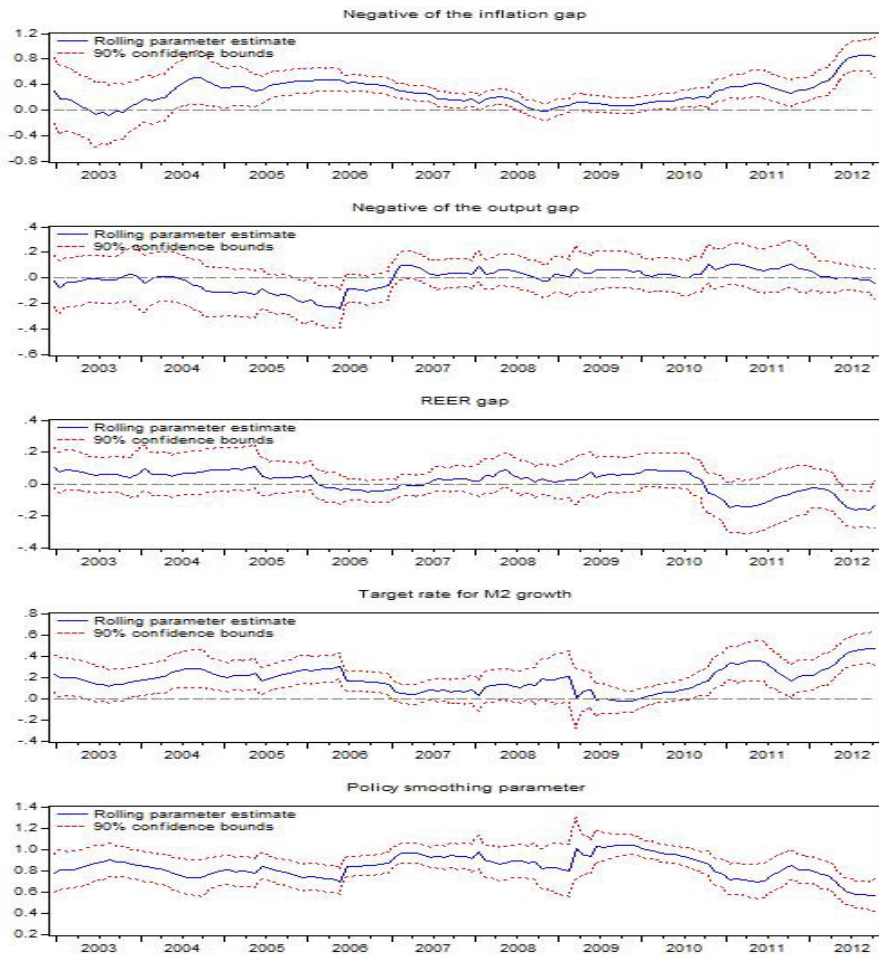


Figure 3: Rolling Hybrid McCallum-Hall-Mankiw rule (eq. 11) parameter estimates using a 48-month rolling window.

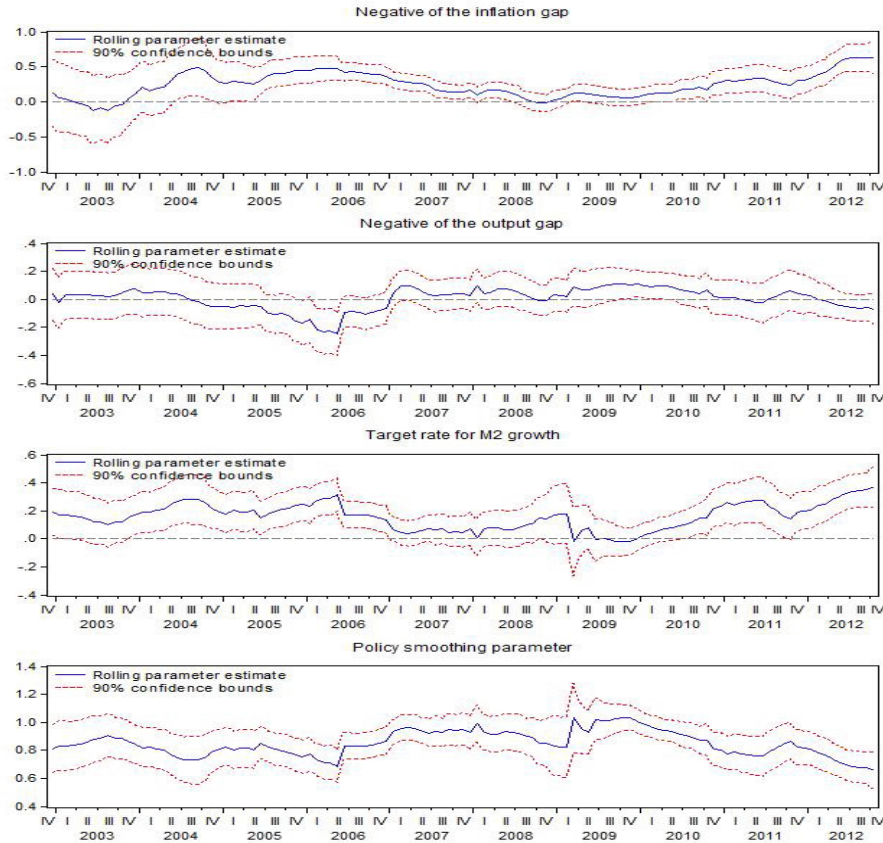


Figure 4: Rolling Hybrid McCallum-Hall-Mankiw rule (eq. 11) parameter estimates, excluding the exchange rate term, using a 48-month rolling window.

In addition to the consumer price inflation, the rolling estimations are carried out using the corporate goods price index (CGPI) as the price measure. The corporate goods prices can be seen to be more closely related to industrial production, which is our output measure. The results using the CGPI inflation are presented in figure A5 in Appendix 4. The figure confirms the findings from the previous section that the policy responses to consumer price changes are very similar to the policy responses to corporate goods prices.

Rolling parameter estimates with the 90% confidence bounds for the Taylor rule (eq. 12) are presented in figure 5. The figure shows that before 2008 the PBC benchmark lending rate has not been responsive to any of the macroeconomic variables. During 2008 – 2010 the interest rate policy reacted to the output gap but not to consumer prices.

The results of the rolling estimation are similar to those in the previous section, where we found that adding the exchange rate variable to the Taylor rule renders the other policy variables statistically less significant. Because the real effective exchange rate (REER) gap is statistically significant only for a short period in late-2008 – 2009, for the purpose of comparison we also estimate the Taylor rule without the exchange rate. The results are shown in figure 6. The change in the interest rate policy to accommodate the changes in output after mid-2008 is clearly visible. On the other hand, the interest rate remains unresponsive to the inflation gap. To analyze this further, we also estimate the Taylor rule (without the exchange rate) by using the corporate goods prices as the measure for inflation. The results are presented in figure A6 in Appendix 4. Again, similar to the Hybrid McCallum-Hall-Mankiw rule, the choice of the price index measure does not greatly affect the Taylor rule estimation results. The policy interest rate reacted to the corporate goods prices only in mid-2008 – mid-2009, a time when all prices (corporate goods as well as consumer prices) rapidly declined (see figure A1 in Appendix 2).

