



**A NEW KEYNESIAN MODEL FOR ANALYSING MONETARY POLICY IN
MAINLAND CHINA**

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Abstract

This paper adopts a three-equation New Keynesian model to evaluate the appropriateness of China's monetary policy framework. Our simulation results show that a hybrid rule that relies on both interest rate and quantity of money to conduct monetary policy appears to be more suitable than its alternatives at the current stage of economic and financial market development. Our simulation results also show that a sharp appreciation of the renminbi exchange rate would be disruptive to the inflation and output processes of the economy, despite its effectiveness in curbing inflation.

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The views and analysis expressed in this paper are those of the authors, and do not necessarily represent the views of the Hong Kong Monetary Authority.

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Executive Summary:

- *Empirical observations suggest that due to structural impediments and limited developments of the financial market, it may not be effective for the People's Bank of China (PBoC) to use only interest rate to conduct monetary policy. However, by relying on the quantity targets of monetary aggregates alone, the PBoC would also be deprived of using the interest rate instrument as a tool to fine-tune the economy in the interim once these targets are set. It thus appears that a hybrid monetary policy rule that applies instruments of both quantity and price may be preferable at the current stage of economic and financial market development.*
- *This paper adopts a three-equation New Keynesian model to assess whether the current monetary policy framework in Mainland China is appropriate. The three-equation model includes a forward-looking Phillips curve, an IS curve, and a monetary policy reaction function based on a monetary policy rule.*
- *Our model simulations show that the hybrid rule has the lowest volatilities in the processes of inflation and output. Therefore, it should be preferable to the alternative rules such as an interest rate rule and a quantity of money rule when implementing monetary policy in China.*
- *Our simulation analysis also has important policy implications. Although the exchange rate policy may have a limited role in helping decelerate rapid economic growth, it is effective in helping curb inflation. The authorities could thus take advantage of this feature of the exchange rate policy by adjusting the pace of the renminbi appreciation when facing rising inflationary pressures.*

I. INTRODUCTION

The Law of People's Bank of China (PBoC) states that the objective of China's monetary policy is to maintain price stability so as to promote economic growth.¹ The policy instruments at disposal for the PBoC to achieve these policy objectives include reserve requirement ratio, central bank base interest rates, re-discounting, central bank lending, open market operations, and other administrative policy instruments (including window guidance) specified by the State Council. These legal mandates of the PBoC are similar to those of many industrial economies, although the PBoC does not have operational independence as enjoyed by other major central banks in the world. In reality, China's monetary policy appears to have more targets than those mandated by the Law. According to Governor Zhou Xiaochuan, the PBoC targets not only price stability and economic growth but also unemployment and balance of payments. Furthermore, it has the responsibility to promote financial liberalisation and financial sector reform. To achieve these objectives, the PBoC applies "instruments of both quantity and price in nature" to conduct monetary policy, largely reflecting severe structural impediments of a transition economy and the limited developments in financial markets.²

An interesting set of research questions naturally arises: How do we evaluate the effectiveness of the current monetary policy framework in China? Is the approach applying both instruments of quantity and price in nature more effective than a single instrument policy rule such as the Taylor rule or the quantity of money rule? What is the role of the renminbi exchange rate in managing economic overheating in the current round of economic stabilisation?

In order to answer these questions, we first apply a small three-equation New Keynesian macroeconomic model to assess quantitatively the appropriateness of the existing monetary policy regime in China. Although the model is small with only three equations, it has some appealing properties: First, it is general equilibrium as the key variables concerned are endogenously determined. Secondly, it has a New Keynesian emphasis on nominal and real rigidities and a role of aggregate demand in output determination. Thirdly, the model is influenced by some elements of the real business cycle model as random shocks affect each endogenous variable. Finally, the model allows the incorporation of forward-looking elements with rational expectations.

¹ We will use China for Mainland China henceforth.

² The phrase in quotation marks is translated from Chinese by the authors from "Opinion", *Caijin* (Finance and Economics) Magazine, 25 December 2006. Indeed, because of these multiple targets, inflation targeting framework is not a viable option for China at this juncture.

Although these three equations have an origin from the first order conditions of open-economy dynamic stochastic general equilibrium (DSGE) models, the specifications of these equations are not necessarily tied down completely by the theoretical construct. In practice, these equations are often modified so as to capture the reality of the economy. Thus, it can be interpreted that the three-equation model engages economic theory but does not completely wed it (Leeper, 2003). Applying such a model-based approach to monetary policy analysis, we are also able to conduct policy simulations based on the estimated coefficients from actual data. It is hoped that these policy simulations will shed light on some important policy debates on China's monetary policy.

The rest of the paper proceeds as follows: Section II discusses the rationales behind the price and quantity approach to monetary policy making on the Mainland. Section III presents the three-equation model and discusses issues on model evaluation and selection. Section IV conducts policy simulations based on the monetary reaction function of a hybrid rule that incorporates elements of both quantity and price. Section V concludes the paper.

II. THE MONETARY POLICY FRAMEWORK IN CHINA

The process of setting the monetary policy framework in China can be probably described as follows: The PBoC first sets numerical quantity of money supply and credit growth as the intermediate targets at the beginning of each year (Peng, *et al*, 2006 and Laurens and Maino, 2007). These intermediate quantity targets are then monitored closely during the course of the year. Deviations from these targets are fine-tuned by a number of policy instruments such as reserve requirements, open market operations, policy interest rates, and moral suasion (or administrative and window guidance measures). Laurens and Maino (2007) argue that this approach to monetary policy, though second best, seems to be quite appropriate for China at the current stage of economic transition and financial market developments. Indeed, as shown in Figures 1 and 2, neither a standard Taylor rule (Taylor, 1993) nor a quantity of money rule in the spirit of McCallum (2003) tracks PBoC's policy rate and M2 growth well.³

³ Not shown here, it appears that various estimates of these two standard policy rules specification give us similar shapes of the simulated Taylor and McCallum rules.

