Examining Monetary Policy Reaction in the People's Republic of China – A Markov Switching Policy Index Approach.

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Abstract

This paper estimates a monetary policy rule for the People's Republic of China (PRC) using a standard OLS estimation and a Markov switching model. As the People's Bank of China (PBOC) generally uses a battery of instruments in the conduct of its monetary policy, these models are estimated using a constructed monetary policy index (MPI) in place of the traditional interest rate. This allows for a better understanding of the role the PBOC has played in the PRC's unprecedented economic growth and its relatively low inflation over the last twenty years. This paper will not only examine the unique characteristics of Chinese monetary policy but may also give a more general insight into the dynamics of monetary policy reactions in other emerging markets and economies in transition.

Keywords: Monetary Policy, Exchange Rate Regime, Taylor Rule, Markov Switching, Structural Breaks

JEL Classification: E50, E58, E32

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1. Introduction

The ever increasing influence of the Chinese economy on the world stage has meant that the analysis of monetary policy and the actions of the People's Bank of China (PBOC) have received a great deal of attention, from both academics and policy makers. Studies of monetary policy in the People Republic of China (PRC) have generally used the standard model of monetary policy analysis. In the canonical New Keynesian (NK) models, monetary policy rules take the form of the Taylor rule (1993). In the Taylor rule, the central bank sets the interest rate as a function of inflation and the output gap (or unemployment rate) by linking the monetary policy instrument to deviations of inflation from its target and of output from its potential. In its simplest form, the rule implies that positive deviations in the inflation gap, or the output gap, would lead to a tightening monetary stance. The traditional rule often uses an interest rate or an exchange rate channel to examine the dynamics of a central bank's monetary policy stance. For example, an increase in the interest rate would raise the cost of investment and therefore reduce aggregate demand. Similarly, an appreciation of the domestic currency would make exports more expensive and therefore reduce aggregate demand (Rudebusch 2006).

Standard economic models such as the Taylor rule are often not applicable to the PRC however. This is because of the unique characteristics of the Chinese economy, namely with regard to the role of the government and the structure and philosophy of the central bank. This makes the measurement of the PRC's monetary policy stance notoriously difficult. There have also been a large number of institutional changes and reforms which make the modelling of Chinese monetary policy cumbersome. The PRC has embarked on a series of bold reforms of its financial sector since 1980 to make the exchange rate more flexible; expand the interbank money, bond, and stock markets; open the banking sector to more competition; and liberalize interest rates (IMF 2014). Meanwhile, the PRC's monetary policy has historically been exercised through quantity controls on bank lending and direct instruments guided by monetary aggregate targets (Laurens and Maino 2007). This further complicates an estimation of a stable monetary policy rule.

The PBOC operates under the dual mandate of *'maintaining the stability of the currency and thereby promoting economic growth'*. While these objectives are similar to that of most central banks in advanced economies, the instruments that the Chinese central bank use to achieve these targets are, in themselves, quite unique. Table 1 gives a brief outline of the main tools at the disposal of PBOC.

[INSERT TABLE 1 HERE]

Since the PBOC has adopted a wide range of monetary policy instruments over the last three decades, including price based instruments, quantity based instruments and administrative instruments, it is likely that no single variable can be used to adequately capture their monetary policy stance. Unlike many advanced monetary authorities, the PBOC has been more reluctant to use the interest rate as an operating target, instead setting intermediate targets for money supply growth and the exchange rate[1]. Consequently, using a standard "Taylor type" monetary policy rule would not be appropriate. Another potential problem is the widespread economic and political change the economy has experienced in the last twenty years. Consequently, studies of the Chinese economy often suffer from the problem of structural breaks, asymmetry and non-linearity in the time series. These issues have been well documented in the literature (see for example Chang et al. 2015, You and Sarantis 2012, Chen et al. 2011). This can make a stable model of monetary policy very difficult to estimate. Moreover, as is typical in a transition economy, some important features, such as the shifting preferences and nonlinearities of policymakers' choices, might play an important role in monetary policy conduct, and a thorough understanding of the PRC's monetary policy will not emerge unless these special characteristics have been effectively taken into account. Therefore, this paper will estimate a set of augmented monetary policy "Taylor type" equations using a monetary policy index (MPI) in place of the interest rate. This equation is then estimated in a Markov switching framework. The exchange rate is also included as the PBOC's intermediate target. Making the necessary adjustments to account for the specifics of the Chinese economy and its central banking

[1] The crawling peg which China adopts is often seen to play a very important role within the Chinese monetary policy framework (Geiger 2008).

system, the paper aims to improve the understanding of how the PBOC reacts to its main policy target variables.