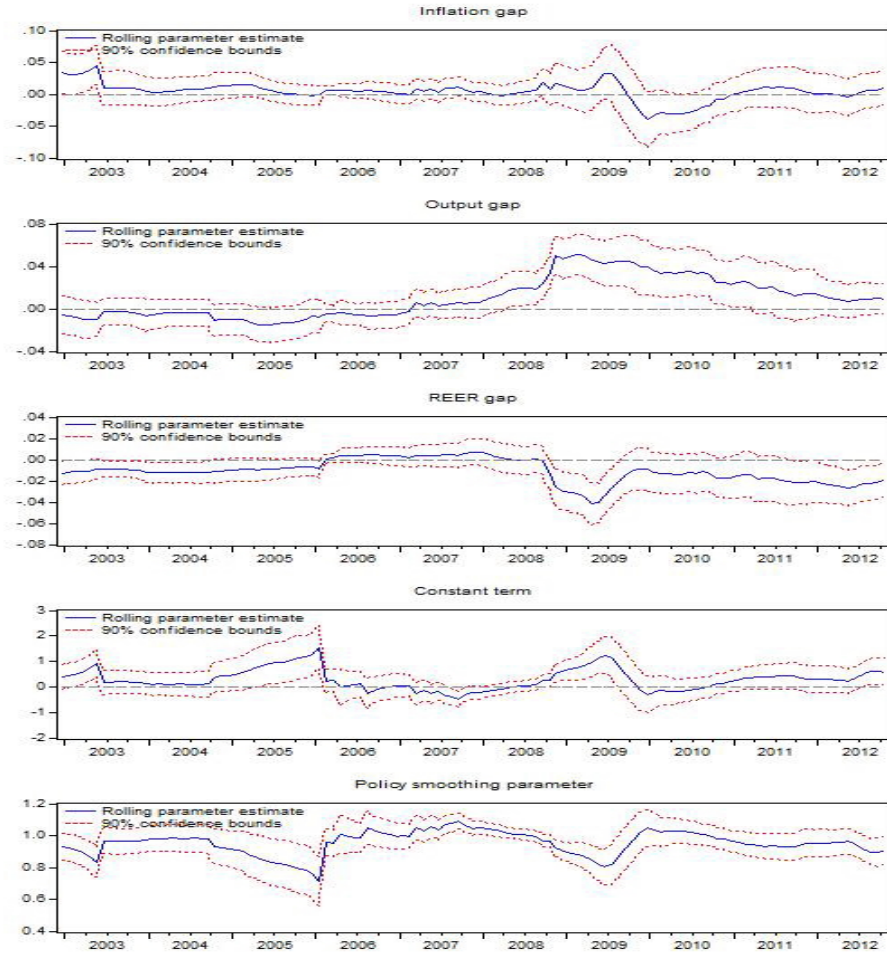


Figure 5: Rolling Taylor rule (eq. 12) parameter estimates using a 48-month rolling window.

In all the Taylor rule estimations the policy smoothing parameter is very large, at times greater than one. The interest rates remain very persistent, despite the fact that the policy has become more responsive to changes in output from its trend level. The likely explanation for this is that, even though the PBC lending rates have been more frequently altered in the recent years, the policy rate remains a more infrequently used policy instrument, compared to many others (including RRR hikes to alter the monetary base).

Figure 7 depicts the rolling parameter estimates for the last estimated policy rule, the Hybrid McCallum-Taylor interest rate rule (eq. 13). Here the Taylor rule inflation and output gaps are replaced by the nominal output deviation. The estimation results show that the PBC benchmark lending rate has responded statistically significantly to the nominal output gap only in a few months in late 2008. The exchange rate gap, on the other hand, has been statistically significant at the 90% level for the interest rate setting from the start of 2009. As with the Taylor rule, however, the policy smoothing parameter again exhibits values that are very high. For comparison, the Hybrid McCallum Taylor rule is also estimated without the exchange rate variable, even though it is statistically significant in all the sub-samples in the more recent years. These results are presented in figure 8. The exclusion of the exchange rate does not seem to drastically change the policy responses to the nominal output gap in the Hybrid McCallum Taylor rule.

It is clear that monetary policy in China is conducted using a variety of policy instruments. What remains unclear is the way the instruments are chosen to achieve the policy targets. In addition to multiple instruments, the final goal for policy is also twofold. The objective of monetary policy in China is to control prices, but at the same time also contribute to economic growth.

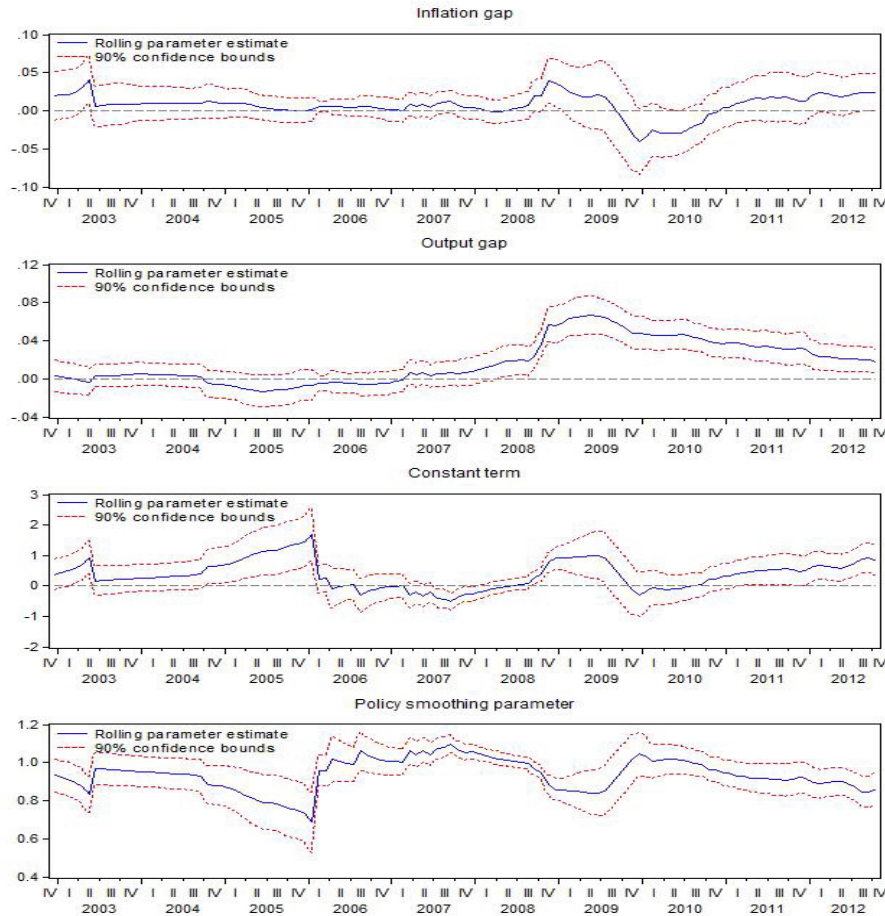


Figure 6: Rolling Taylor rule (eq. 12) parameter estimates, excluding the exchange rate term, using a 48-month rolling window.

The rolling policy parameter estimations, presented in this section, provide many interesting insights into PBC policy settings and selections from among the different instruments. First of all, it seems clear that roughly after 2008 the policy has been set so that the interest rate instrument is used to control real economic activity. The policy interest rate is raised in times of overheating (when output is above trend rate) and lowered in periods of a slowdown (when output falls below trend). The quantity-based money supply instrument is reserved for restraining inflation. When inflation is below trend or target level the money supply has been relatively expansive, and in times of rising inflation it has been tightened.

Secondly, the findings show a clear change in the policy setting pattern. The interest rate became responsive to changes in output after 2008m4. This results from the advances in the market-based interest rate reform, whereby the policy rates have also been harnessed to function as a more timely instrument. During 2007 there were signs of economic overheating in China, and the PBC had to tighten its policy stance. This changed in 2008, following the global financial turmoil, and the policy had to be rapidly loosened. In this environment the policy interest rates were also used more actively than before.