Figure 1: A Standard Taylor Rule⁴

$$R_t = r_t^* + \pi_t + 0.5(\pi_t - \pi_t^*) + 0.5\hat{Y}_t$$

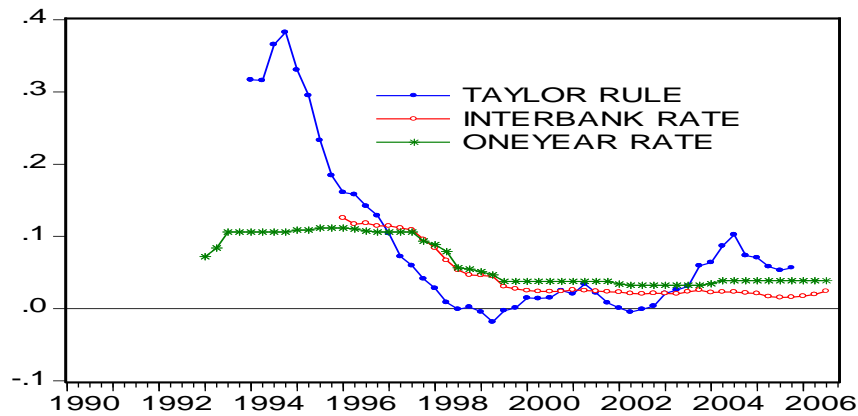
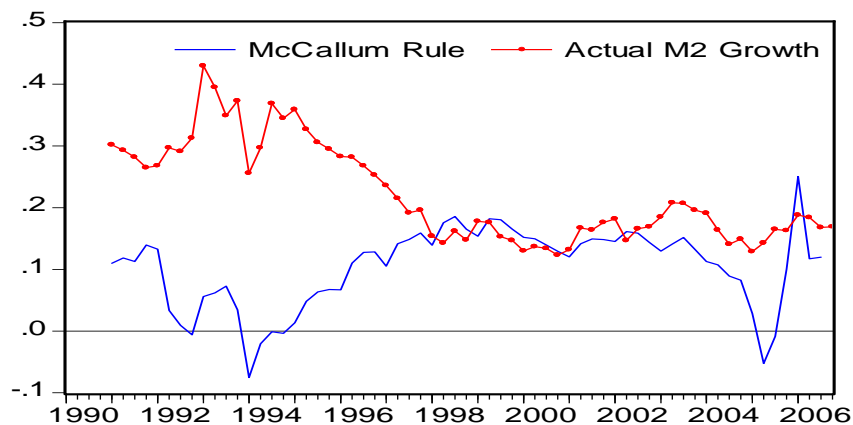


Figure 2: The McCallum Rule⁵

$$M_t = \Delta x_t^* - \Delta v_t + 0.5(\Delta x_t^* - \Delta x_{t-1})$$



Why is the interest rate rule alone not enough?

Structural impediments such as the emerging banking system and market segmentations may have made the interest rate rule alone inadequate as the monetary policy reaction function at this stage. First, the credit channel of monetary policy transmission via China's banking system does not appear to be effective. Despite the

⁴ Note that r , π , and Y are real interest rate, inflation rate, and real GDP, respectively. Superscript “*”, indicates a target or equilibrium value of r or π . Symbol “^” indicates the deviation from the potential real GDP growth rate.

⁵ Note that M denotes nominal money growth (measured by year-on-year growth in M2), Δx_t and Δx_t^* the actual and target GDP growth in nominal terms, and Δv_t the growth in money velocity.⁵

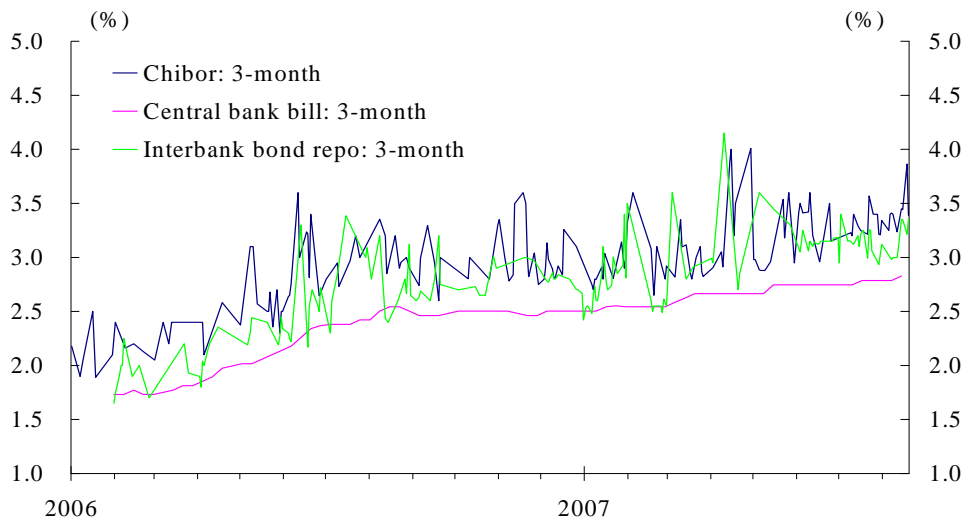
increasing importance of direct financing, China's financial structure continues to be dominated by banks. The banking sector accounts for the largest share of financial assets and intermediates, about 75% of financial capital, suggesting that the credit channel remains the key to monetary transmission.⁶ While the efficacy of the credit channel to monetary policy transmission may have been improved in recent years, as indicated by a sharp drop of the non-performing loans from the estimated 40%-50% of the total banking assets in the late 1990s to less than 7% in 2006, operational reforms in commercial banks, especially those large state-owned commercial banks, have just begun and most banks are slow to use the interest rate instrument to price risks. For example, Podpiera (2006) finds that the lending decisions by the four largest state-owned commercial banks continued to be driven by the availability of funds (savings deposits), rather than by a careful screening of borrowers' risk profiles. This suggests the role of interest rates in allocating capital and in pricing risks remains inadequate despite years of reforms and increased pace of interest rate liberalisation.⁷

Market segmentations may have also prevented effective transmissions of monetary policy via the interest rate policy. China's money markets consist of three submarkets. The first one is the interbank market where banks lend funds among themselves from overnight to up to four months. The second one is the interbank bond market where PBoC bills, fiscal bonds, and policy and commercial bank bonds are issued. This is by far the most liquid market (Peng, *et al*, 2006). The third component is the bond repo-market where short-term borrowing is often conducted. Although less liquid than the interbank bond market, it is more liquid and less volatile than the interbank market. Regulatory restrictions, though having been progressively relaxed over time, may have limited arbitrage activities among them (Figure 3). Indeed, market segmentation may have also contributed to the lack of a benchmark term structure of interest rates fundamental to pricing bonds and other debt instruments, despite some promising initial estimates (Chen and Yeung, 2006).

⁶ The estimate is from the McKinsey Global Institute (2006).

⁷ Interest rate has largely been liberalised after the removal of ceilings on lending rates and of a floor on deposits in October 2004. However, a floor is retained for lending rates and a ceiling for deposit rates, though differentiated by maturity and size of the deposits. Money market rates are mostly liberalised. However, interest rate for bond issues is still regulated. Nevertheless, interest rate will have greater role in conducting monetary policy going forward.

Figure 3: Short-term Interest Rate in China



The limited transmission of monetary policy via interest rate is also confirmed by some empirical findings. Using a vector autoregression framework, Laurens and Maino (2007) find that there is a vague relationship between inflation and policy interest rate, implying the interest rate policy alone may be inadequate to help achieve the final target of price stability.

Why is the quantity of money rule alone not enough, either?

Geiger (2006), in an informative analysis on China's monetary policy targets, instruments, and effectiveness, shows that the intermediate target of M2 is often missed, although the final targets of growth and inflation are met or exceeded, particularly after the 1994-95 high inflation episode (Table 1). Some have attributed these misses of intermediate targets to the unstable money multiplier and some more recently to the pegged exchange rate regime. Green and Chang (2006) find that there has not been a relationship between growth in both reserve money (M0) and M2, despite the ability of the PBoC to control the growth of reserve money. Indeed, the unstable money multiplier may help explain the missing link. For example, Laurens and Maino (2007) find that there has been a trend of irregular deceleration in the money multiplier since 1994, reflecting technological progress related to the payment systems, financial liberalisation, and the opportunity costs of holding money. Furthermore, their VAR analysis indicates that money does not have any short-run impact on output, although there is a limited impact of interest rate on output.