2. The People's Bank of China (PBOC) & Chinese Monetary Policy

2.1 Brief History of PBOC

From 1950 to 1978, the People's Bank of China (PBOC) was the only bank in the PRC and was responsible for both central and commercial banking. Before the Chinese economy "opened up" in 1978, the financial and banking system operated under an almost entirely centralised philosophy. With the introduction of economic reforms, pioneered by Deng Xiaoping, four "independent" banks were established in 1984 to carry out the commercial functions of the PBOC. These four banks however, remained under the remit of the state and so were "independent" in name but not in nature. In the early 1990's, problems arose with these commercial banks in the form of huge amounts of non-performing loans due to a culture of policy lending, with "the big four"[2] being encouraged to support often inefficient state owned companies. In January 1994[3], the Chinese authorities introduced three new policy banks[4] to disburden the commercial banks from the problem of policy lending mentioned above. Prior to 1994, the intermediate targets adopted by the PBOC had been currency in circulation and the portfolio of commercial bank loans. The PBOC also began to release the statistical data for money supply in this year and gradually took it as the intermediate target with the introduction and definition of three new indicators.[5] At the time, the interest rate was not (and still has not, as of 2015) totally liberated and did not serve as the operation target of PRC's monetary policy.

While the State Council announced that the PBOC would function solely as a central bank in 1983, its central bank status was not legally confirmed until March 1995 at the 3rd Plenum of the 8th

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[2] These are the Bank of China (BOC), the China Construction Bank (CCB), The Agricultural Bank of China (ABC) and the Industrial & Commercial Bank of China (ICBC)
[3] The estimation period of this paper begins in 1994, which corresponds conveniently to important institutional changes and reforms in the Chinese financial and banking system.
[4] The three policy banks being Agricultural Development Bank of China (ADBC), China Development Bank (CDB), and the Export-Import Bank of China (Chexim)
[5] M0, M1 & M2

National People's Congress. Since the law officially acknowledged the PBOC as the central bank of the PRC on the 1st of July 1995, many private banks have been established as well as foreign subsidiaries after the ascension into the World Trade Organisation (WTO) in 2001. 1997 saw the establishment of the Monetary Policy Committee (MPC), the consultative body of the PBOC assigned to formulate, adjust and set targets for monetary policy. However, the MPC of the PBOC is very different from the Monetary Policy Committee (MPC) of the Bank of England and the Open Markets Committee (FOMC) of the Federal Reserve, as it only advises on monetary policy rather than determines it. The State Council has the ultimate power to decide the substantial monetary policy measures (Long 2012). Therefore, many of the PBOC's objectives were, and are still, established directly by the government. In 1998, the PBOC underwent major restructuring and all the former provincial and local branches were abolished. In lieu of these, the PBOC opened nine regional branches in Tianjin Shenyang, Shanghai, Nanjing, Jinan, Wuhan, Guangzhou, Chengdu and Xi'an. In 2003, the 10th National People's Congress strengthened the institution even further by approving laws and amendments which gave the PBOC more power in implementing monetary policy for safeguarding the overall stability of the economy and the provision of financial services. This coincided with the establishment of the Chinese Banking Regulatory Commission (CBRC) which was established to regulate and supervise the commercial banking sector. These amendments conclusively defined the PBOC as the central bank we see today and the organizational system was also specified[6].

2.2 Examining the Reactions of the PBOC

Despite the reforms in the banking sector and the increased autonomy that the monetary authority now possess, examining the monetary policy reactions of the PBOC using standard macroeconomic models is hindered by a number of factors. As mentioned, the PBOC does not exclusively use the interest rate as an operating instrument, opting instead to set intermediate targets for both money supply and the exchange rate. This makes the standard Taylor rule estimation inappropriate in the

[6] For a definitive outline of the structure of the PBOC see Geiger (2008)

Chinese case. Secondly, identifying the instruments used by the PBOC to conduct monetary policy is difficult. Girardin et al. (2014) point to three main categories of policy instrument employed by the PBOC; 1) Price based instruments (such as interest rates on bank deposits and lending, excess reserves etc. 2) Quantity based instruments (such as reserve requirement ration (RRR)) and 3) Administrative instruments such as ‘window guidance’, which of course are difficult to estimate or model as they are not directly observable. Window guidance can be defined as exercising controls on bank lending. In the PRC, this takes the form of the central government setting the direction for sector development and for stimulating growth of certain industries - often propping up ineffective and inefficient state owned enterprises, thus denying more efficient private corporations investment.