Thirdly, the results suggested that different policy instruments are used to control real economic activity and price stability. Therefore the nominal policy rules for China cannot optimally account for this behavior. Nominal output merges the changes in real output and prices and is therefore a poor target variable, if one wants to detect policy actions that are directed only towards one of these.

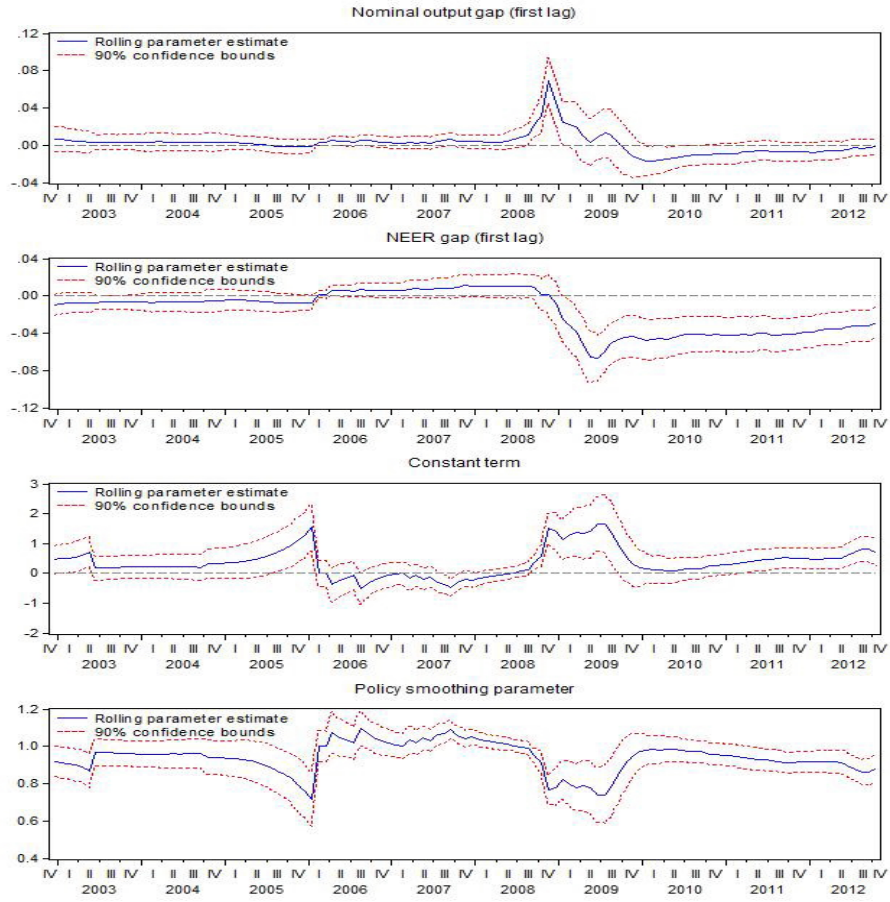


Figure 7: Rolling Hybrid McCallum-Taylor rule (eq. 13) parameter estimates using a 48-month rolling window.

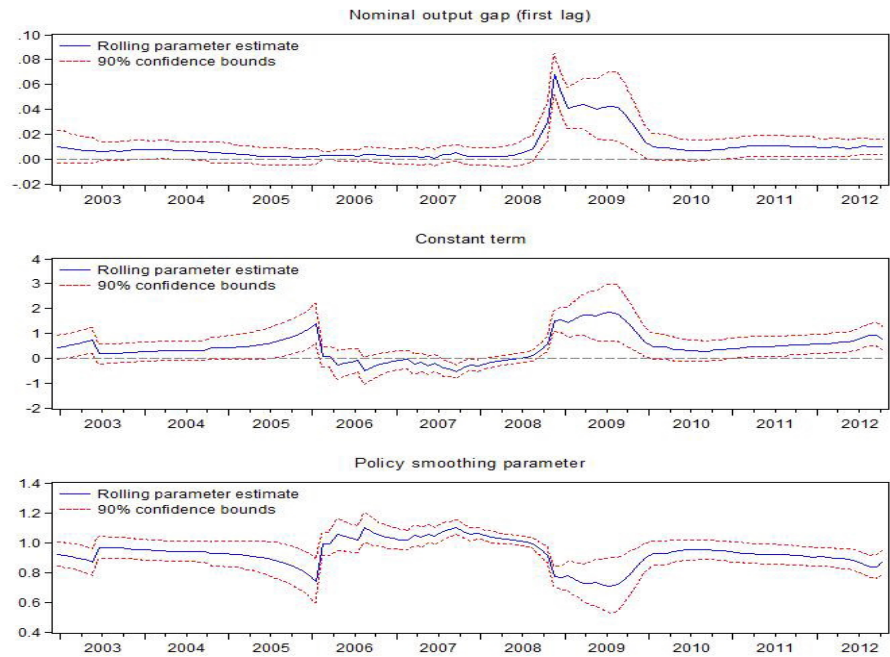


Figure 8: Rolling Hybrid McCallum-Taylor rule (eq. 13) parameter estimates, excluding the exchange rate term, using a 48-month rolling window.

7 VAR analysis

In the final section of this paper, the policy rules are estimated in a vector autoregressive (VAR) setting. This section shows the dynamic linkages between the instruments and the policy target variables. As in the earlier section, to make the results more compatible, we only use the HP-filtered variables for the gap series and choose the broad money (M2) as our monetary aggregate.

The optimal lag order in all the VAR specifications is based on the final prediction error information criterion with a maximum of 12 lags. To reduce the number of parameters to be estimated, the least significant parameter coefficients are eliminated. The model is re-estimated at each step of the elimination, always removing the coefficient with a lowest t -value, until all the remaining parameters are statistically significant at the 90% level. All the estimations are carried out using data for the 1999m1 – 2012m10 period.

The McCallum rule VAR is estimated using three lags. The final estimated model, after eliminating the insignificant coefficients, is

$$\begin{aligned}
 X_t \equiv \begin{bmatrix} \Delta b^{M2} \\ -\hat{x} \\ \hat{e}^{neer} \end{bmatrix}_t &= \begin{bmatrix} 0.80 & - & 0.10 \\ - & 1.08 & - \\ 0.16 & - & 1.31 \end{bmatrix} X_{t-1} + \begin{bmatrix} - & - & - \\ -0.17 & -0.60 & - \\ -0.32 & - & -0.55 \end{bmatrix} X_{t-2} \\
 &+ \begin{bmatrix} - & 0.08 & - \\ - & 0.34 & - \\ 0.15 & - & 0.13 \end{bmatrix} X_{t-3} + \begin{bmatrix} 0.21 & - \\ 0.19 & -0.59 \\ - & - \end{bmatrix} \begin{bmatrix} \Delta b^{M2*} \\ d^{rrr} \end{bmatrix}_t + \epsilon_t, \quad (14)
 \end{aligned}$$

where ϵ_t is a 3×1 vector containing the residuals.

Figure 9 displays the transmission of shocks in the McCallum-rule VAR. The figure shows the impulse responses of the variables to a one-standard-deviation shock in each of the variables, one at a time. The dashed lines show the 90% confidence intervals. VAR estimation gives similar results as the single-equation models. A negative shock to the nominal output growth, reducing it below the long-run trend, increases the broad money supply. The same happens if the nominal effective exchange rate is hit by a positive shock. The effects on money supply are long lasting; the effects of shocks vanish only after two years.

The VAR model for the Hybrid McCallum-Hall-Mankiw rule, after eliminating all insignificant coefficients, is given by equation (15). Again, the matrix ϵ_t represents the model residuals. Impulse response functions of the reduced form Hybrid McCallum-Hall-Mankiw rule are presented in figure 10. These impulse responses are in line with the theory: the money supply responses to inflation and output gap are negative (i.e. positive impulse responses to the negative values of these gaps).

$$\begin{aligned}
 X_t \equiv \begin{bmatrix} \Delta b^{M2} \\ -\hat{\pi}^{cpi} \\ -\hat{y} \\ \hat{e}^{reer} \end{bmatrix}_t &= \begin{bmatrix} 0.84 & 0.46 & - & 0.08 \\ - & 0.87 & - & 0.06 \\ -0.14 & 0.17 & 0.82 & 0.19 \\ 0.22 & 0.52 & - & 1.13 \end{bmatrix} X_{t-1} \\
 &+ \begin{bmatrix} - & -0.26 & - & - \\ - & - & 0.06 & - \\ - & - & -0.33 & - \\ -0.22 & -0.60 & - & -0.31 \end{bmatrix} X_{t-2} + \begin{bmatrix} 0.17 & - \\ - & -0.19 \\ 0.14 & - \\ - & - \end{bmatrix} \begin{bmatrix} \Delta b^{M2*} \\ d^{rrr} \end{bmatrix}_t + \epsilon_t. \quad (15)
 \end{aligned}$$

The estimated reduced-form Taylor rule VAR is

$$\begin{aligned}
 X_t \equiv \begin{bmatrix} i \\ \hat{\pi}^{cpi} \\ \hat{y} \\ \hat{e}^{reer} \end{bmatrix}_t &= \begin{bmatrix} 1.20 & 0.04 & - & -0.03 \\ - & 0.88 & - & -0.07 \\ - & 0.40 & 0.82 & -0.18 \\ - & -0.55 & - & 1.12 \end{bmatrix} X_{t-1} + \begin{bmatrix} -0.24 & -0.03 & - & 0.02 \\ - & - & 0.06 & - \\ - & -0.38 & -0.32 & - \\ - & 0.62 & - & -0.28 \end{bmatrix} X_{t-2} + \begin{bmatrix} 0.23 \\ - \\ - \\ - \end{bmatrix} + \epsilon_t. \quad (16)
 \end{aligned}$$

The impulse responses for the Taylor rule are presented in figure 11. A one-time shock to inflation induces a future hike in the central bank interest rate. In line with the theory, an opposite movement in the interest rate follows after a positive shock to the real effective exchange rate. On the other hand, shocks to the output gap seem not to have a statistically significant effect on the future interest rate. This is more in line with earlier studies that find the output gap often statistically insignificant in Taylor rule models (Mehrotra & Sánchez-Fung 2010; Fan et al. 2011).

The final estimated VAR model is that for the Hybrid McCallum-Taylor rule:

$$\begin{aligned}
X_t \equiv \begin{bmatrix} i \\ \hat{x} \\ \hat{c}^{neer} \end{bmatrix}_t &= \begin{bmatrix} 1.07 & - & -0.03 \\ - & 1.11 & -0.30 \\ - & - & 1.22 \end{bmatrix} X_{t-1} + \begin{bmatrix} - & - & 0.02 \\ -0.75 & -0.66 & - \\ - & - & -0.37 \end{bmatrix} X_{t-2} \\
&+ \begin{bmatrix} -0.15 & - & - \\ - & 0.47 & - \\ -1.73 & - & - \end{bmatrix} X_{t-3} + \begin{bmatrix} - & - & - \\ - & -0.13 & - \\ 1.98 & - & - \end{bmatrix} X_{t-4} + \begin{bmatrix} 0.11 \\ 1.20 \\ - \end{bmatrix} d_t^{rrr} + \begin{bmatrix} 0.47 \\ 4.12 \\ -1.48 \end{bmatrix} + \epsilon_t. \quad (17)
\end{aligned}$$

Figure 12 shows the impulse responses for this model. A shock to the nominal output will slightly increase the future level of the interest rate. Again, an opposite effect on the interest rate is observed when the nominal effective exchange rate is hit by a shock.

Overall, all the estimated VAR models are in line with theoretical assumptions and broadly confirm our previous results from the single-equation analysis. The impulse response functions also reveal that the effects of macroeconomic shocks to policy instruments are in general long lasting, usually dying out only after two years.

8 Conclusions

The empirical study presented in this paper focuses on examining monetary policy actions in China. The goal of this exercise is to offer information about the monetary policy setting practices of the People’s Bank of China. China’s case is interesting: along with developments in the surrounding economy, monetary policy is going through a transition from a previous strict implementation of quantity-based policy to a more price-based form of policy conduct. According to our analysis, the actual Chinese data support this story.

We estimate the monetary policy reaction functions for China for the period of 1999–2012. The more recent and higher frequency data utilized in the analysis provide results that are novel to the policy-function estimation literature for China. All the estimated policy rules perform reasonably well in terms of countercyclical policy reactions to inflation and output deviations; or nominal output deviation that is a combination of these two. However, in many instances the sizes of the estimated response coefficients are smaller than those proposed in the literature.

The paper presents detailed analysis of policy responsiveness over time. The overall sensitivity of the policy instruments to macroeconomic variables has increased in recent years. An interesting finding is that the interest rate has become responsive to the output gap after 2008, whereas prior to that it was unresponsive to all the target variables. Moreover, the money supply instrument has been responsive only to price changes and generally not to the output gap. These results can be seen as a division of policy instruments in a way that different instruments are directed at different exclusive targets. The money supply instrument is utilized to control the price level, whereas the interest rate instrument is reserved for achieving the output growth target.

In the last section of the paper, we estimated the monetary policy rule models in a VAR framework. The VAR system allows for more dynamics between monetary policy instruments and macroeconomic target variables. The impulse responses from the VAR models provide further support for our results: in general, the policy instruments react to macroeconomic variables in line with the theoretical assumptions.

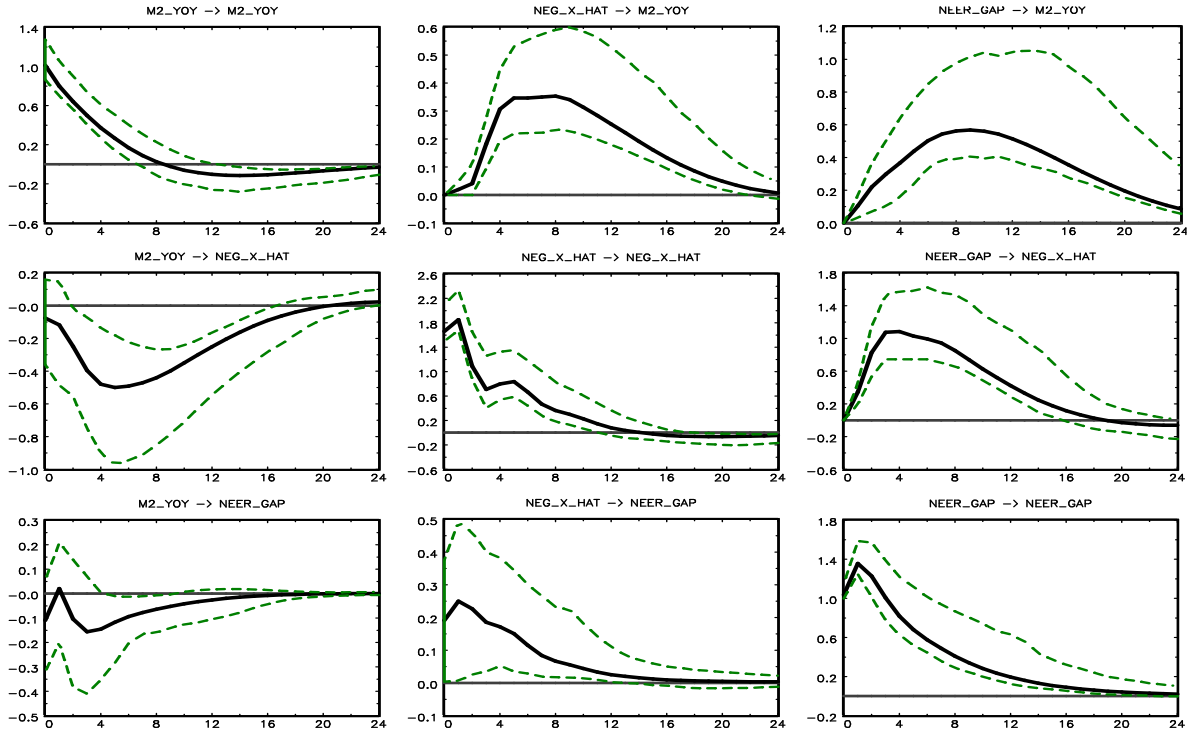


Figure 9: McCallum rule impulse responses. Dashed lines indicate the 90% confidence intervals. The left column shows the responses to money supply shocks, middle column to the (negative) nominal output gap shocks and right column to the NEER gap shocks. The money supply responses are on the top row, the (negative of) nominal output gap responses on the middle row and the NEER gap responses on the bottom row.