Table 1: Intermediate Policy Targets

	M1 growth (YoY)		M2 growth (YoY)		Inflation rate		GDP growth rate	
	target	actual	target	actual	target	actual	target	actual
1994	21	26.2	24	34.5	10	24.1	9	13.1
1995	21-23	16.8	23-25	29.5	15	17.1	8-9	10.9
1996	18	18.9	25	25.3	10	8.3	8	10.0
1997	18	16.5	23	17.3	6	2.8	8	9.3
1998	17	11.9	16-18	15.3	5	-0.8	8	7.8
1999	14	17.7	14-15	14.7	2	-1.4	8	7.6
2000	15-17	16	14-15	14	1	0.4	8	8.4
2001	13-14	12.7	15-16	14.4	1--2	0.7	7	8.3
2002	13	16.8	13	16.8	1--2	-0.8	7	9.1
2003	16	18.7	16	19.6	1	1.2	7	10.0
2004	17	13.6	17	14.6	3	3.9	7	10.1
2005	15	11.8	15	17.6	4	1.8	8	10.4
2006	14	17.5	16	16.9	3	1.5	8	10.7
2007			16		3	2.2	8	10

Source: Geiger (2006), CEIC, People's Bank of China, and National People's Congress.

While the findings of the unstable money multiplier are well documented, the argument that links the misses of intermediate targets to the pegged exchange rate system has been controversial.⁸ First, the PBoC has been able to use open market operations to sterilise the effect of net capital inflows on monetary aggregates. Second, it appears that sterilisation operations are largely effective, as there is no visible sign that domestic interest rates have been driven up because of the increasing costs of large scale of sterilisation operations.

However, these pieces of empirical evidence do not imply there is no relationship between money and inflation in the long run. In fact, a stable statistical relationship between money and inflation in the long run has been consistently found (Gerlach and Kong, 2005 and Laurens and Maino, 2007), suggesting that the intermediate targets for monetary aggregates may have played a useful operational role in helping stabilise expectations of inflation in the long run.

The empirical evidence surveyed appears to indicate that neither the quantity of money nor interest rate is adequate enough to be relied upon to conduct monetary policy in China. But does it imply that a hybrid approach would work? At the surface, it appears that the hybrid approach would allow the policy makers to take advantage of the benefit of using the intermediate targets to anchor inflation expectations, while it also allows the PBoC to use the interest rate instrument to fine-tune the economy in the interim so as to achieve the ultimate objective of monetary policy, that is, price stability and economic growth. Although appealing, there has been little empirical evidence to demonstrate quantitatively that this is indeed the case. Next section takes this

⁸ See Goldstein and Lardy (2004).

challenge and applies a three-equation New Keynesian model for China to evaluate whether these hypothetical attributes from the hybrid approach to monetary policy can be indeed justified.

III. A MODEL-BASED APPROACH TO MONETARY ANALYSIS FOR CHINA

In this section, we modify the three-equation New Keynesian model, as illustrated by Berg *et al* (2006), by allowing both rules of interest rate and quantity of money in order to capture the unique feature of China's monetary policy framework. Specifically, the three equations refer to a Phillips curve with both forward and backward-looking expectations, an IS curve to capture aggregate demand, and a monetary policy reaction function to steer the economy back to equilibrium via the instruments at the disposal of the monetary authority. In our case, the monetary reaction function contains a hybrid rule of interest rate and quantity of money.

The Model

The three-equation model of the New Keynesian model with a hybrid monetary policy rule is described in Table 2, together with coefficient estimation and parameterisation.

The Phillips curve: The generalised Phillips curve specified in Table 2 contains both forward- and backward-looking elements of inflation, in addition to the standard explanatory variables such as real GDP gap and real exchange rate. The forward-looking elements of inflation come from the forward-looking behaviour of firms in price setting. Empirical findings also support the inclusion of forward-looking variable in China's Phillips curve estimation. For example, Scheibe and Vines (2005b) find that the Phillips curve for China with forward-looking inflation expectations tends to provide a better fit than those only with backward-looking variables.⁹

⁹ Funke (2005) also estimates a Phillips curve for China using annual data from 1977 to 2003. While both the lead and the lag of inflation rate are used, the estimated magnitude appears to be quite different from results found in Scheibe and Vines (2006). Our estimation is closer to that of Scheibe and Vines (2006) probably because of the same data frequency.

**Table 2: Estimation and Parameterization of the Three-Equation Model
(t-statistics are in parentheses)**

Equation	Parameter	Description	Value (t-st.)	R^2
Phillips curve	$\pi_t = \alpha_1 E_t \pi_{t+4} + (1 - \alpha_1) \pi_{t-1} + \alpha_2 \hat{Y}_{t-1} + \alpha_3 (z_t - z_{t-1}) + \varepsilon_t^\pi$			
	α_1	Lead of inflation	0.20 (31.71)	0.97
	$1 - \alpha_1$	Lag of inflation	0.80	
	α_2	Lag of output gap	0.08 (3.14)	
	α_3	Exchange rate changes	0.12 (10.60)	
IS curve	$\hat{Y}_t = \omega_1 E_t \hat{Y}_{t+1} + \omega_2 \hat{Y}_{t-1} - \omega_3 \hat{r}_{t-1} + \omega_4 \hat{m}2_{t-1} + \omega_5 (z_t - z_{t-1}) + \omega_6 \hat{Y}_t^w + \varepsilon_t^y$			
	ω_1	Lead of output gap	0.10	0.98
	ω_2	Lag of output gap	0.91 (44.35)	
	ω_3	Real interest rate gap	0.04 (4.64)	
	ω_4	Lag of money growth gap	0.06 (7.24)	
	ω_5	Exchange rate changes	0.02 (2.07)	
	ω_6	World output gap	0.08 (10.00)	
Quantity of money rule	$M2_t = M2_t^* + \theta_1 M2_{t-1} - \theta_2 \hat{Y}_t - \theta_3 (\pi_t - \pi_t^*) + \varepsilon_t^m$			
	θ_1	Lag of nominal money growth	0.88 (21.15)	0.86
	θ_2	Output gap	0.16 (3.59)	
	θ_3	Inflation	0.06 (1.55)	
Interest rate rule	$R_t = R_t^* + \phi_1 R_{t-1} + \phi_2 E_t (\pi_{t+4} - \pi_{t+4}^*) + \phi_3 \hat{Y}_t + \phi_4 (z_t - z_{t-1}) + \varepsilon_t^r$			
	ϕ_1	Interest rate lag	0.82	
	ϕ_2	Lead of inflation	0.15	
	ϕ_3	Output gap	0.51	
	ϕ_4	Exchange rate changes	0.16	

With respect to notations, π_t denotes CPI inflation measured as the annualised quarterly change in percentage terms; E is expectation operator and $\pi 4_t$ is four-quarter or year-on-year CPI inflation. Specifically, $\pi_t = 400(\log CPI_t - \log CPI_{t-1})$ and $\pi 4_t = 100(\log CPI_t - \log CPI_{t-4})$.¹⁰ The magnitude of the coefficient, α_1 , determines the degree of forward-looking elements in explaining the inflation process. z_t denotes the log of the real effective exchange rate (REER), with an increase implying a depreciation. ε_t^π is a white noise.¹¹ The “hat” symbol “^” above a variable denotes the deviation of the variable from its equilibrium value. For example, \hat{Y}_t is output gap, namely, $\hat{Y}_t = Y_t - Y_t^*$, with Y_t being the log of real GDP and Y_t^* the log of equilibrium (or potential) real GDP.