Finally, there is the issue of identifying structural breaks in the Chinese economic data, which is symptomatic of an economy which has changed and reformed its institutions rapidly in a relatively short period of time. These have included changes in structures of government organisations such as those of the PBOC, indicative of an economy in transition. Structural changes in an economy and breaks in its time series make standard linear models infective for empirical interpretation as they can lead to incorrect inferences. Therefore, non-linear estimations need to be carried out to get a more accurate representation of monetary policy dynamics in the PRC.

The paper is structured as follows. Section 3 reviews the literature on the monetary policy rule, the asymmetry of monetary policy reactions and on monetary policy in the PRC. Section 4 gives a brief overview of the methodology while Section 5 describes the data and a detailed description of our estimated monetary policy index. Section 6 presents the estimations and results and performs robustness tests on the results. Finally, Section 7 concludes.

3. Literature Review

The Taylor rule (1993) has been used for many years to examine monetary policy in advanced economies such as the US (Bernanke 2010 and Taylor 2009), The UK (Clarida et al. 1999 and McCallum 2000) and the Euro area (Peersman and Smets 1999 and Gerlach-Kristen 2003). In its most common and basic form, the Taylor rule links monetary policy rates dynamically to the deviation of inflation from its target rate and output (or unemployment) from its natural level.

In more recent studies, academics and policy makers have focused on the asymmetry and non-linearity in monetary policy reactions. A central bank may respond differently to deviations of aggregates from their targets depending on factors such as the current phase of the business cycle (Castro 2008). In this case, it would be more appropriate to model either a structural change or a non-linear type Taylor rule to explain the behaviour of monetary policy. Kim and Nelson (2006) employ a time-varying parameter model to examine US monetary policy since the 1950's and fInd that the reaction was indeed unstable. Davig and Leeper (2007) use a similar technique to the one employed in this paper by specifying that the reaction of coefficients in the monetary policy rule evolve according to a Markov process. Dolado et al. (2005) and Surico (2007a, 2007b) have shown evidence that central banks respond differently to deviations of inflation and output from their target levels. Hamilton (1989) also makes the point that inflation and output gaps tend to have an asymmetric adjustment to the business cycle. For example, recessions tend to be sharp, while recoveries are longer and smoother. Inflation on the other hand usually increases more rapidly than it decreases. Markov (2012), using a regime switching Taylor rule for the Euro area, finds that the main ECB policy rate switched between two regimes. The first regime emphasised stabilising the economic outlook of the Euro area, while the second, more aggressive regime, put a greater emphasis on real output growth expectations. Murray et al. (2013) estimate a Taylor rule with endogenous Markov switching coefficients and variance for the US to correspond with the tenure of various Federal Reserve Chairmen. They found that while the Federal Reserve consistently adhered to the Taylor rule before 1973 and after 1984, it followed the Taylor rule from 1975-1979 and did not follow the Taylor rule from 1980-1984. Castro (2008) examines if major central banks are following a linear or nonlinear (augmented) Taylor rule. The author finds that the ECB and the Bank of England tend to follow a nonlinear Taylor rule but the same is not true for the Federal Reserve. Hofmann and Bogdanova (2012) also state that there has been a symmetric reaction of monetary policy to the different stages of the financial cycle in core advanced countries.

The Taylor rule has also become increasingly popular as a gauge for assessment of emerging market economies (EME's). Taylor (2000) himself states that the use of monetary policy rules in EME's has many of the same benefits that have been found in research and in practice in developed countries. He adds the caveat, however, that market conditions in emerging market economies may require modifications of the typical policy rules that have been recommended with more developed financial markets in mind. While the focus of nonlinear monetary policy rule models have been taken by the US, the UK and the Euro area, there have been fewer studies of the asymmetric effects of monetary policy in emerging markets such as the PRC. This is surprising as emerging economies are often characterised by ongoing reforms, political and economic changes, market liberalisation etc. which would make standard linear estimations such as OLS inappropriate for analysing monetary policy. Jawadi et al. (2011) argue that for emerging markets, a nonlinear Taylor rule may give a more realistic description of the response of the monetary authority to economic development as it allows the analysis of asymmetric, discontinuous and time varying monetary policy reaction.