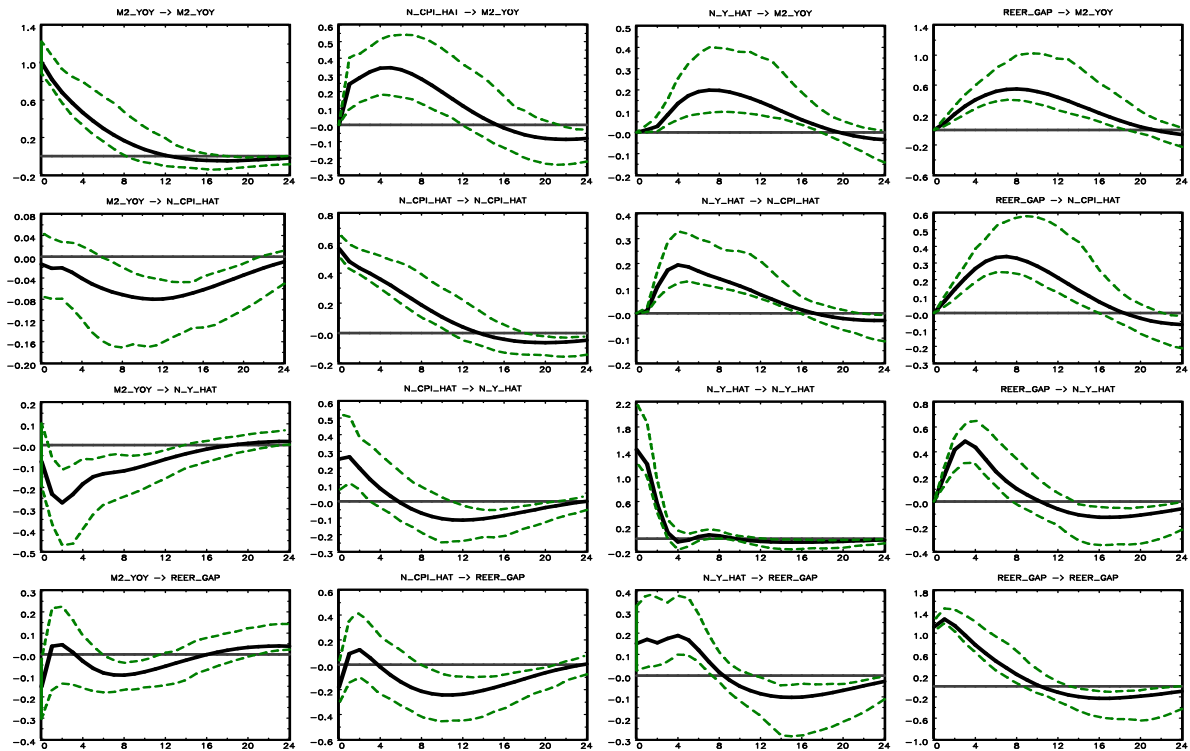


Figure 10: Hybrid McCallum-Hall-Mankiw rule impulse responses with 90% confidence intervals. The first column shows the responses to the money supply shocks, second column to the (negative) inflation shocks, third column to the (negative) output gap shocks and fourth column to the REER gap shocks. The money supply responses are on the top row, the (negative of) inflation responses on the second row, the (negative of) output gap responses on the third row and REER gap responses on the bottom row.

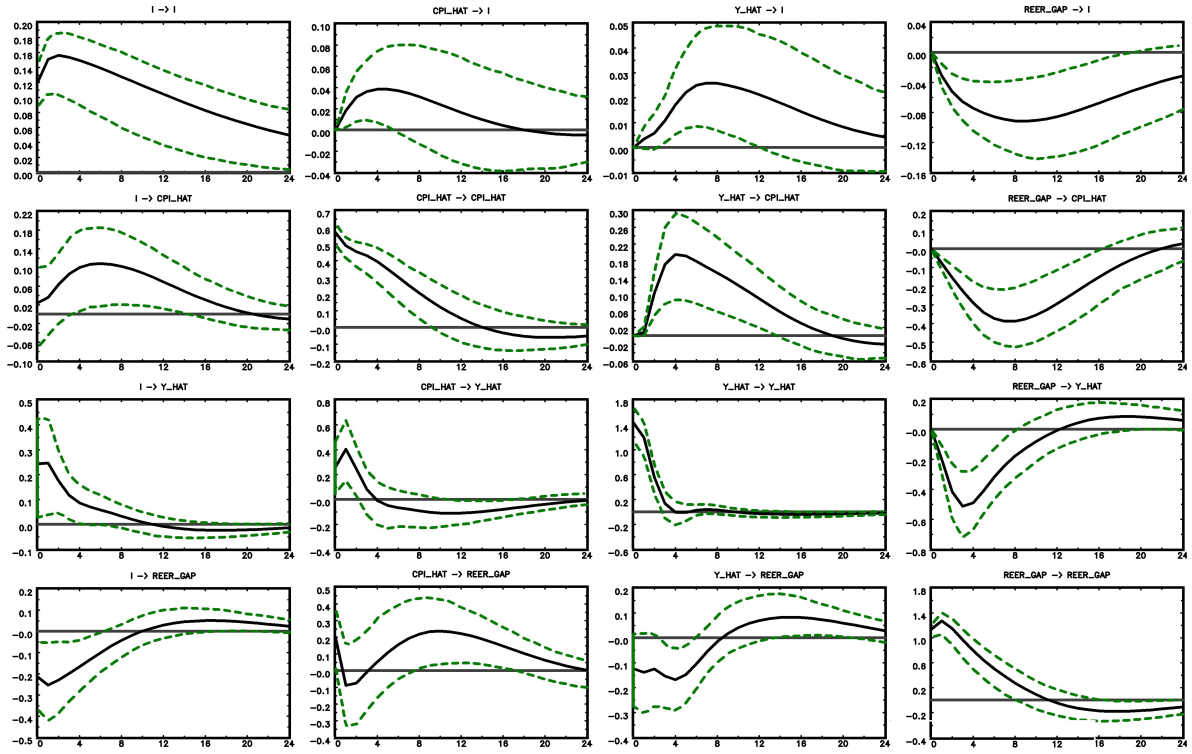


Figure 11: Taylor rule impulse responses. Dashed lines indicate the 90% confidence intervals.

The first column shows the responses to the interest rate shocks, second column to the inflation shocks, third column to the output gap shocks and fourth column to the REER gap shocks. The interest rate responses are on the top row, the inflation responses on the second row, the output gap responses on the third row and the REER gap responses on the bottom row.

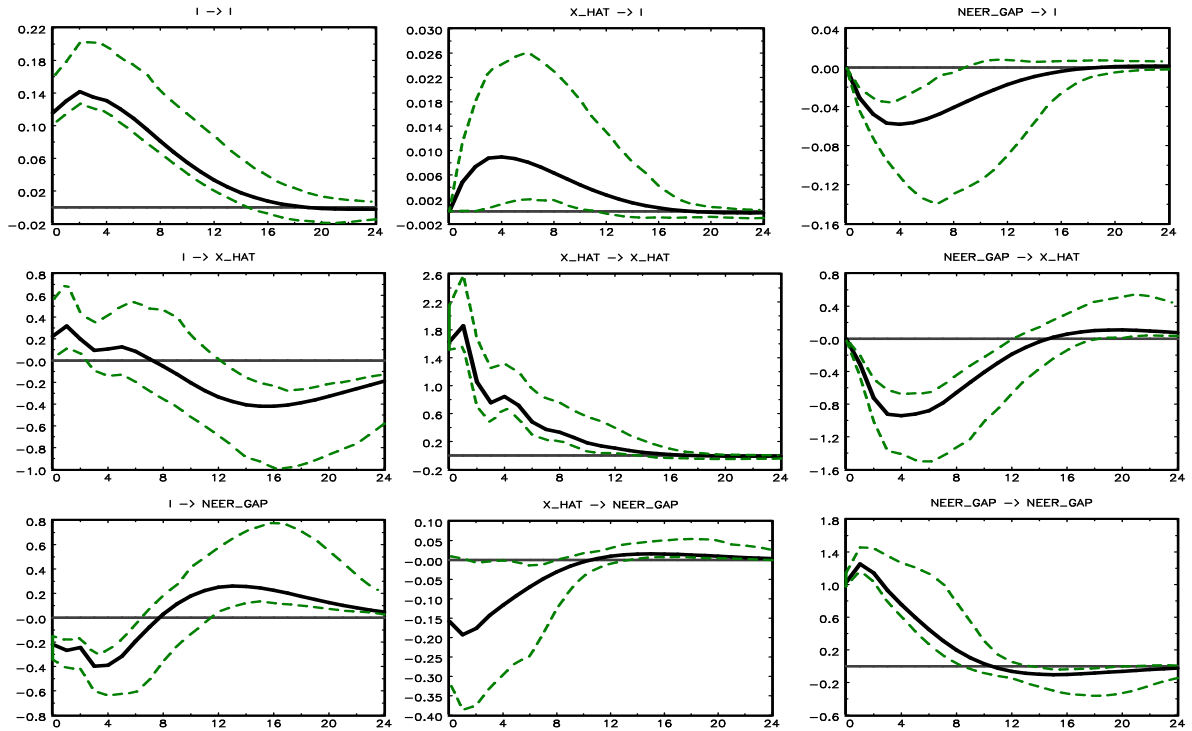


Figure 12: Hybrid McCallum-Taylor rule impulse responses with 90% confidence intervals.

The left column shows the responses to the interest rate shocks, the middle column to the nominal output gap shocks and the right column to the NEER gap shocks. The interest rate responses are on the top row, the nominal output gap responses on the middle row and the NEER gap responses on the bottom row.

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Appendix 1. Variables.

Table A1: Variables used in the paper.

Variable	Description	Source*	Notes
Interest rate			
i	People's Bank of China RMB 1-year benchmark loan rate	PBC	
Money supply			
Δb^{rm}	Annual y-o-y rate of change in the log of reserve money	IMF	data available 1999M6 onwards
Δb^2	Annual y-o-y rate of change in the log of M2 supply	PBC	
Δb^{*M2}	Official annual target growth rate for broad money (M2) supply	NPC	
Δb^{*rm}	Annual target rate for reserve money growth, generated from M2 target		Δb^{*M2} — money multiplier trend (see text)
Inflation			
π^{cpi}	Annual change in consumer price index from same month previous year	NBS	
π^{cgpi}	Annual change in corporate goods price index from same month previous year	PBC	
π^{*cpi}	Official annual target rate for CPI inflation	NPC	
π^{*cgpi}	Annual target rate for CGPI inflation, generated from official CPI inflation target		$1.65 \times$ CPI inflation target -1.40 . (see text)
$\hat{\pi}^{cpi}$	CPI inflation gap, defined as deviations of π^{cpi} from Hodrick-Prescott filtered trend		HP smoothing parameter $\lambda=14\ 400$
$\hat{\pi}^{cgpi}$	CGPI inflation gap, defined as deviations of π^{cgpi} from Hodrick-Prescott filtered trend		HP smoothing parameter $\lambda=14\ 400$
Output			
Δy	Real output growth; y-o-y change in industrial production index	NBS	adjusted for the Chinese new year (see text)
Δx	Nominal output growth from the same month previous year		defined as: $(\Delta y + \pi^{cgpi})$
Δy^*	Annual target rate for output growth, generated from official annual GDP growth target	NPC	$1.33 \times$ GDP growth target (see text)
Δx^*	Annual target rate for nominal output growth, generated from CPI and GDP targets	NPC	$\Delta x^* = (\Delta y^* + \pi^{*cgpi})$
\hat{y}	Output gap, defined as deviations of Δy from Hodrick-Prescott filtered trend		HP smoothing parameter $\lambda=14\ 400$
\hat{x}	Nominal output gap, defined as deviations of Δx from Hodrick-Prescott filtered trend		HP smoothing parameter $\lambda=14\ 400$
Exchange rate			
Δe^{reer}	Annual y-o-y change in the log of real effective exchange rate (REER) index	IMF	REER index series is seasonally adjusted
Δe^{neer}	Annual y-o-y change in the log of nominal effective exchange rate (NEER) index	IMF	NEER index series is seasonally adjusted
\hat{e}^{reer}	REER gap, defined as deviations of REER index from Hodrick-Prescott filtered trend		HP smoothing parameter $\lambda=14\ 400$
\hat{e}^{neer}	NEER gap, defined as deviations of NEER index from Hodrick-Prescott filtered trend		HP smoothing parameter $\lambda=14\ 400$
Auxiliary variable			
d^{rrr}	Dummy variable for periods of 'continuing frequent RRR increases'	(PBC)	see Appendix 3

Note: All data are in percentages. * IMF = International Monetary Fund, NBS = China National Bureau of Statistics, NPC = The National People's Congress of the People's Republic of China, PBC = People's Bank of China.

Appendix 2. Data and descriptive statistics.

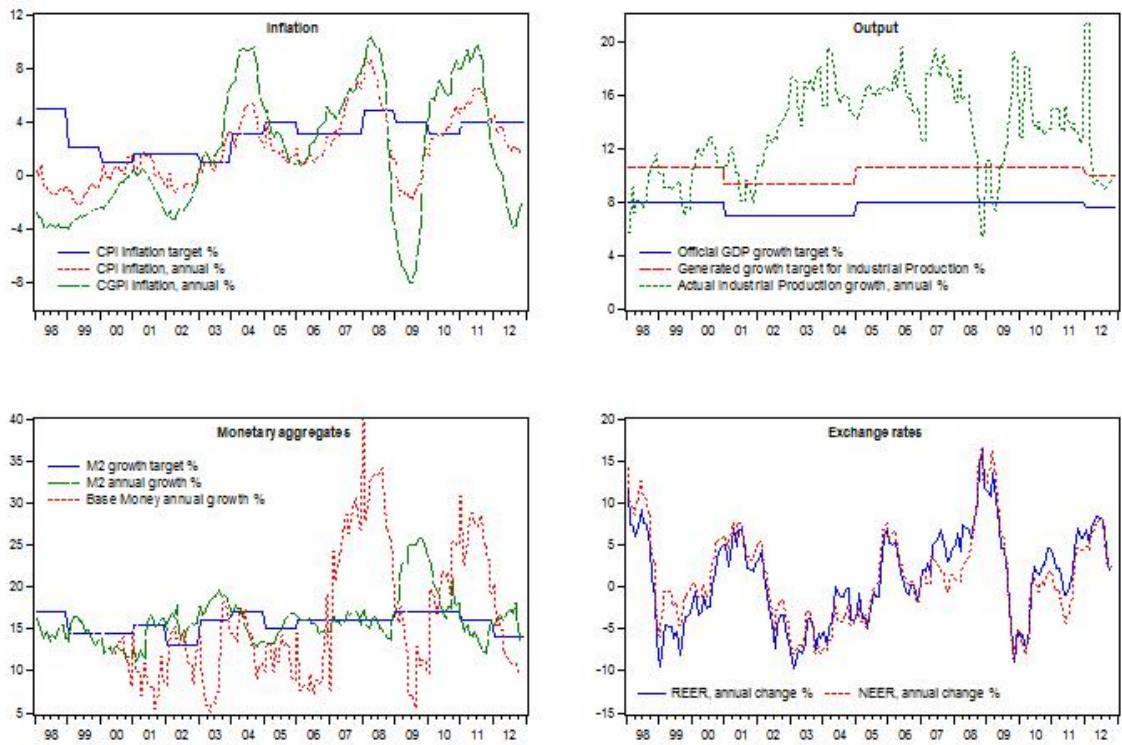


Figure A1: Data

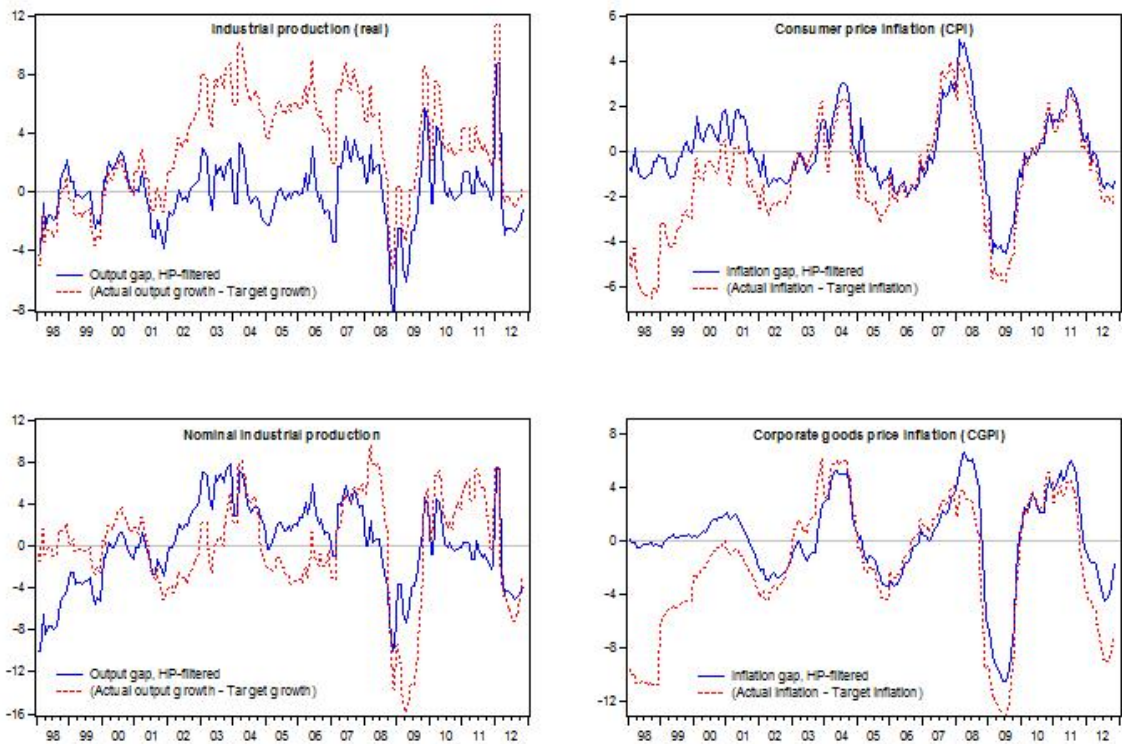


Figure A2: Output gap and Inflation gap measures.

Table A2: Descriptive statistics and unit root test statistics of the variables.

Variable	Obs	Basic statistics				Unit root tests (level stationarity)					
		Mean	Max	Min	St.Dev.	Skew.	Kurt.	ADF		KPSS	
								t-stat.	(prob.)	exog.	LM-stat.
i_t	178	6.00	8.64	5.31	0.74	1.29	4.25	-3.87***	(0.003)	constant	0.156
Δb_t^{rm}	149	16.10	40.01	5.05	7.81	0.79	2.68	-2.61*	(0.093)	constant	0.555**
Δb_t^{M2}	178	16.00	25.96	11.36	2.93	1.39	5.49	-2.56	(0.103)	constant	0.450*
$\hat{\pi}_t^{cpi}$	178	0.01	4.90	-4.54	1.76	0.10	3.52	-3.56***	(0.000)	none	0.031
$\hat{\pi}_t^{cgpi}$	178	0.05	6.54	-10.55	3.43	-0.72	4.15	-4.19***	(0.000)	none	0.028
$(\pi - \pi^*)_{t}^{cpi}$	178	-1.12	3.90	-6.50	2.43	-0.20	2.70	-2.17**	(0.030)	none	0.372*
$(\pi - \pi^*)_{t}^{cgpi}$	178	-1.83	6.06	-13.25	4.89	-0.53	2.51	-2.73***	(0.007)	none	0.223
\hat{y}_t	178	-0.06	8.76	-8.27	2.37	0.04	5.31	-4.24***	(0.000)	none	0.043
\hat{x}_t	178	0.02	9.55	-15.76	4.79	-0.83	4.18	-3.52***	(0.001)	none	0.029
$(\Delta y - \Delta y^*)_t$	178	3.06	11.35	-5.21	3.66	-0.13	2.26	-1.86*	(0.060)	none	0.484**
$(\Delta x - \Delta x^*)_t$	178	0.08	7.81	-10.01	4.01	-0.32	2.75	-2.66***	(0.008)	none	0.308
Δr_t^{reer}	178	1.11	16.37	-9.70	5.45	0.10	2.39	-1.61	(0.102)	none	0.338
Δr_t^{neer}	178	1.30	16.46	-8.65	5.47	0.44	2.84	-1.78*	(0.071)	none	0.123
\hat{r}_t^{reer}	178	0.04	9.73	-5.47	3.02	0.87	3.51	-4.03***	(0.000)	none	0.044
\hat{r}_t^{neer}	178	0.11	9.87	-4.46	2.98	0.80	3.58	-4.14***	(0.000)	none	0.054

Note: All data in percentages. Data for 1998m1–2012m10.

Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests are carried out to test for stationarity. The null hypothesis in ADF test is that the series has a unit root, whereas the null hypothesis in KPSS test is that the series is stationary. Exogenous variables in ADF test equation include a constant term, when the data series is not concentrated around zero. MacKinnon one-sided p-values for ADF t -statistic are: ***1% level: -3.47, **5% level: -2.88 and *10% level: -2.58 with a constant term, and: ***1% level: -2.58, **5% level: -1.94 and *10% level: -1.62 without a constant term. Lag length in the ADF test equation is selected according to Schwarz information criterion, with maximum of 13 lags. Asymptotic critical values for KPSS LM-Statistic (with a constant term) are: ***1% level: 0.739, **5% level: 0.463 and *10% level: 0.347.

Appendix 3. Dummy variable for the reserve requirement ratio increases.

The central bank deposit reserve requirement ratio merits special attention, when studying the PBC's monetary policy conduct. In recent years changes in the reserve requirement ratio (RRR) have been frequent (figure A3) and largely targeted to sterilize the central bank foreign exchange purchases. Contrary to Western economies, in China RRR is used as an active policy tool. The role of RRR as a policy tool in China and the consequences of this policy are discussed in detail in Ma et al. (2013).

Changes in RRR serve as an indicator instrument in communicating the monetary policy stance to the general public. Depending on the situation, the reserve requirement changes can also affect monetary aggregates and commercial banks' interest rates. Frequent changes in RRR may create a situation where other policy actions can be delayed, or the RRR changes may even be enough to fine tune the economy so that further policy interventions become unnecessary. It can be assumed that during periods in which the RRR increases have been frequent, the monetary policy environment is different compared to times when the RRR instrument has not been used. Policy reactions to macroeconomic variables may thus differ depending on the frequency of RRR changes. To account for this possibility, we create a dummy variable to indicate periods of 'frequent RRR changes'.

The RRRs were differentiated for large and small banks in late 2008, depicted in figure A3. The dummy series get a value 1, when the average RRR has been increasing in at least three of the preceding six months. This is the case in three separate occasions: first from November 2006 to September 2008, second covering May and June 2010 and the third period running from January to September 2011. Periods indicated by the dummy series are highlighted in figure A3. Figure A4 relates these periods to developments in the policy instruments.

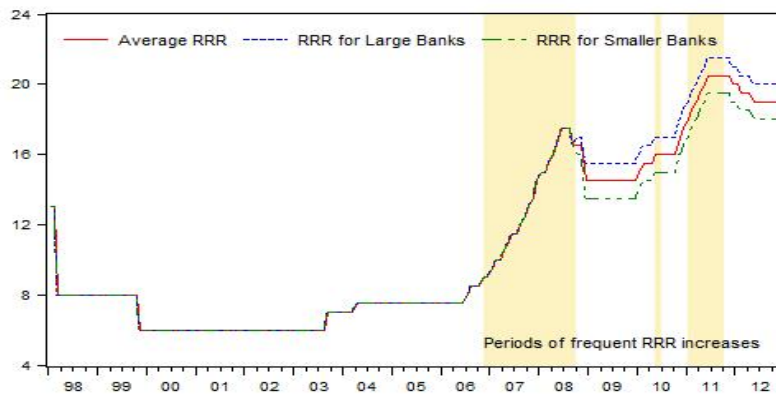


Figure A3: Reserve requirement ratio (RRR).

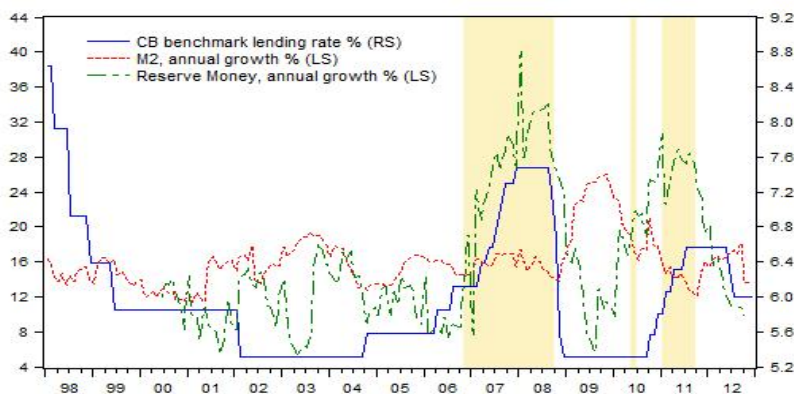


Figure A4: Development of monetary policy instruments.

Appendix 4. Rolling parameter estimates with corporate goods price inflation.

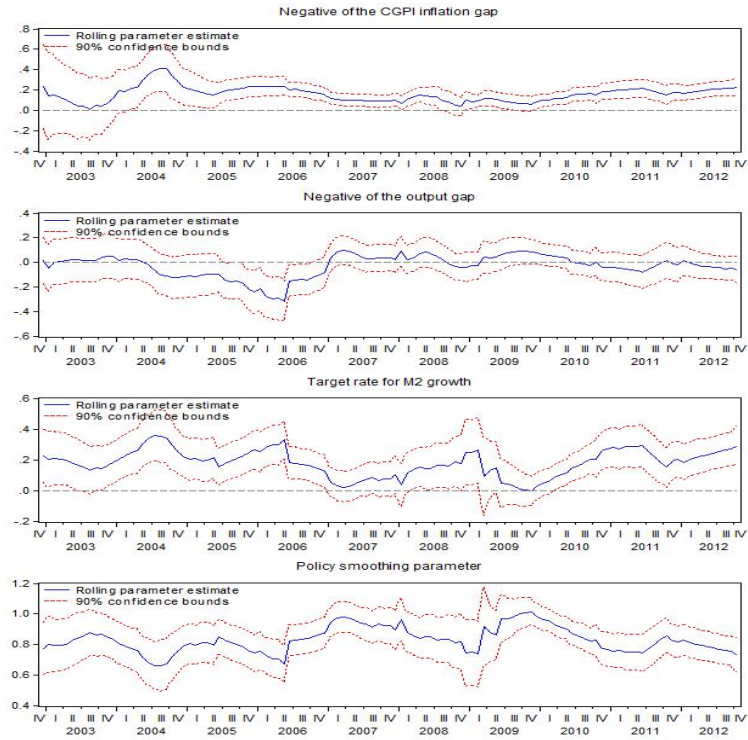


Figure A5: Rolling Hybrid McCallum-Hall-Mankiw rule (eq. 11) parameter estimates with CGPI inflation, and excluding the exchange rate term, using a 48-month rolling window.

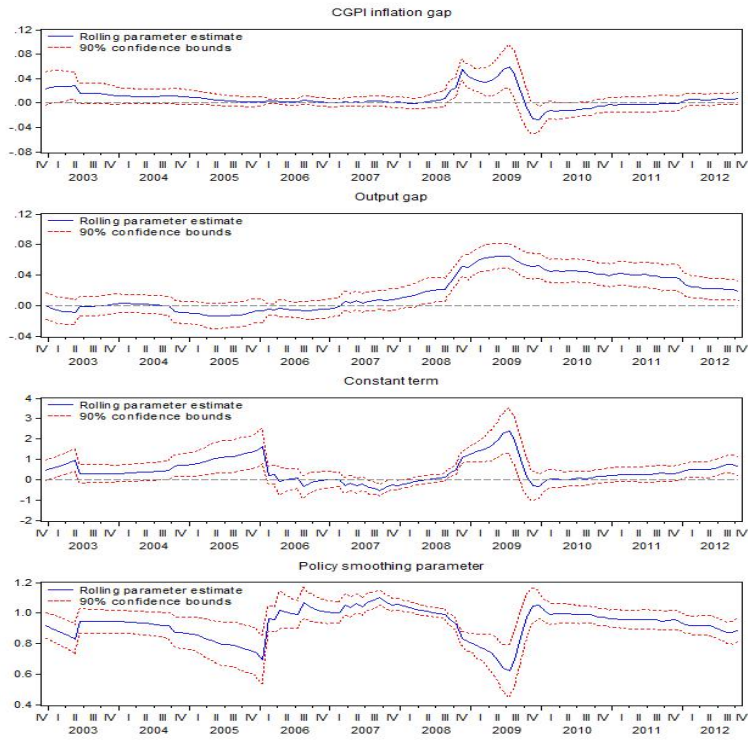


Figure A6: Rolling Taylor rule (eq. 12) parameter estimates with CGPI inflation, and excluding the exchange rate term, using a 48-month rolling window.

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