The IS (Demand) curve: The IS curve contains both forward- and backward-looking real GDP gaps, external demand gaps, real interest rate, real money growth gap, and changes in real exchange rate. With respect to notation, \hat{r} denotes the deviation of real interest rate from the equilibrium one. The real interest rate is defined as $R_t - E_t \pi_{t+1}$ with R_t denoting the short-term nominal policy rate, measured by nominal lending rate in the case of China. \hat{Y}_t^w is world output gap. Different from the specification in Berg *et al* (2006), we use the change in real exchange rate, rather than the deviation from the equilibrium exchange rate, to capture the exchange rate effect on output gap, because of the controversies in estimating the equilibrium exchange rate for China. Note that both real interest rate and real money growth gap enter the IS equation because of our specification of the monetary reaction function. Specifically, the real money gap is defined as the difference between the observed or actual money supply and the equilibrium money demand. Following the procedure of Masuch, Pill and Willeke (2001), we define the equilibrium money demand as a cointegration relationship among the logarithms of money, output and CPI inflation, that is, $M_{eqm}^* = \alpha_0 + \alpha_1 y_t + \alpha_2 CPI_t$. The Johansen cointegration test does show there is a cointegration relationship among these three variables.¹² Once the equilibrium real money demand is estimated, the money gap is then defined as, $\hat{M}_t = (M_t - M_{eqm}^*) / M_{eqm}^*$.¹³

¹⁰ The relationship between $\pi 4_t$ and π_t and its lags can be derived as $\pi 4_t = 0.25(\pi_t + \pi_{t-1} + \pi_{t-2} + \pi_{t-3})$ after some algebraic manipulation.

¹¹ For consistency, ε will be denoted as a white noise error term for other equations but with a distinct superscript.

¹² It is not presented here to save space.

¹³ In estimating the models, we use the deviation of actual money from its equilibrium as a proxy for the money growth gap. Note that $M2$ stands for money growth in nominal terms and $m2$ in real terms.

Monetary policy reaction function: The monetary policy reaction function consists of two rules, one is the quantity of money rule and the other is the interest rate rule. The quantity rule of money is specified empirically to allow it to target both potential GDP and the equilibrium inflation rate.¹⁴ Indeed, this rule has an origin from Taylor (1979) where he estimates a macroeconomic model with money supply rather than interest rate as the instrument. Minimizing the loss function of inflation and output gap, he finds that the optimal monetary policy, with monetary aggregate as the instrument, can be set as a function of output gap and inflation. Although Taylor has started to use interest rate as the instrument since the mid 1980s, he claims that monetary aggregate can still be a reasonable monetary instrument in emerging market economies in a recent paper (Taylor, 2000).

The interest rate rule is an expanded Taylor's rule, which is determined by the lagged interest rate (R_{t-1}) and a linear combination of the equilibrium interest rate, current annual inflation rate, deviation of the expected annual inflation rate from the target, GDP gap, and changes in the real exchange rate. The expanded Taylor rule specifies that the PBoC sets the nominal rate as a function of changes in real exchange rate, deviations of inflation from its target and output gap. With respect to notations, R_t and R_t^* denote, respectively, actual and equilibrium nominal interest rate. π_t^* is target inflation rate implicitly set by the PBoC (it is 3% in our simulation). Different from the specifications in Berg, *et al* (2006), we add changes in real exchange rate. This addition is justified by the empirical finding that changes in policy interest rate appear to react to those in real exchange rate because of a high degree of openness of the economy (Scheibe and Vines, 2005a). To some extent, the combination of a quantity rule and a price rule in our case is similar to a monetary conditions index. Normally, once the quantity of money is determined and if market clears, one can immediately find the corresponding interest rate. This is perhaps the reason why only one rule is needed for such an economy. However, in the case of China at this stage of economic and financial developments, market may not clear because of structural impediments aforementioned. As a result, it is possible that both rules may have a role to play.¹⁵

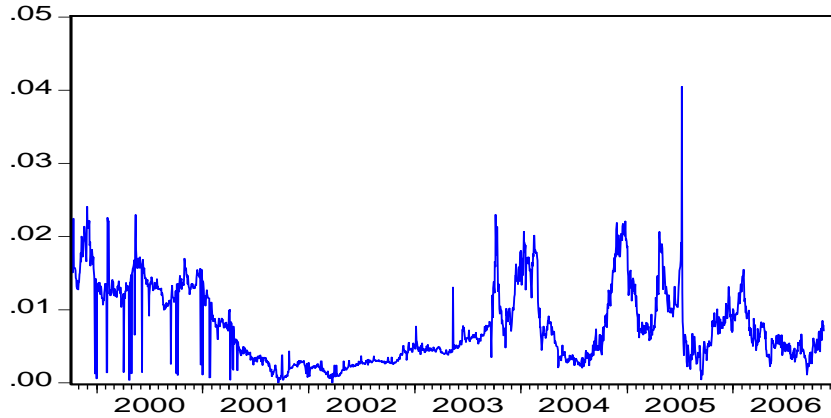
The path of nominal exchange rate: Because of capital controls, the interest rate parity condition may no longer hold. Thus, China's domestic financial markets are segmented from the rest of the world. Monetary policy can maintain independence and the nominal exchange rate can also be set independently and used as a policy instrument. As

¹⁴ A typical McCallum rule (McCallum, 1988) appears to perform rather poorly for China, largely because of the instability of the velocity of money. We have fit an expanded McCallum rule to include real exchange rate and foreign exchange reserves, following the suggestions of Burdekin and Siklos (2005). The estimated coefficients for real exchange rate and reserves often have wrong signs.

¹⁵ This is also the reason why there is little concern among market watchers as to which interest rate to use when measuring China's monetary conditions.

indicated by Figure 4, there have been large and persistent interest differentials calculated from the uncovered interest rate parity condition.¹⁶ Because of the effectiveness of capital controls, the exchange rate policy can still be used as an instrument for macroeconomic management. We will return to the exchange rate issue in the section on policy simulations.

Figure 4: Absolute Value of Deviation of the Interest Parity Condition



Model estimation and parameterisation: The coefficients in Table 2 are mostly estimated empirically. In cases where empirical estimates have wrong signs or do not lead to convergence in simulations, we then follow theoretical prediction and the general suggestions from Berg, *et al* (2006). Output gap (\hat{Y}_t) is estimated using a production function approach, following the study of He *et al.* (2007). The world output gap (\hat{Y}_t^w) is calculated as percentage deviation of the trade-weighted real GDP of China's ten largest export markets from its HP-filtered trend. The Phillips curve and the IS curve are estimated with the generalized methods of moments (GMM) using quarterly data from 1990 Q2 to 2005 Q4.¹⁷ Following the general suggestions of Berg *et al* (2006), we preset the coefficient for the lead of output at 0.10. Our estimates of output lag lie between 0.75 and 0.95, also consistent with what was found in Laxton and Scott (2000), who claim

¹⁶ See Liu, Otani and Zhang (2006) and Ma and McCauley (2006) for detailed arguments. The deviation of uncovered interest parity (DUIP) condition is expressed as

$$DUIP = \frac{(1 + R_{rmb} / 400) S_t}{(1 + R_{usd} / 400) S_{t,t+k}^e} - 1, \text{ with } R_{rmb} \text{ denoting the 3-month deposit rate of}$$

renminbi in Hong Kong, R_{usd} the 3-month deposit rate of the US dollar in Hong Kong, and $S_{t,t+k}^e$ the expected exchange rate of RMB/USD formed at time t for $t+k$. R_{rmb} before March 2004 is proxied by the 3-month deposit rate of RMB in mainland China. S_t is the cross exchange rate of RMB/USD calculated with the Hong Kong dollar. $S_{t,t+k}^e$ is measured with the 3-month non-deliverable forward exchange rate of RMB/USD.

¹⁷ The instruments include 1-4 lags of output gap, REER growth, real interest rate, inflation rate, world output gap and a constant.

that the sum of the parameters of real interest rate and real exchange rate should be smaller than that of the output gap, largely owing to the limited effect of the interest rate and exchange rate on output because of significant lags in monetary transmission mechanism in most economies.

Note that we use changes in real interest rate, rather than the real interest rate gap, to estimate ω_3 , as the original specification by Berg *et al* (2006) is difficult to estimate empirically.

The interest rate rule is parameterised using the findings from both Scheibe and Vines (2005a) and Xie and Luo (2002). While Scheibe and Vines (2005a) estimate an interest rate rule with real exchange rate as an additional variable for China without forward-looking behaviour, Xie and Luo (2002) estimate a forward-looking Taylor rule, following the specification of Clarida, Gali and Gertler (1998). Following these two studies, we set the coefficient of the lagged nominal interest rate, ϕ_1 , to 0.82. We also set ϕ_2 and ϕ_3 at 0.15 and 0.51, respectively, based on the findings of Xie and Luo (2002). The coefficient for inflation expectation is then 0.15, significantly smaller than one, which is consistent with the specification in the Phillips Curve. We set ϕ_4 at 0.16 so that the coefficient of REER is equal to the sum of the coefficients of lagged REER, similar to the specification of the interest rate rule estimation in Scheibe and Vines (2005a).¹⁸

Following Svensson (1999 and 2000), we assume all exogenous variables to follow AR(1) processes.¹⁹ We set coefficients of the AR(1) processes of world GDP gap (γ_w), US inflation rate ($\gamma_{us\pi}$), US nominal interest rate (γ_{usR}), domestic target inflation rate (γ_π), and long-run nominal policy rate (γ_R) correspondingly at 0.76, 0.96, 0.96, 0.99, and 0.99.²⁰ The estimates of these parameters are obtained by regressing their equilibrium processes (the HP filtered actual data series) on their one-period lags.

¹⁸ Indeed, these preset parameters can be checked by using a formal Bayesian approach to see whether distributions of these priors are consistent with those of posteriors.

¹⁹ The exogenous variables in Svensson (1999 and 2000) include potential output, employment target, foreign inflation, foreign output, and the foreign exchange risk premium.

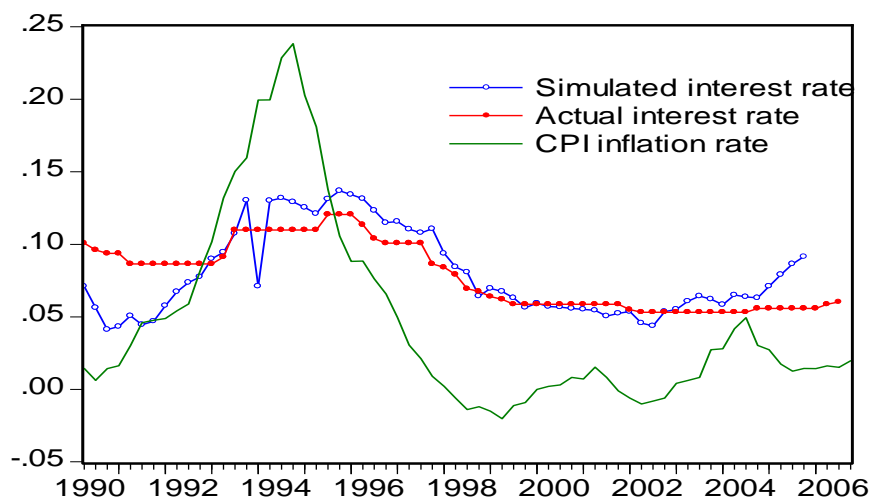
²⁰ We have run the regressions of world output gap on its one-period lag and obtained the estimate of γ_w . Similarly, we have regressed the US inflation rate (CPI growth, 1979Q2-2005Q4) and nominal interest rate (federal funds rate, 1978Q2-2005Q5) on their one-period lags respectively and obtained the estimates of $\gamma_{us\pi}$ and γ_{usR} . We measure the equilibrium values of inflation and nominal interest rate by the HP filtered trends of the actual time series.

Table 3: Parameterization of Exogenous Variables

Equation	Parameter	Description	Value
Potential GDP growth	γ_g	AR(1) coefficient	0.96
US inflation	$\gamma_{us\pi}$	AR(1) coefficient	0.96
US interest rate	γ_{usR}	AR(1) coefficient	0.96
Domestic target inflation	γ_π	AR(1) coefficient	0.99
Domestic equilibrium interest rate	γ_R	AR(1) coefficient	0.99
Domestic equilibrium nominal money growth	γ_m	AR(1) coefficient	0.99
World output gap	γ_w	AR(1) coefficient	0.76