Although many studies have noted that interest rates in the Chinese economy have played a minor role (for example Laurens and Maino 2007, Mehrotra 2007 and Koivu 2009), Wang and Handa (2007) find that the PBOC followed a Taylor type rule for the interest rate with the aim of inflation targeting and output smoothing during their estimation period of 1993-2003. Burdekin and Silkos (2008) model Chinese monetary policy with an augmented McCallum-type rule that takes into account the People's Bank of China's emphasis on targeting the rate of money supply growth. Using cointegration analysis, the authors find that Chinese inflation and monetary policy outcomes seem reasonably captured using a standard monetary approach without the need to appeal to China-specific "structural" factors. Using data from 1994-2006, Li and Wang (2010) find that the Taylor rule is unstable in China. The authors claim that there is less correlation found between the interest rate and the output gap and that the PBOC focuses more on the inflation target than economic growth. Kong (2008) compares four kinds of monetary policy rules for China, including a Taylor and McCallum rule. The author finds that these models can describe the Chinese monetary policy stance in some degree and that Taylor rules are better than McCallum rules in evaluating monetary policy performance. In a more recent paper, Fernald et al. (2014) make the very interesting finding that China's monetary policy transition mechanism is closer to those of Western economies than previously realized.

Early work in the area of the asymmetry of the Chinese monetary policy rule was carried out by Lu and Shu (2002). The authors divided their entire sample using pre specified breakpoints. However, the pre-specification of breakpoints in this manner is arbitrary and often suffers from poor model specification. Chen and Huo (2009) is one of few papers to tackle the issue of asymmetry and instability in the Chinese Taylor rule by estimating a model with drifting coefficients. The authors, however, fail to account for the role of qualitative instruments which is believed to play a very important role in Chinese monetary policy framework (Goodfriend and Prasard 2007). Studying a modified Chinese Taylor's rule with money supply growth rate as the intermediate target, the authors do find however that there were two structural changes in the Chinese monetary policy rule, which take the form of discrete jumps rather than continuous adjustments. In their concluding remarks, the authors state that it may be better to use the Markov regime switching model to estimate the Chinese monetary policy rule. Zheng et al. (2012) found that China's monetary policy can be well characterized by a two-regime forward-looking Taylor rule. They find that in the first regime, the PBOC targets inflation, but does not focuses on the output gap; while in the second regime the central bank targets the output gap and the policy rule is not characterised by a stable framework. Based on the relatively scarce literature, Ma (2014) has pointed out that there are major gaps waiting to be filled in the study of China's monetary policy. For example, the author mentions the existing studies that investigate China's monetary policy have implicitly assumed a price rule, especially a Taylor-type interest rate rule. This may not be appropriate to the Chinese case for the reasons mentioned. The lack of accountability of nonlinearities is also mentioned by the author.

The issue of asymmetry and non-linearity in monetary policy rule estimations is not just a Chinese specific one. Many transition and emerging market economies experience structural breaks and nonlinearities when it comes to the monetary policy reactions of its central banks as they react to the ever changing conditions of the macro economy. From the perspective of a typical transition economy, some important features of monetary policy in transition, such as shifting preferences and nonlinearities of policymakers' choices, have been largely ignored in the existing literature. However, as noted by Hamilton (1989) and Surico (2007a), central banks may have asymmetric preferences in reality, which gives rise to the existence of a nonlinear monetary policy reaction function. Therefore, it is important to examine closely the specific preferences and policy's adopted by these central banks in emerging market economies.

3. Methodology

Taylor characterised monetary policy in the US from 1987-1992 using *Equations 1.1* and *1.2*, which became known as the Taylor rule;

$$i_t = \bar{r}_t + \pi_t + b(\pi_t - \pi_t^*) + c(\bar{y}_t) \tag{1.1}$$

Which can be simplified to

$$i_t = a + (1 + b)\pi_t + c(\bar{y}_t) \tag{1.2}$$

In these equations, i_t represents the nominal short term interest rate, $\bar{r}$ is the equilibrium level of the real interest rate, π_t is the inflation rate, π^* is the target inflation rate and finally $\bar{y}_t$ is the deviation of output from its natural level, i.e., the output gap. Taylor (1993) and later Woodford (2003) state that since the real interest rate drives private decisions, the size of the inflation coefficient, b, needs to ensure that the nominal interest rate is raised enough to increase the real interest rate as a response to a rise in the inflation. This so called "Taylor principle" implies that b should be greater than 1. On the other hand, if b is less than 1 it indicates an accommodative behaviour on the part of the monetary authority to inflation which may result in self-reinforcing inflation. In parallel, the coefficient of the output gap, c, should be positive. The suitability of the Taylor rule of the form in Equation 1.1 and 1.2 can be tested empirically for the PRC using the following interest rate backward-looking Taylor monetary reaction function (similar to that used in Girardin et al. 2014) which also includes the exchange rate as a monetary policy target variable;

$$i_t = a + b(\pi_{t-1} - \pi_t{}^*) + c(\bar{y}_{t-1}) + d\Delta er_t + \epsilon_t \quad (2)$$

In the above equation, i_t is the PBOC lending rate, $(\pi_{t-1} - \pi_t{}^*)$is the CPI inflation rate minus a target level of inflation, $\bar{y}_t$ is the deviation of output from its natural or potential level, referred to simply as the output gap, and finally Δer_t is changes in the nominal effective exchange rate (NEER). The NEER in this paper is defined in foreign currency unit per renminbi (RMB) i.e. an increase in this variable corresponds to an appreciation of the RMB. The Taylor rule (even in this augmented form) was however originally modelled for the US economy. While it has been used extensively for other developed economies, it may not be appropriate in the Chinese case. While Xie and Xiong (2003) state that the Taylor rule can provide a useful benchmark for measuring the stance of monetary policy in emerging economies such as the PRC, the lack of studies in the area points to some difficulty in carrying out such research. Firstly, monetary policy changes in both emerging and transition economies can lack consistency and credibility, often when the economy is undergoing an extensive process of reform, with many emerging markets undertaking major market oriented reform. There is also the reliance of intermediate targets as well as the use of a battery of different instruments, which would ultimately make the interest rate an ineffective measure of the PBOC's monetary policy stance. While the majority of emerging market economies have adopted explicit inflation targeting regimes, the PRC would seem to be an exception to this and no explicit inflation targeting regime has ever been announced by the PBOC (Hutchinson et al. 2013). Instead, the PRC operates a pegged or quasi pegged (to the US dollar) exchange rate regime which is supported by capital controls[7]. This adds to the problem of modelling monetary policy reactions in the PRC. Financial markets in emerging economies are also often underdeveloped and interest rates are often distorted by the monetary

[7] While officially this dollar peg (introduced in 1994) was abandoned in 2005, Morrison and Labonte (2013) argues that China's exchange rate mechanism remains, in practice, a tightly managed currency peg against the dollar. In July 2015, *The Financial Times* also reported that despite progress on reforms since 2005, intervention remains a daily reality (accessed at http://www.ft.com/cms/s/0/1e0a2620-3039-11e5-8873-775ba7c2ea3d.html?siteedition=uk#axzz3giyhsTxL)

authority (Xie and Xiong 2003). The PRC is no different and it is widely accepted that the PBOC directly controls commercial bank decisions.

Another issue which arises in the Chinese case is the problem of structural breaks, instability or non-linearity which can arise in a monetary policy reaction function. This non-linearity can arise from both the preference function of the Chinese authorities and the structure of the Chinese economy (Girardin et al. 2014). Due to these issues with Chinese economic data, standard constant parameter models such as traditional Taylor rules or McCallum rules would not adequately define the dynamics. As pointed out by Ma (2014), it is typical for emerging economies to experience structural change during periods of financial and economic reform which will ultimately lead to regime changes in monetary policy. Most of the literature in this area has focused on nonlinear price rules or quantity rules but very few have examined nonlinearities in the context of a calculated monetary policy index which replicates the monetary stance of a central bank With these arguments in mind this paper models an augmented Taylor rule as the linear benchmark as;

$$MPI_t = a - b(\pi_{t-1} - \pi_t{}^*) - c(\bar{y}_{t-1}) - d\Delta er_t + \epsilon_t \quad (3)$$ [8]

As in Equations 1 and 2 $(\pi_t - \pi_t^*)$ is the deviation of inflation from its target, y_t is the output gap and Δer_t is changes in the nominal exchange rate of the RMB. