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Is Chinese monetary policy forward-looking?

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Is Chinese monetary policy forward-looking?

Abstract

This paper investigates the empirical validity of the claim that China employed a forward-looking monetary policy rule from 2001 to 2016. Survey expectations are used in conjunction with competing money supply and interest rate rules. The paper contributes to the literature by addressing the problems of serial correlation and structural breaks in the underlying policy reaction function. Unlike earlier studies indicating a strong role for expectations in Chinese monetary policy, we find expectations only began to play a significant role after 2008. This finding is robust for expectations series based on surveys of both households and forecasting experts. We also find that the People's Bank of China promotes economic growth in procyclical fashion, but applies countercyclical policy in managing inflation.

Keywords: inflation expectations, monetary policy reaction function, survey data
JEL Classifications: E58; E31

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1 Introduction

Central bank monetary policy operations are treated as a matter of practice, while macroeconomic modelling of the monetary policy reaction function is seen as the province of policy rule theory. Monetary policy rules describe the regular and systematic adjustments central banks make in response to changes in macroeconomic variables. The use of simple feedback rules that prescribe the setting of the policy interest rate as a function of a few key economic indicators accelerated with the formulation of the interest-rate response rule of Taylor (1993).

Over the past two decades, a plethora of monetary policy studies have focused on estimation and evaluation of monetary policy reaction functions in the spirit of Taylor (1993). Presumably this is because monetary policy rules help establish and improve transparency and central bank credibility, and thereby stabilize the economy. Indeed, there is broad consensus in the influential works of Clarida *et al*. (2000) and Rudebusch (2002, 2006), as well as the more recent works of Consolo and Favero (2009), Leith and Wren-Lewis (2016), and Bauer and Neuenkirch (2017), that a Taylor rule monetary policy reaction function provides useful insights for the conduct of monetary policy in developed economies, most notably the United States.

Although Taylor (2000) extends the application of the Taylor rule to emerging market economies and shows that the use of monetary policy rules in emerging market economies offers many of the same benefits to policymakers, there has been limited interest in examining the empirical validity of a Taylor rule monetary policy reaction function in China, the world's largest emerging market economy. This lack of interest seems to have contributed to misreadings of Chinese central bank actions in recent years. In particular, researchers have been vague on exactly how the People's Bank of China (PBOC) is forward-looking in its policy moves to influence its ultimate targets – the real economic output growth rate and the inflation rate.[1]

Given that the Chinese government and the PBOC reiterate the importance of "expectations management" in monetary policy adjustment, a number of studies take as given that China's monetary policy is forward-looking. For example, Zhang (2009) provides an important contribution in quantifying the effectiveness of an interest rate rule relative to a money supply rule in China between 1993 and 2005 using a dynamic stochastic general equilibrium (DSGE) model. Notably, the theoretical model and quantitative analysis in the paper *assume* the PBOC is forward-looking throughout the underlying sample period.

[1] The Law of the People's Republic of China on the People's Bank of China stipulates that the ultimate goals of monetary policy are to maintain the stability of the currency value and thereby promote economic growth.

The empirical analyses in Fan *et al*. (2011) and Zheng *et al.* (2012) also indulge the view that the PBOC's actions have been consistently forward-looking. Specifically, Fan *et al*. (2011) investigate the responsiveness of the Chinese monetary policies in terms of the money supply and interest rates to economic conditions and the effectiveness of these policies in achieving the goals of stimulating economic growth and controlling inflation. Their results for quarterly data in the period 1992–2009 suggest that a money supply rule influenced the future inflation rate and real output, while an interest rate rule had no impact on expectations for the inflation rate or real output. Girardin *et al*. (2014) argue that, even with its declared interest rate rule, China essentially followed a forward-looking Taylor rule from 2002 to 2013.

Zheng *et al*. (2012) introduce a regime-switching forward-looking Taylor rule to describe Chinese monetary policy behavior and consider its estimation using the two-step maximum likelihood estimator procedure proposed by Kim and Nelson (2006) and Kim (2009). Their results with quarterly data for China over the period from 1992 to 2010 show that the actual reactions of China's monetary policy can be characterized as a two-regime forward-looking Taylor rule.

While these studies undoubtedly provide important contributions to the understanding of Chinese monetary policy as, by definition, a forward-looking rule requires the policymaker to take a view on the nature of expected future inflation and real output in the monetary policy reaction function. Many authors, including those mentioned above, employ realized future inflation data to proxy expectations using instrumental variables (IV) estimations or generalized methods of moments (GMM) to account for the resulting endogeneity. While this approach provides a single analytical framework, it assumes rationality that may be subject to problems of weak instruments (Mavroeidis, 2004). It may also conflate the roles of future and lagged values when the latter act as instruments (Rudd and Whelan, 2007), or may induce a volatile measurement error that distorts inferences (Sun and Phillips, 2004; Zhang *et al.*, 2008).

An alternative approach is to use observed expectations data derived from surveys to measure forward-looking variables in the underlying model. Survey data may more accurately mimic the responses of agents to economic information than realized future values of inflation and real output (see Roberts, 1995). This view is supported by the studies of Orphanides (2001, 2003) that emphasize the importance of using real time forecasts as measures of inflation expectations when analyzing historical monetary policy. Further, Roberts (1998) shows that expectations based on observed survey data match more closely the empirical costs of reducing inflation in the transmission of monetary policy. Ang *et al*. (2007) also find that surveys forecast more accurately than a range of macroeconomic and statistical models.

These studies suggest expectations are complex phenomena not well captured using simple assumptions. Therefore, it may be valuable to examine the nature of the monetary policy rules using survey data of expectations. Different groups of agents likely possess different information sets, so no single expectations series is necessarily appropriate for use in the policy reaction function.

Another important, yet often overlooked, issue is possible serial correlation in the popular stylized monetary policy reaction function with a single backward lag term. The possible presence of serial correlation is crucial in identifying valid instruments for IV or GMM estimations (all lags of the dependent variable are invalid instruments in the presence of autoregressive serial correlation). Since lags of dependent variables are typically employed as instruments for estimations, the consistency of these estimates depends on the lack of serial correlation.

This paper contributes to the discussion by investigating Chinese monetary policy rules using directly observed forecast series from survey data as measures of expectations for inflation and real output, while addressing serial correlation and its consequences. In common with most of the empirical literature on Chinese monetary policy rules – and based on the persuasive arguments in Chinese monetary policy reports – we use both a money supply rule and an interest rate rule to capture the reaction behavior of Chinese monetary policy. Our study considerably extends the stylized model of the Chinese monetary policy reaction function in the literature that employs rational expectations approximation while neglecting possible serial correlation in the empirical estimations. To overcome this drawback, we use two different sets of survey forecast data to capture the views of agents and use IV estimation to address endogeneity in typical forward-looking models. Our principal finding, which is robust to the different expectation series used, is that expectations only began to play a significant role after 2008. We also find that the PBOC promotes economic growth in a procyclical way, but pursues countercyclical policy in dealing with inflation. These asymmetrical reactions to inflation and real output hamper the Chinese central government in achieving its overarching goal of economic stabilization.

The paper is organized as follows. Model specification is described in section 2. Section 3 describes the data used in the empirical analysis. Section 4 presents empirical results for the Chinese monetary policy reaction functions. Section 5 discusses the implications of the empirical findings and concludes the paper.

2 Model specification

The Taylor rule of monetary policy reaction function proposed by Taylor (1993) has become the workhorse model for modern monetary policy analysis. It postulates that the central bank adjusts interest rate according to the following feedback mechanism,

$$i_t^* = i^* + \alpha_1 \left(\pi_t - \pi^*\right) + \alpha_2 y_t . \qquad (1)$$

Equation (1) is a numerical formula that relates the central bank's target for interest rate to the current state of the economy. It describes the relationship between short-term target interest rate i_t^* and the equilibrium level of interest rate i^*, inflation rate π_t, target inflation rate π^*, and the real output gap y_t. In this setup, the short-term interest rate is the relevant instrument under the control of the policymaker that reacts to the rate of inflation and real economic slack.

Over the past two decades, many studies have attempted to extend the stylized model of the underlying Taylor rule as in Equation (1). Among these extensions, perhaps the two biggest innovations are the introduction of expectations and smoothness into the monetary policy reaction function.

Clarida *et al.* (1998, 1999, 2000) replace current period inflation rate π_t in Equation (1) with inflation expectations ($E_t \pi_{t+1}$) to generate a forward-looking style monetary policy reaction function. The introduction of expectations puts the rule in line with the framework of modern macroeconomics (e.g. mitigating the Lucas critique), and enhances its consistency with the growing importance of expectations management and central bank credibility in monetary policy practice.

The second innovation has been the addition of interest rate smoothness in the underlying reaction function. Clarida *et al.* (2000) highlight the central bank's tendency to adjust the interest rate gradually to a desired level, which leads to interest rate smoothness. This smoothing behavior is easily understood. While large external shocks occasionally force central banks to take quick action and make dramatic interest rate adjustments, incremental changing of the interest rate is a more prudential and feasible strategy in practice. Thus, Clarida *et al.* (2000) propose the following function to describe the smoothing adjustment of actual nominal interest rate i_t:

$$i_t = \rho(L) i_{t-1} + (1-\rho) i_t^* , \qquad (2)$$

where $\rho(L)=\rho_1+\rho_2 L+\dots+\rho_n L^{n-1}$, L denotes lag operator with order n, and $\rho \equiv \rho(1)$. In this setup, the value of ρ measures the degree of smoothness of the underlying interest rate, ranging between 0 and 1. A small value of ρ means little smoothing behavior, while a large value of ρ suggests a high degree of interest rate smoothing.

Combining the forward-looking factors with the smoothing mechanism, we obtain the following operational rule for a central bank:

$$i_t = \rho(L) i_{t-1} + (1-\rho)\left[i^* + \gamma_1\left(E_t \pi_{t+1} - \pi^*\right) + \gamma_2 E_t y_{t+1}\right] + \varepsilon_t, \tag{3}$$

where ε_t is a specification error and $E_t \pi_{t+1}$ and $E_t y_{t+1}$ denotes expectations of inflation rate and real economic slack at period t+1 conditional on the information set available up to time t. Equation (3) is a forward-looking Taylor rule that can be used to examine the empirical nature of central bank responses to inflation rate and real output. In econometric analysis, we can subsume the equilibrium real interest rate and inflation target into a constant term and rewrite Equation (3):

$$i_t = c + \rho(L) i_{t-1} + \alpha_\pi E_t \pi_{t+1} + \alpha_y E_t y_{t+1} + \varepsilon_t. \tag{4}$$

Empirical estimation of Equation (4) is non-trivial. The first difficulty lies in the measurements for expected variables. A common approach in the literature is to use a realized variable at t+1, together with the rational expectations assumption. Taking inflation expectations, for example, this approach implies $\pi_{t+1} = E_t \pi_{t+1} + \omega_{t+1}$, where ω_{t+1} denotes the forecast error. The rational assumption facilitates econometric estimations. However, this approach introduces an additional forecasting error into the underlying regression model that generates a compound error with both a specification and forecast error. Thus, the estimation with this approach of rational assumption is likely to lead to inaccurate inferences (Zhang *et al.*, 2009).

Additionally, reliance on ex post facto statistics means that the series for expected inflation rate cannot truly reflect the actual inflation expectations of people (see Orphanides, 2001, 2004).

A second difficulty in estimating model (4) relates to the optimal lag order in the lag polynomial $\rho(L)$. The introduction of lagged dependent variables helps to capture the central bank's backward-looking behavior and mitigate omitted variable problem (Sims and Zha, 2006). The specification of the lag order should be sufficient to mitigate potential serial correlation in the model specification error, which is essential for the validity of the estimates in the underlying dynamic model. In particular, the estimation of model (4) with instantaneous and expected variables often involve endogeneity problem and hence IV estimation methods (or GMM more generally) are warranted. The presence of serial correlation in (4) complicates the issue of endogeneity and hence the choice of instruments. To obtain an appropriate lag order, we use the Akaike information criterion (AIC) and an IV serial correlation test as diagnostic tools.

Another equally important issue in the model specification is the choice of rule. The monetary policy target in model (4) is the interest rate. Although the interest rate rule is general and appears to work well in the United States and many developed countries, China is not a developed country in terms of its monetary policy transmission process. In China, monetary aggregates and interest rates are both used as monetary policy variables. Indeed, while the PBOC has recently promoted the development of market-based interest rates as policy instruments (e.g. the Shanghai interbank offered rate was introduced in 2007), this mixed approach is still is explicitly stated in PBOC’s quarterly Monetary Policy Report.

Therefore, it makes sense to consider both an interest rate rule and money supply rule in examining the empirical nature of the Chinese monetary policy reaction function. To accommodate interest rate and money supply rules, we rewrite model (4) as:

$$MP_t = \alpha_0 + \sum_{i=1}^{n} \beta_i MP_{t-i} + \alpha_\pi E_t \pi_{t+1} + \alpha_y E_t y_{t+1} + \varepsilon_t \, , \tag{5}$$

where MP_t is the intermediate target of monetary policy at period *t*, MP_{t-i} is the lag term of MP_t, *n* is the optimal lag order (determined by AIC and serial correlation test).

To estimate model (5), rather than adopting rational expectations, we employ survey-based inflation forecasts in conjunction with alternative monetary policy rules. In particular, we try to determine whether the Chinese central bank significantly reacts to inflation expectations and real output. We use alternative survey data for inflation expectations to ensure the robustness of empirical results. We also explicitly address the issue of serial correlation in the stylized model, which leads to an extended specification of the reaction function with sufficient dynamics.

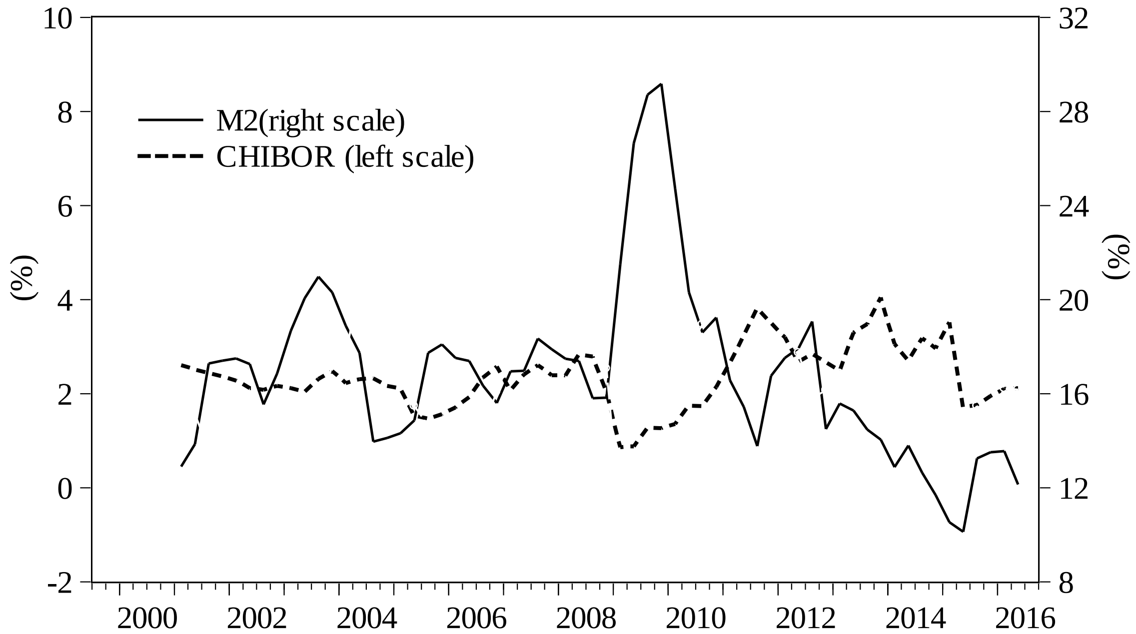
3 The data

The baseline empirical analysis relies on monetary policy variable series and expectations survey data on inflation rate and GDP growth rate, in combination with series for actual inflation and real GDP growth rates. The data sample spans the period from the first quarter of 2001 to the second quarter of 2016 (2001Q1–2016Q2). Inflation rate figures are subject to the availability of quarterly inflation forecasts from the survey of Chinese professional forecasters. Expectations data from surveys of households and professionals are obtained from PBOC publications and *Capital Week* (a Chinese business news magazine). Other data are collected from the China Economic Information Network database.

3.1 Monetary policy variables

For the intermediate monetary policy targets, i.e. MP_t in Equation (5), we use the rate of the aggregate money supply growth for our money supply rule and the weighted average interest rate of the China interbank offered rate (CHIBOR) for our interest rate rule. The rate of money supply growth is calculated as the year-on-year growth rate of M2, i.e. $100 \times [(M2_t/M2_{t-4})-1]$. The interest rate (CHIBOR) is the trading volume weighted average of the China interbank offered rate of all categories of maturity in the underlying quarter.[2] Figure 1 plots the time series evolution of the growth rate of money supply and the China interbank offered rate over the underlying sample period (2001Q1 to 2016Q2).

Figure 1 Growth rate of money supply and interbank offered rate in China



[2] We obtain similar empirical results using China's interbank repo rate as an alternative interest rate.

3.2 The survey data

We consider two sets of survey data on inflation expectations in China: household inflation expectations and professional inflation forecasts. The data on household inflation expectations (denoted CPI_PBOC) are obtained from the PBOC's quarterly survey *Urban Residents' Confidence on Income and Price Level in China*. Around 20,000 Chinese households across 50 different cities are surveyed in February, May, August, and November. The survey asks respondents to answer a single question: Do you expect prices to rise, fall, or remain the same in the coming quarter? The survey is similar to the Surveys of Consumers conducted by the University of Michigan Survey Research Center in the US, but unlike the Michigan survey, which asks respondents to provide a quantitative statement about expected change in price levels, the PBOC's survey question is descriptive. It only asks households whether they think prices will go up, stay the same, or fall over the coming quarter.

While the raw data only provide a qualitative measurement for inflation expectations, the qualitative information can be quantified into quarterly forecasts of consumer price inflation using statistical methods.

There are generally two methods for quantifying qualitative information. The first is a simple balance method that subtracts the proportion of respondents answering "fall" from the proportion that answered "rise" to obtain a net balance value and compute quantitative inflation expectations (see Batchelor, 1986). The second is Carlson and Parkin's (1975) approach, which assumes that expectations are normally distributed and that participant responses are determined by comparison of expectations and specific thresholds. The Carlson-Parkin method is slightly more complicated than the simple balance method (Balcombe, 1996).

To ensure the robustness of our empirical analysis, we use both methods to convert the qualitative PBOC data into quantitative expectations data. Note that the actual inflation involved in the conversion is measured as year-on-year change in the consumer price index (CPI). As the empirical results show that the baseline findings in our empirical analysis are robust to alternative series, we only present the results pertaining to the Carlson-Parkin method here.

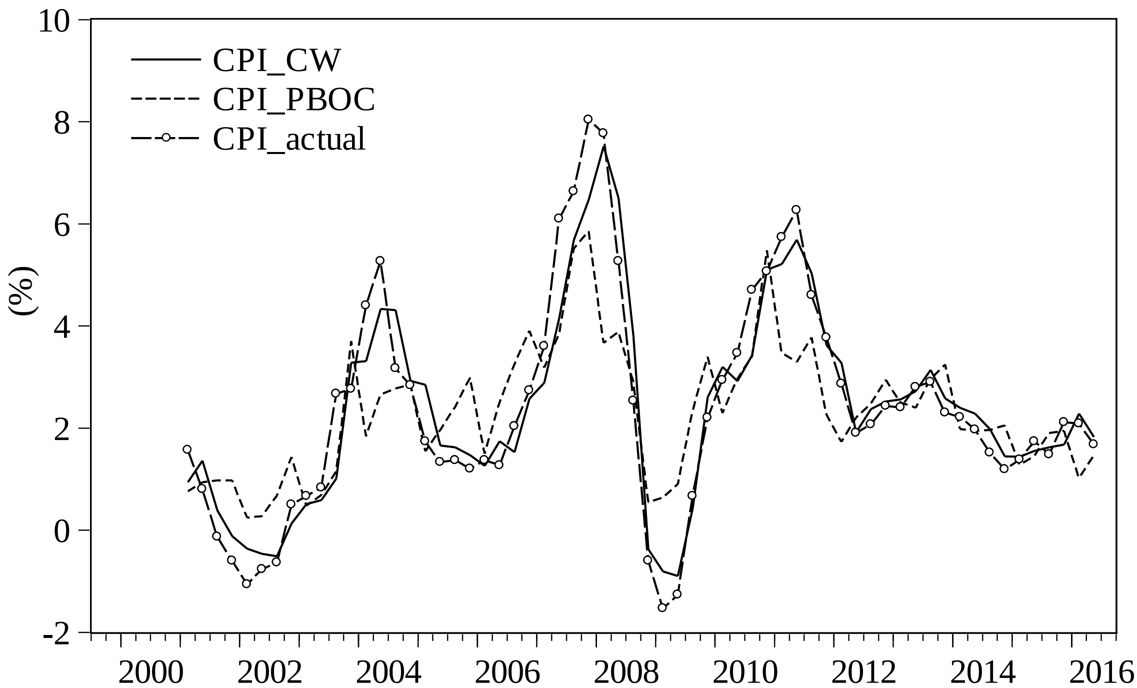
Another set of inflation expectations series is the survey of professional inflation forecasts (denoted CPI_CW). We gather our raw data manually from the Chinese business news magazine, *Capital Week*, which conducts quarterly macroeconomic forecast campaigns among Chinese professional forecasters. The quarterly survey polls experts at 30 private and public institutions in China at the start of each quarter.[3] Respondents are asked to share their inflation expectations (as well as

[3] Since the survey was first conducted in 2001, the number of participating institutions has grown from 9 to 30.

expectations concerning other major economic indicators) for the current quarter. The results are published in subsequent issues of the magazine. We calculate the mean of these forecasts and use this result as the measure of professional forecasters' expectations. The survey of professional forecasts states that inflation rate expectation are reported on a year-on-year basis.

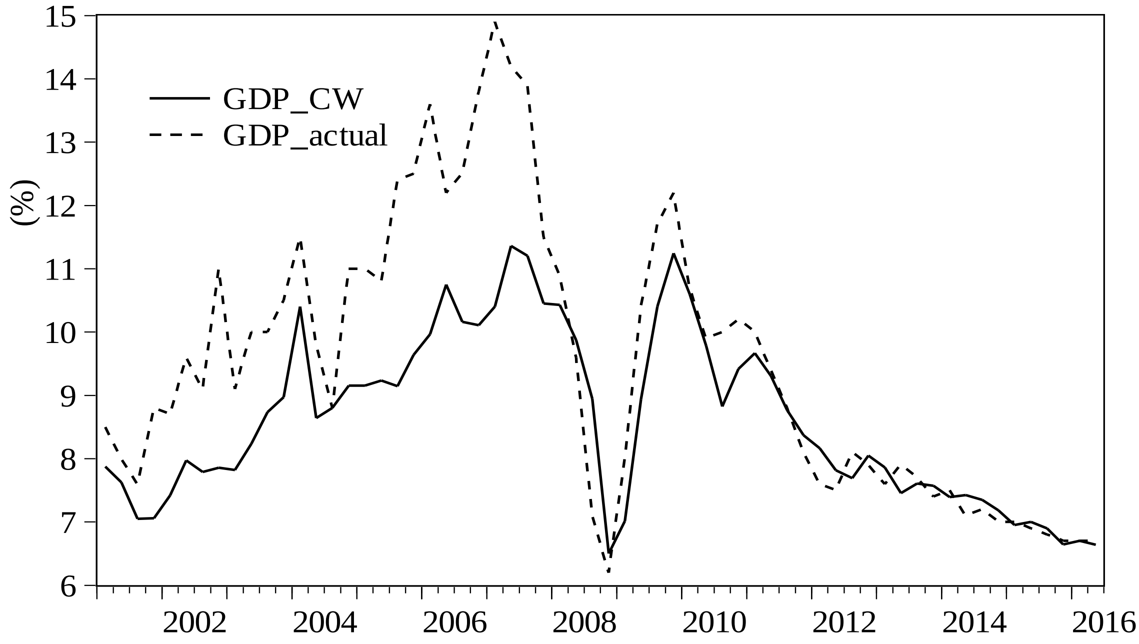
Based on the preceding descriptions, Figure 2 plots inflation expectations of households and professionals in conjunction with the actual future inflation. The actual inflation rate is measured by the year-on-year change in the consumer price index (denoted CPI_actual). In general, the evolving pattern of the two expectations series is similar and mimics the moving pattern of actual future inflation. The lead-lag behaviors and peaks and troughs of the two expectations variables differ, however. Household inflation expectations are also always above zero, while professional forecasts may have negative values (e.g. in 2002 and 2009). These subtle differences imply that the expectation formation process is different for the two groups, suggesting multiple sets of expectations are involved in the central bank reaction function.

Figure 2 Inflation expectations series and actual inflation rate in China（2001Q1–2016Q2)



Note that the survey of professional forecasters contains expectations for the real GDP growth rate (denoted GDP_CW). Figure 3 plots the survey of professional forecasts for the real GDP growth rate in conjunction with the actual future real GDP growth rate (denoted GDP_actual). Figure 3 shows that the general evolving pattern of the two series is similar, but the gap between the forecasts and the actual future data is much more distinctive before 2008. The accuracy of the professional forecasts on the real output growth rate appears to improve substantively after 2008. This change in forecast accuracy could indicate a potential structural break in the PBOC's reaction to the underlying forecasting variables. Naturally, such an assertion needs to be verified in the empirical analysis.

Figure 3 Expected and actual future real GDP growth rates in China



4 Empirical analysis

4.1 Econometric issues

In the underlying forward-looking monetary policy reaction function, survey inflation expectations may be endogenous as they are collected during the underlying quarter (CPI_PBOC survey data, for example, are collected mid-quarter), and hence may contain some current-period information. Therefore, model (5) may require IV estimation.[4] To address this concern, we use the Durbin-Wu-Hausman (DWH) test (Durbin, 1954; Wu, 1973; Hausman, 1978) to test for the null hypothesis that ordinary least squares (OLS) estimators are consistent in estimating model (5). If the null hypothesis is rejected, then IV estimator is employed. Otherwise, the least squares method is used.

[4] The literature suggests survey data may be treated as endogenous or exogenous. Rudebusch (2002) describes the possible endogeneity of inflation forecasts, while Roberts (1998) and Orphanides (2001, 2003, 2004) assume observed inflation forecasts to be exogenous. In addition, there appears no clear evidence on whether the contemporaneous output gap is correlated with the error term (see Roberts, 1998).

For the choice of instrumental variables, both the economic relationship between IV and other variables in the model and the number of instruments matter. We also need to make sure that the instruments are uncorrelated with the error term. We choose the lagged terms of each independent variable as our instruments, including a constant, with the number of lags determined to be 1 to 4. The choice of instruments is also tested by Hansen's (1982) *J*-test. The null hypothesis of the *J*-test assumes all instruments to be exogenous. An acceptance of the null hypothesis justifies the choice of instruments.

It should be noted that if current-period shocks in the model are serially uncorrelated, then lagged values of the observed variables provide valid instruments. However, the presence of serial correlation in (5) complicates the issue of endogeneity, and hence the choice of instruments. In particular, the lagged terms on the right-hand side of (5) are correlated with the disturbance if the error term is serially correlated. Therefore, we must ensure that the model is free of serial correlation problem with proper serial correlation tests. Traditional serial correlation tests such as Breusch–Godfrey *LM* tests work in OLS estimations, but fail in the case of IV estimation (Godfrey, 1994). Therefore, we use the Godfrey (1994) IV serial correlation test in IV estimations and the Breusch-Godfrey *LM* serial correlation test in OLS estimations to test for serial correlation in the underlying model.

Overall, the choice of instruments and model specification are verified through several diagnostic tests. First, the optimal lag order in model (5) is specified by AIC with maximum 8 lags. Second, we use Hansen's *J*-test to verify over-identifying restrictions. Third, the possibility of disturbance serial correlation in IV estimation is checked using the serial correlation tests proposed by Godfrey (1994).[5] If serial correlation is present, we correct the model by re-specify the lag order of *MP* in Equation (5) until the model is free from serial correlation.

4.2 Full sample estimation

Table 1 reports full sample estimation results of Equation (5) using household inflation expectations and professional forecasts. Note that we use professional forecasts of real GDP growth rate for both regressions as survey data of GDP for households are unavailable. The estimation method in each regression is specified by the Durbin-Wu-Hausman test. The DWH test results show that the *p*-value

[5] This test is implemented by adding appropriate lagged residuals from the initial estimation to the regressors of the initial model and checking their joint significance by the Lagrange Multiplier (LM) principle. In this test, the lagged residuals are also added as instruments.

for the regression of professional expectations with money supply rule is statistically significant, but insignificant in other regressions. The serial correlation tests described in the foregoing section are also implemented to ensure that the regressions are free from serial correlation.

Table 1 Estimation results of Equation (5)

$$MP_t = \alpha_0 + \sum_{i=1}^{n} \beta_i MP_{t-i} + \alpha_\pi E_t \pi_{t+1} + \alpha_y E_t y_{t+1} + \varepsilon_t$$

	α_0	β_1	β_2	α_π	α_y	$\overline{R^2}$	p-endo	p-auto	p-J
Money supply rule, $MP_t = M2_t$(lag order=2)									
1 CPI_PBOC	1.685 (1.472)	1.149*** (0.140)	-0.376*** (0.123)	-0.381* (0.214)	0.351 (0.220)	0.79	0.180	0.466	
2 CPI_CW	0.668 (1.484)	0.994*** (0.130)	-0.250** (0.115)	-0.595*** (0.187)	0.587** (0.249)	0.80	0.007	0.071	0.123
Interest rate rule, $MP_t = CHIBOR_t$(lag order=1)									
3 CPI_PBOC	0.735* (0.422)	0.740*** (0.091)		0.150*** (0.043)	-0.055 (0.040)	0.65	0.770	0.699	
4 CPI_CW	0.967** (0.431)	0.681*** (0.100)		0.109*** (0.030)	-0.056 (0.038)	0.66	0.796	0.423	

Notes: The survey of household inflation expectations (CPI_PBOC) is used in regressions 1 and 3, and the survey data of professionals (CPI_CW) are used in regressions 2 and 4. The sample spans 2001Q1–2016Q2. Instrumental variables in the IV estimations include four lags of each of the regressors in the model. White heteroskedasticity-robust standard errors are reported in parentheses. *p*-endo refers to Durbin-Wu-Hausman test (with the null hypothesis of consistency of the OLS estimator; heteroskedasticity robust); *p*-auto refers to *p*-values of serial correlation tests with Breuch-Godfrey LM tests for the OLS regressions and Godfrey (1994) IV serial correlation tests for the IV regressions; *p*-J refers to the J-test proposed by Hansen (1982) with null hypothesis assuming all instruments to be exogenous. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

The coefficient estimates for expectations of the two groups of survey data shed light on a key question of this investigation. Inflation expectations exert a positive and significant impact on the interest rate, and negatively impact on the money supply growth rate. This finding suggests that the PBOC reacts to inflation expectations in a countercyclical way. Numerically, when professional (household) expectations increase by 1%, the PBOC raises the interest rate by 0.11% (0.15%) and decreases the money supply growth rate by 0.60% (0.38%). The central bank's reaction to professional and household expectations appears slightly different in terms of magnitude and significance of the underlying coefficient estimates (i.e. the estimates of α_π) as attested to by the results shown in Table 1.

The coefficient estimates for the real output variable (i.e. the estimates of α_y) show that the central bank essentially does not react to real output growth rate expectations (except for the second regression). The second regression result indicates that the central bank adjusts for real economic growth in a procyclical way. This result may reflect that, in practice, the officially announced economic growth rate target in China provides lower bound guidance. It may also reflect that Chinese government prefers high economic growth over stable growth. Consequently, the PBOC has strong incentive to promote economic growth.[6]

The policy is further reinforced by the procyclical nature of the credit cycle. When the banking system foresees blossoming economic activity in the near future, its willingness to lend increases, thereby increasing the money supply. The statistically insignificant α_y in the interest rate rule may also indicate that the PBOC puts less weight on price-based instruments in comparison to the money supply rule.

4.3 Structural break and subsample analysis

Theoretical advances in the literature of unknown structural break tests, and the contributions by Andrews (1993) and Hansen (1997) in particular, enable us to identify possible changes and the associated timing in the underlying model with considerable precision. In this paper, we employ the conventional supreme Wald test of Andrews (1993) to test for unknown structural breaks in the Chinese monetary policy reaction function. The test is designed to test for the null hypothesis of no structural break in the underlying parameters of interest. The corresponding *p*-values of the underlying tests are computed using the method of Hansen (1997).

By construction, the sup-Wald statistic is the maximum Wald statistic for testing a break through all possible break points over a specified searching range, say τ, which is given by

$$SupWald = \ sup W_T(\tau_i) \big| \tau_i \in [\tau_{\min}, \tau_{\max}] \qquad , \tag{6}$$

where $W_T(\tau_i)$ denotes the sequential Wald-statistic testing for the null hypothesis of no structural break in the underlying parameter. We set a customary searching interval $\tau_i \in [0.15,\ 0.85]$ of the full sample T to allow a minimum of 15% of effective observations contained in both pre- and post-

[6] A recent study by Chen *et al.* (2016) also note that the PBOC prefers to promote economic growth and depress inflation. The authors believe that the PBOC is totally backward-looking.

break periods. In practice, heteroscedasticity-robust covariance estimates are computed throughout the tests based on the residuals under the null hypothesis of no break for computational convenience.

Table 2 summarizes the results of the Andrews (1993) unknown structural break tests for the Equation (5) with the survey of professional forecasts as measures of expectations (household expectations data are not used because they do not contain expectations for real output variable). The break tests are performed on all the coefficients overall and then on individual coefficients. Specifically, the statistic (all) in the first row of Table 2 tests for stability of all the coefficients in model (5). The second statistic (α_0) tests for the intercept term assuming that the remaining coefficients are constant. Likewise, the third statistic (β_i) tests for joint stability of the dynamic coefficients on the lagged variables assuming the other coefficients are constant. The last two statistics (α_π and α_y) test for stability of the expectation variables. For each regression, the optimal lag order in the model is chosen by the AIC with maximum eight lags.

The structural break test for the overall parameters in Table 2 show statistically significant evidence of instability in both the monetary supply rule and interest rate rule of the Chinese monetary policy reaction function, with *p*-values of all the Andrews' test statistics smaller than 1%. Investigating the other four tests in each regression reveals that instability for the money supply rule is primarily concentrated in the dynamic coefficients, while instability for the interest rate rule seems to originate from the coefficients on the expected variables. In addition, the break date statistics do not provide uniform break points for different monetary policy rules. The break point is 2012Q4 for the money supply rule and 2008Q2 for the interest rate rule.

Table 2 Results of Andrews unknown breakpoint tests for Equation (5)

	all	α_0	β_i	α_π	α_y
Money supply rule, $MP_t = M2_t$(lag order=2)					
p-Sup	0.000	0.366	0.009	0.511	0.227
break date	2012Q4	2007Q3	2012Q4	2014Q1	2007Q3
Interest rate rule, $MP_t = CHIBOR_t$(lag order=1)					
p-Sup	0.003	0.220	0.383	0.001	0.064
break date	2008Q2	2011Q1	2004Q1	2011Q1	2011Q1

Notes: The survey of professional forecasts is used to measure the expectations in model (5). The full sample spans 2001Q1–2016Q2 prior to lag adjustment. *p*-Sup denotes *p*-values of the sup-Wald *F*-test for the null of stability, while *break date* corresponds to the break point at which the maximum Wald *F*-statistic is achieved. The structural break tests are implemented over the central 70% of the underlying sample to avoid possible extreme results.

Overall, the Andrews statistics in Table 2 suggest that, while the Chinese monetary policy reaction function was generally unstable over the 2001–2016 period, the break points and the origins of the instability for the two different policy rules differ.

This disparity could, of course, reflect conceptual differences between the money supply rule and the interest rate rule. However, because the break point in money supply rule (2012Q4) is close to the extreme point in the searching interval, the result may be misled by the extreme sample problem. We therefore narrow the searching interval to the central 50% for the model of the money supply rule and obtain the result of the break point for the overall model stability in 2008Q4, which is very close to the break point of 2008Q2 for the model of the interest rate rule. Additionally, 2008 is the watershed year for the most recent financial crisis, i.e. a year in which we would expect structural breaks in monetary policy reaction function. Therefore, we choose 2008Q2 as the break point for subsample analysis.

Table 3 Estimation results of model (5) over subsamples

$$MP_t = \alpha_0 + \sum_{i=1}^{n} \beta_i \, MP_{t-i} + \alpha_\pi E_t \pi_{t+1} + \alpha_y E_t y_{t+1} + \varepsilon_t$$

	α_0	β_1	β_2	α_π	α_y	$\overline{R^2}$	p-endo	p-auto	p-J
Money supply rule, $MP_t = M2_t$(lag order=2)									
Pre-2008Q2	5.659** (2.185)	1.037*** (0.131)	-0.395** (0.147)	-0.077 (0.113)	0.073 (0.226)	0.63	0.184	0.074	
Post-2008Q2	-4.692 (3.124)	0.513* (0.269)	-0.106 (0.129)	-1.529*** (0.319)	2.252** (0.879)	0.86	0.012	0.092	0.554
Interest rate rule, $MP_t = CHIBOR_t$(lag order=1)									
Pre-2008Q2	0.766 (0.787)	0.690*** (0.171)		0.036 (0.033)	-0.017 (0.059)	0.52	0.798	0.271	
Post-2008Q2	1.117** (0.532)	0.627*** (0.110)		0.233*** (0.058)	-0.096 (0.057)	0.71	0.749	0.541	

Notes: The survey of professional forecasts is used to measure expectations. Other notations follow Table 1.

Table 3 reports the estimation results of model (5) with professional forecasts using 2008Q2 as the break point. The results for subsamples estimations confirm that the reactions of monetary policy on expectations before and after 2008 are dramatically different. In particular, we find that Chinese monetary policy did not react to inflation expectations or output growth rate expectations before

2008. This finding applies to both the money supply rule and interest rate rule. This finding of imperviousness to expectations contrasts starkly to claims in the existing literature that Chinese monetary policy was forward-looking from 2001 to 2008.

The results for the post-2008 sample period suggest that monetary policy reacted to the expected variables after 2008 and that the reaction mechanisms for the two policy rules are different. In particular, the monetary growth rate reacts to expectations of both the inflation rate and real output growth rate, while the interest rate only reacts to inflation expectations. The magnitude (absolute value) of the coefficients on expectations of inflation rate and output growth rate also increases substantively in the period after 2008 in comparison to the period before the structural break.

4.4 Robustness assessments

The foregoing analyses reveal a significant structural break. There is little role for expectations in the underlying monetary policy reaction function before 2008, and a significant role in Chinese monetary policy thereafter. To assess the robustness of our baseline findings, we carry out four sets of sensitivity exercises.

First, since rational approximation is widely used in the literature of forward-looking monetary policy analysis, we investigate whether our findings are robust to rational expectations approximation. The corresponding results are reported in Table 4. They generally confirm the baseline finding that estimation results using rational expectations show that both inflation expectations and expectations for the real GDP growth rate are significant in affecting the monetary supply rule over the period from 2008 to 2016. In contrast, there is no significant role for the two expected variables in the money supply rule before 2008. For the interest rate rule, the coefficient estimate on inflation expectations is statistically significant whereas the coefficient estimate on the expected real output growth rate is insignificant during the post-2008 period. These results are consistent with those reported in Table 3.

Table 4 Estimation results using rational expectations

$MP_t = \alpha_0 + \sum_{i=1}^{n} \beta_i \, MP_{t-i} + \alpha_\pi \pi_{t+1} + \alpha_y y_{t+1} + \varepsilon_t$

Sample	α_0	β_1	β_2	α_π	α_y	$\overline{R^2}$	*p*-endo	*p*-auto
Money supply rule, $MP_t = M2_t$(lag order=2)								
2001Q1–2016Q2	1.961* (1.048)	1.101*** (0.128)	-0.316*** (0.116)	-0.266** (0.111)	0.241*** (0.089)	0.81	0.073	0.693
2001Q1–2008Q2	5.391*** (1.865)	1.047*** (0.136)	-0.419** (0.153)	-0.029 (0.064)	0.097 (0.119)	0.63	0.426	0.097
2008Q3–2016Q2	-2.597** (1.160)	0.520** (0.199)	-0.110 (0.118)	-0.941*** (0.193)	1.773*** (0.353)	0.90	0.319	0.126
Interest rate rule, $MP_t = CHIBOR_t$(lag order=1)								
2001Q1–2016Q2	0.786** (0.310)	0.702*** (0.096)		0.082*** (0.024)	-0.030 (0.020)	0.66	0.205	0.573
2001Q1–2008Q2	1.054 (0.625)	0.626*** (0.162)		0.038* (0.020)	-0.029 (0.032)	0.54	0.688	0.220
2008Q3–2016Q2	0.842* (0.450)	0.670*** (0.114)		0.180*** (0.045)	-0.057 (0.040)	0.69	0.050	0.512

Notes: Rational expectations approximation is used to measure the expected variables. Other notations follow Table 1.

Second, we assess the robustness of the baseline finding by replacing the real GDP growth rate with real output gap. We perform this robustness exercise because output gap was used in the original Taylor rule equation. Note that since survey data for the output gap is unavailable, we use the realized future output gap (obtained through Hodrick-Prescott filter) to approximate the corresponding expectations. The results in Table 5 generally provide similar impressions as those in Table 3 and 4, except for the money supply rule regression with output gap (the upper panel in Table 5) in which coefficient estimates on expectations appear significant before 2008.

Table 5 Estimation results with real output gap

$MP_t = \alpha_0 + \sum_{i=1}^{n} \beta_i MP_{t-i} + \alpha_\pi E_t \pi_{t+1} + \alpha_y gap_{t+1} + \varepsilon_t$

Sample	α_0	β_1	β_2	α_π	α_y	$\overline{R^2}$	*p*-endo	*p*-auto	*p*-J
Money supply rule, $MP_t = M2_t$(lag order=2)									
2001Q1–2016Q2	3.349*** (1.067)	1.171*** (0.125)	-0.324*** (0.116)	-0.303** (0.128)	0.169 (0.160)	0.80	0.092	0.605	
2001Q1–2008Q2	5.931** (2.363)	0.944*** (0.139)	-0.243 (0.142)	-0.247** (0.116)	0.459** (0.187)	0.55	0.046	0.028	0.924
2008Q3–2016Q2	3.314** (1.346)	1.128*** (0.151)	-0.243 (0.151)	-0.610** (0.263)	0.096 (0.194)	0.83	0.098	0.738	
Interest rate rule, $MP_t = CHIBOR_t$(lag order=1)									
2001Q1–2016Q2	0.429** (0.177)	0.738*** (0.093)		0.079*** (0.028)	0.023 (0.030)	0.66	0.733	0.648	
2001Q1–2008Q2	0.740*** (0.230)	0.660*** (0.104)		0.017 (0.017)	0.043 (0.030)	0.54	0.152	0.626	
2008Q3–2016Q2	0.246 (0.197)	0.713*** (0.102)		0.184*** (0.048)	0.043 (0.051)	0.71	0.493	0.453	

Notes: The survey of professional inflation forecasts (CPI_CW) is used to measure $E_t \pi_{t+1}$. Other notations follow Table 1.

Third, we examine the estimation results for alternative model specifications when $E_t y_{t+1}$ is replaced by $E_{t-1} y_t$ and y_{t-1} respectively. Because different forms of real economic variable *y* have been used in the literature, we carry out this excise to examine whether our finding of the forward-looking behavior in inflation is robust to the alternative forms of *y*. The results in Table 6 also suggest that expectations (in particular inflation expectations) played a very limited role prior to 2008 and a significant role thereafter.

Table 6 Estimation results of alternative model specifications

Panel A: $MP_t = \alpha_0 + \sum_{i=1}^{n} \beta_i MP_{t-i} + \alpha_\pi E_t \pi_{t+1} + \alpha_y E_{t-1} y_t + \varepsilon_t$

Sample	α_0	β_1	β_2	α_π	α_y	$\overline{R^2}$	*p*-endo	*p*-auto	*p*-J
Money supply rule, $MP_t = M2_t$(lag order=2)									
2001Q1-2016Q2	0.124 (1.838)	1.091*** (0.147)	-0.356*** (0.130)	-0.707** (0.276)	0.703* (0.360)	0.78	0.004	0.310	0.160
2001Q1-2008Q2	5.382* (2.684)	1.041*** (0.134)	-0.394** (0.147)	-0.094 (0.168)	0.099 (0.305)	0.63	0.199	0.104	
2008Q3-2016Q2	0.695 (4.359)	1.010*** (0.195)	-0.263 (0.183)	-1.149* (0.638)	0.760 (1.146)	0.80	0.030	0.848	0.236
Interest rate rule, $MP_t = CHIBOR_t$(lag order=1)									
2001Q1-2016Q2	0.887** (0.412)	0.701*** (0.090)		0.110*** (0.030)	-0.052 (0.040)	0.66	0.230	0.616	
2001Q1-2008Q2	0.364 (0.869)	0.743*** (0.168)		0.018 (0.042)	0.019 (0.073)	0.52	0.819	0.490	
2008Q3-2016Q2	1.030** (0.377)	0.657*** (0.094)		0.238*** (0.047)	-0.095** (0.040)	0.72	0.205	0.310	

Panel B: $MP_t = \alpha_0 + \sum_{i=1}^{n} \beta_i MP_{t-i} + \alpha_\pi E_t \pi_{t+1} + \alpha_y y_{t-1} + \varepsilon_t$

Sample	α_0	β_1	β_2	α_π	α_y	$\overline{R^2}$	*p*-endo	*p*-auto	*p*-J
Money supply rule, $MP_t = M2_t$(lag order=2)									
2001Q1-2016Q2	1.900 (1.232)	1.137*** (0.145)	-0.340** (0.136)	-0.562*** (0.201)	0.301** (0.145)	0.78	0.008	0.616	0.083
2001Q1-2008Q2	5.709*** (1.806)	1.029*** (0.134)	-0.385** (0.147)	-0.086 (0.104)	0.056 (0.112)	0.63	0.114	0.055	
2008Q3-2016Q2	3.096 (2.365)	1.077*** (0.144)	-0.211 (0.198)	-0.881* (0.439)	0.141 (0.603)	0.82	0.048	0.979	0.124
Interest rate rule, $MP_t = CHIBOR_t$(lag order=1)									
2001Q1-2016Q2	0.756*** (0.264)	0.703*** (0.089)		0.108*** (0.027)	-0.033 (0.023)	0.67	0.746	0.525	
2001Q1-2008Q2	0.649 (0.587)	0.704*** (0.149)		0.032 (0.033)	-0.006 (0.037)	0.52	0.349	0.297	
2008Q3-2016Q2	1.066*** (0.297)	0.652*** (0.095)		0.259*** (0.051)	-0.101*** (0.035)	0.72	0.077	0.222	

Notes: Survey of professional inflation forecasts (CPI_CW) is used to measure $E_t\pi_{t+1}$. $E_{t-1}y_t$ is one lag of $E_t y_{t+1}$, which is the expected real GDP growth rate from the survey of professional forecasts. Other notations follow Table 1.

Fourth, we estimate an augmented model with the real effective exchange rate as an additional regressor to the baseline model. It is an implicit goal of the PBOC is to maintain a stable exchange rate, so the exchange rate could well be an important reaction factor for the central bank. The estimation results for this exercise are reported in Table 7. They show that the baseline results barely change with the addition of exchange rate.

Table 7 Estimation results in the augmented model with exchange rate

$$MP_t = \alpha_0 + \sum_{i=1}^{n} \beta_i MP_{t-i} + \alpha_\pi E_t \pi_{t+1} + \alpha_y E_t y_{t+1} + \alpha_e s_t + \varepsilon_t$$

Sample	α_0	β_1	β_2	α_π	α_y	α_e	$\overline{R^2}$	p-endo	p-auto	p-J
Money supply rule, $MP_t = M2_t$(lag order=2)										
2001Q1–2016Q2	-0.967 (1.464)	0.986*** (0.120)	-0.204* (0.112)	-0.654*** (0.174)	0.694*** (0.239)	0.091** (0.044)	0.81	0.003	0.253	0.399
2001Q1–2008Q2	6.182*** (2.186)	1.039*** (0.119)	-0.448*** (0.146)	-0.037 (0.112)	0.098 (0.232)	-0.045 (0.043)	0.62	0.603	0.014	
2008Q3–2016Q2	-6.222** (2.955)	0.557** (0.261)	-0.124 (0.124)	-1.370*** (0.336)	2.297*** (0.819)	0.073 (0.058)	0.87	0.036	0.201	0.470
Interest rate rule, $MP_t = CHIBOR_t$(lag order=1)										
2001Q1–2016Q2	1.076** (0.435)	0.704*** (0.094)		0.112*** (0.030)	-0.072* (0.040)	-0.014 (0.010)	0.67	0.791	0.718	
2001Q1–2008Q2	0.820 (0.782)	0.683*** (0.174)		0.029 (0.032)	-0.019 (0.058)	0.011 (0.067)	0.52	0.859	0.234	
2008Q3–2016Q2	1.279** (0.602)	0.660*** (0.104)		0.208*** (0.052)	-0.110 (0.065)	-0.015 (0.016)	0.71	0.735	0.382	

Notes: st in the regression model denotes real effective exchange rate (REER) obtained from the Bank of International Settlements and calculated as the weighted averages of bilateral exchange rates adjusted by relative consumer prices. We use the year-on-year REER growth rate in the estimations. The survey data of professionals (CPI_CW) are used to measure expectations in all regressions. Instrumental variables in the IV estimations include four lags of each of the regressors in the model (REER is treated as an exogenous variable).

The serial correlation problem in these estimations does not arise here. By design, the lag order specification in our regressions avoids a significant serial correlation problem. Overall, the results of the robustness exercises support the baseline finding that expectations generally play little role before 2008 and that Chinese monetary policy displays forward-looking behavior after 2008.

5 Conclusions

This paper empirically investigated the nature of Chinese monetary policy reaction function using directly observed forecasts (survey data) from 2001Q1 to 2016Q2 as measures of expectations in the underlying model. The findings suggest expectations played little role in the Chinese monetary policy reaction before 2008, but began to play a significant role thereafter. This finding is robust whether the expectations series used relates to individual consumers (households) or professional forecasters. We also find that the People's Bank of China promotes economic growth in a procyclical way, but pursues a countercyclical policy for inflation.

Our results provide novel insights into Chinese monetary policy. They augment, for example, the work of Zhang (2009), who examines the money supply rule and interest rate rule for China in a DSGE model. The simulation exercises in that paper assumed a forward-looking monetary policy reaction system for China. By providing more information on formulation of the Chinese monetary policy analysis framework, we show that the forward-looking behavior was extremely weak before 2008. Thus, any assumption of forward-looking behavior in Chinese monetary policy analysis should be used with great caution in discussing the period before 2008.

Our empirical findings contradict Fan *et al*. (2011), who argue that monetary policy in China has distinct effects on the future inflation rate and real output. Our results also warrant caution in using a forward-looking Taylor rule to describe the Chinese monetary policy behavior as in Xie and Luo (2003) and Zheng *et al.* (2012).

The imposition of the rational expectations proxy through the use of actual future inflation, together with the selection of instruments in the presence of serial correlation, may account for these differing results.

Our subsample estimation results (statistical significance on the forward-looking variables) indicate that the interest rate rule dominates monetary policy reaction behavior in China throughout the post-2008 period. This reflects an important shift in Chinese monetary policy implementation from traditional quantitative adjustment to price-based adjustment as also evidenced by (Angrick and Yoshino, 2018).

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