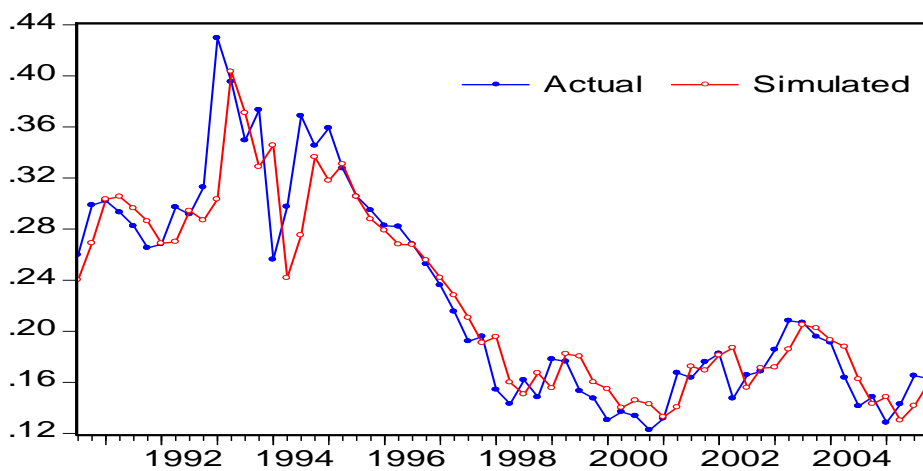
Figure 5 presents the simulated interest rate rule, together with the actual one-year lending rate and the CPI inflation rate. It appears that the extended Taylor rule can capture most turns in the actual interest rate. It is at least better than the simple Taylor rule presented in Figure 1 in section 2, which does not consider expectations and smoothing behaviour. The large decline in the simulated rate in 1994 is due to the exchange rate reform which devalued the nominal RMB exchange rate by about 50% against the US dollar. The extended Taylor rule suggests that that China's monetary policy was probably too tight at the beginning of the 1990s. It seemed to be too loose in 1994-1996 with run-away inflation. In the recent period of 2004-2006, the monetary policy seemed to be accommodative and further tightening may be required.

Figure 5: Actual and Simulated Interest Rate



As shown in Figure 6, the simulated quantity rule of money captures the actual growth in M2 quite closely, suggesting the specification of our quantity rule that targets both output gap and inflation appears to be adequate. Note that the quantity rule of money only includes backward-looking elements and does not allow forward looking variables, following Taylor (1979). However, our estimated coefficient on the lagged growth in M2 does show large persistence in M2 growth, which appears to be consistent with how intermediate targets of money growth is determined in reality. This also partly explains why the simulated rule captures the actual one well.

Figure 6: Simulated Quantity Rule of Money and Actual M2 Growth



Model Evaluation

Taylor (1994) defines the optimal monetary policy rule as the one that minimizes a weighted sum of variances of inflation and output, with the weight attached to inflation and output as the preference that is determined by the monetary authorities. In its simplest form, a loss function of the PBoC can be written as $L(y, \pi) = \text{var}(y_t) + \mu \text{var}(\pi_t)$.²¹ Following this criterion of model evaluation, we calculate the volatilities of inflation and output for the three monetary policy rules from shocks to inflation and output of same magnitude.

The simulations in this paper are undertaken using the software WinSolve. A detailed description of the stochastic simulations with rational expectations can be found in Pierse (2006). WinSolve allows us to use the following methods to generate shocks: Cholesky method, Bootstrap method, user covariance, and general distributions.

²¹ The properties of the loss function can be found in Rudebusch and Svensson (1999).

While the first and second methods produce shocks based on the empirical data, the third one provides the user with the possibility to set the (co-)variance at his or her disposal. The last method generates shocks which are not necessarily subject to normal distribution. The program also provides the choice of using antithetic shocks, which forces the distribution of shocks to be exactly symmetric. Experience shows that when a large number of replications are conducted, the simulation results using non-antithetic shocks are relatively close to those using antithetic shocks. The program also allows a modeller to decide the number of replications and the size of random seed. It appears that the more replications, the lower the standard deviation of simulated variables will be. In order to make simulations comparable, one usually uses the same seed of random shocks so that shocks remain unchanged across simulations. In the simulations below, we use the third approach to generating random shocks. The estimated variances from the actual data series are the basis for those of random shocks in the simulations.

Single replication

In the simulations below, we will conduct the experiments with one replication, assuming only inflation and output are subject to white noise shocks. Each experiment is conducted for 500 periods.

In the first simulation, we assume only the interest rate rule is allowed to respond to shocks in inflation and output and the quantity rule of money is shut off. Specifically, θ_2 and θ_3 are set at zero for the interest rate rule, while θ_1 remains at 0.88. ε_t^M also drops out of the equation.

In the second simulation, we assume only money growth responds to shocks in inflation and output, while nominal interest rate is treated as an exogenous variable. Specifically, ϕ_2 , ϕ_3 and ϕ_4 are set at zero for the quantity rule, while ϕ_1 remains at 0.82. ε_t^R also drops out of the equation.

In the third simulation, we assume both interest rate and money growth respond to shocks in inflation and output. Therefore, a combination of these two rules is employed to manage the economy. Note that in all three simulations inflation and output are subject to the same magnitude of shocks so that the results are comparable.

The standard deviations of inflation and output gap from the three simulations are shown in Table 4. It appears that that inflation and output gap under the hybrid policy rule have the lowest volatilities. While inflation and output gap under the interest rate rule have higher volatilities than those under the hybrid rule, inflation and output gap under the quantity of money rule have the highest volatilities.

Table 4: Standard Deviations of Inflation and Output Gap
(single replication)

	Inflation	Output Gap
Interest rate rule	0.1685	0.1040
Quantity rule	0.1959	0.1390
Hybrid rule	0.1046	0.0665

Multiple replications

The above experiments are conducted with one replication only, suggesting that the responses of inflation and output gap can be highly dependent on the random shocks drawn in each period. In the simulations below, we run each experiment with 100 replications for 500 periods so that the responses of inflation and output gap approach to their true values. The means of standard deviations of inflation and output gap across the 100 replications under these three rules are shown in Table 5. The results obtained here are similar to those in Table 4, that is, inflation and output gap under the hybrid rule have the lowest mean of standard deviations, although the magnitude of these calculated standard deviations have decreased because of the large number of replications. In responses to the same magnitude of random shocks, our simulation results indicate that the hybrid rule consistently gives us the lowest mean of volatilities in inflation and output gap. Therefore, the hybrid rule should be a preferred monetary policy rule.

Table 5: Means of Standard Deviations of Inflation and Output Gap
(multiple replications)

	Inflation	Output Gap
Interest rate rule	0.1599	0.1022
Quantity money rule	0.1876	0.1355
Hybrid rule	0.0987	0.0652

IV. POLICY SIMULATIONS

This section conducts three policy simulations that are relevant to the current policy debates: A) Suppose the economy is one percentage point above its potential level, how would inflation and output gap respond under these three monetary policy rules? B) Is a large nominal exchange rate appreciation useful in helping curb economic overheating? C) How does a sharp appreciation of the renminbi exchange rate compare with the ongoing gradual approach to the renminbi appreciation?

A. Economic Overheating

Suppose the economy is initially growing one percentage point above its potential, how would the economy perform in terms of inflation and output under different monetary policy rules? The responses of inflation and out gap under these three rules are shown in Figure 7 and Figure 8. Given there are no random shocks to the system, these graphs can be considered as impulse response curves to an initial shock to the output gap.

Figure 7: Responses of Inflation under the Three Rules

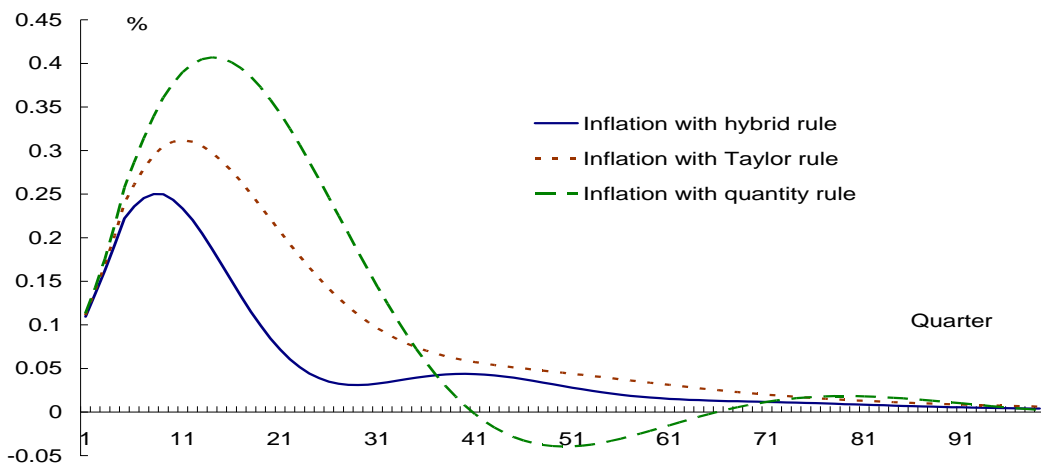
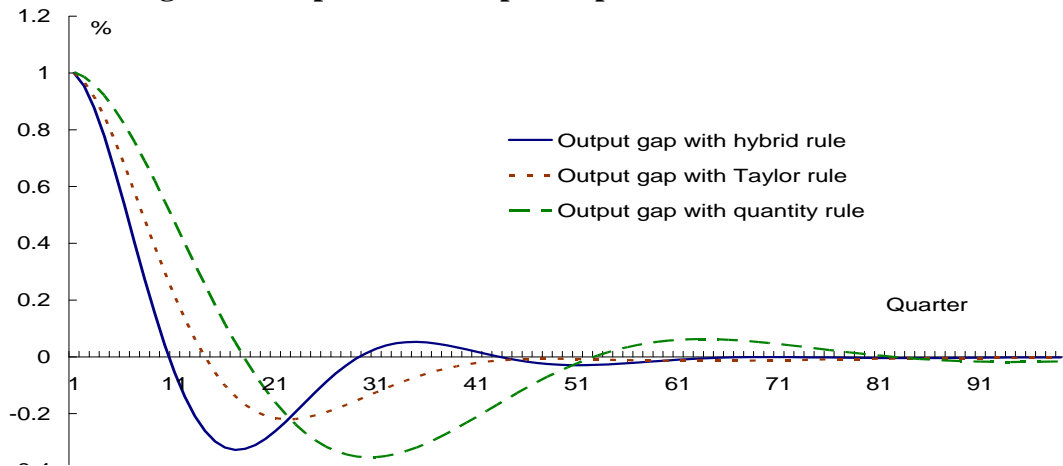


Figure 8: Responses of Output Gap under the Three Rules



As shown in Figure 7, the impulse response of inflation under these three policy rules all rises according to theoretical predictions. Under the hybrid rule, the response is the smallest among these three policy rules, while the response of the interest rule stands in the middle. It appears inflation under the quantity of money rule would have the strongest reaction to economic overheating. For example, the initial response of inflation would shoot up by more than 0.4 percentage point. Similarly, the response of output gap as shown in Figure 8 also returns to equilibrium faster under the hybrid rule

than under the other two rules. These graphical observations are also confirmed by calculation of the sum squared deviations from their corresponding steady states of inflation and output gap. As shown in Table 6, the sum squared deviations of inflation and output gap from their steady states are also the smallest under the hybrid rule and the largest under the quantity of money rule. The sum squared deviations of inflation and output gap under the interest rate rule falls in the middle.

Table 6: Sum Squared Deviations from Steady States of Inflation and Output Gap

	Inflation	Output Gap
Interest rate rule	0.003	0.012
Quantity money rule	0.006	0.019
Hybrid rule	0.001	0.010

B. A Sharp (20%) Appreciation of the Renminbi Exchange Rate

The slow appreciating renminbi exchange rate has been blamed as the key reason behind China's recent macroeconomic problems such as the increasing external imbalance, unsustainable economic growth, and more recently the rapidly rising inflation. Therefore, it has been suggested that the renminbi exchange rate should be altered by a one-off and large appreciation. The simulation below investigates the effects of such a policy in our model. Specifically, we allow the nominal renminbi exchange rate to appreciate sharply by 20% and investigate its impact on output gap and inflation under the hybrid rule. As shown in Figure 9, inflation declines by about 2.4 percentage points in the first quarter, while output gap declines by only 0.5 percentage point over the same period and then quickly rebounds to above its potential. The effect of the nominal appreciation on output was probably weakened by a smaller real exchange rate appreciation because of a decline in domestic inflation relative to foreign ones. In addition, the effect could also be gradually offset by the complex responses with respect to real interest rate and real money growth under the hybrid rule over time. Although this may appear that a large appreciation may not be harmful to the real economic activities, its impact on inflation is quite substantial. This probably reflects China's trade structure that relies increasingly on large imports of raw materials, oil, and other energy products, in addition to its traditional reliance on intermediate goods used in its processing trade sector. Despite its effective role in bringing down inflation, the tradeoff of a large nominal appreciation is that it brings about large shocks to the economy. For example, the sum squared deviations resulting from a 20 percent appreciation on inflation and output gap would be about 16 times as large as those resulting from a 5 percent appreciation in the renminbi exchange rate (Table 7).

These simulation results suggest that a large appreciation of the nominal renminbi exchange is perhaps more effective in addressing a run-away inflation, while its role in bringing the economy back to a sustained path of growth appears to be rather limited. However, the sharp appreciation policy tends to lead to large welfare losses, as it brings about large fluctuations in both inflation and output, as measured by the sum of squared deviations from their steady states. Therefore, it would be detrimental to macroeconomic stability. In addition, our findings also imply that a sharp appreciation of the renminbi may also run the risk of a sharper-than-expected drop in inflation and even a deflation. Therefore, the gradual approach to appreciating the nominal renminbi exchange rate is quite appropriate. Given the risk of deflation, this policy appears to be prudent as well.

Figure 9: A 20% Nominal Appreciation of the Renminbi

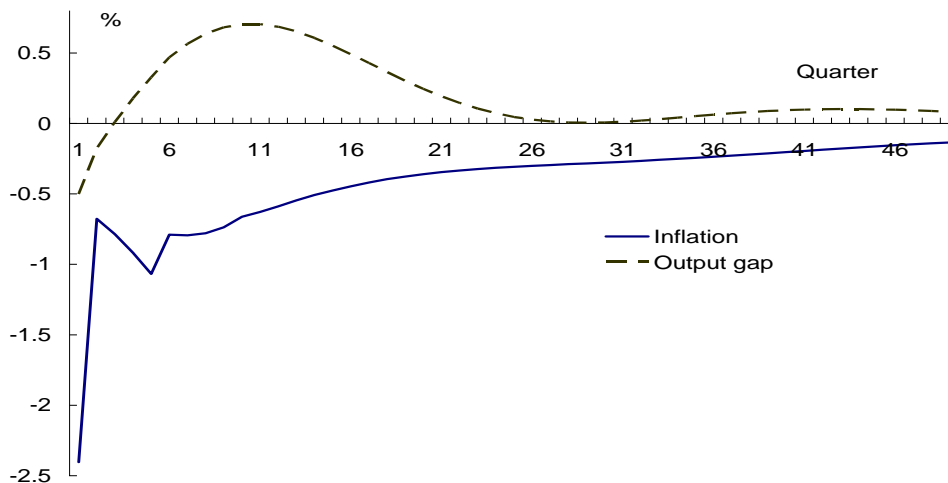


Table 7: Sum of Squared Deviations from Steady States of Inflation and Output Gap (exchange rate appreciation)

Appreciation	Inflation	Output gap
5%	0.0020	0.0006
20%	0.0300	0.0100

C. Comparison with the Gradual Appreciation Approach

While it may not be surprising that a large one-shot nominal appreciation brings about high fluctuations in inflation and output, how does it compare with the ongoing gradual appreciation strategy taken by Chinese authorities? In the experiments below, we compare the responses of inflation and output gap under three experiments: 1) a one-shot sharp nominal appreciation of the renminbi of 30%, 2) a gradual 10%

appreciation per year cumulative to 30% of nominal appreciation in 3 years, 3) a more gradual 5% per year cumulative to 30% of nominal appreciation in 6 years. In experiments 2 and 3, once they reach the 30% cumulative nominal appreciation required, the nominal renminbi exchange rate would remain constant thereafter. As indicated in Figures 10 and consistent with Figure 9, a large nominal renminbi appreciation tends to have a large effect in bringing down inflation. Though still effective in curbing inflation, the gradual appreciation approach tends to provide us with a much less volatile paths of inflation responses than the sharp appreciation approach. Similarly, as shown in Figure 11, the gradual approach to the renminbi appreciation also provides us with lower volatility in output. Similar to what has been found in the previous experiment, the exchange rate policy has a limited effect in slowing rapid economic growth.

Figure 10: Responses of Inflation to Nominal Exchange Rate Appreciation

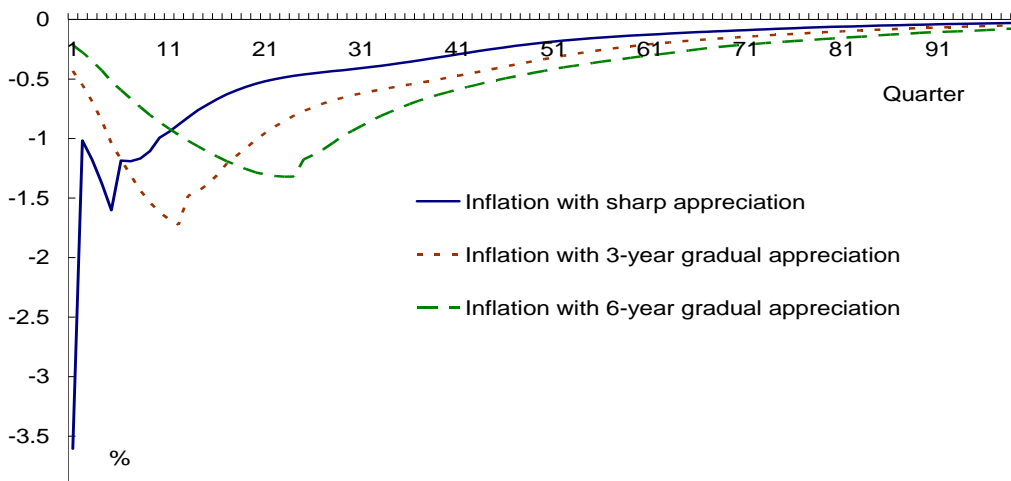
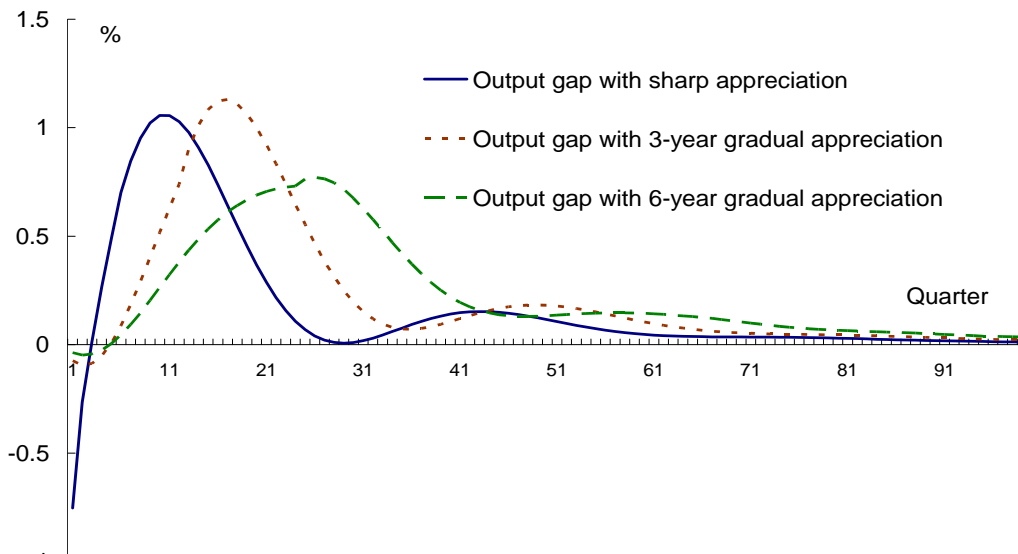


Figure 11: Responses of Output Gaps to Nominal Exchange Rate Appreciation



V. CONCLUDING REMARKS

This paper is perhaps one of the first ones to adopt a three-equation New Keynesian model to analyse China's monetary policy reaction function and to evaluate whether the current monetary policy framework in China is appropriate. Our simulation results seem to demonstrate that the current approach adopted by the PBoC that uses both interest rate and quantity of money to conduct monetary policy is appropriate. Largely because of structural impediments such as the segmentation of financial markets and the emerging modern banking system, it may not be effective for the PBoC to use only interest rate to conduct monetary policy. However, simply relying on the quantity rule of money alone is not adequate, either, as it takes away the interest rate instrument for the PBoC to fine-tune the economy in the interim. Our model simulations do show that the monetary policy rule that combines both interest rate and quantity of money for monetary policy operations brings about the largest welfare gains measured by volatilities in inflation and output gap.

Our simulation analysis also has some important policy implications. First, the exchange rate policy, although effective in helping curb inflation, has a limited role in slowing rapid economic growth. Secondly, a sharp appreciation of the renminbi exchange rate would be too disruptive to the inflation and output processes of the economy. A gradual appreciation, on the other hand, is much less disruptive than a sharp revaluation. Therefore, it should be a preferred policy option. It should be noted that the gradual approach to exchange rate appreciation does not exclude the policy option that the authorities could also adjust the pace of the exchange rate appreciation in light of inflationary pressures of the domestic economy.

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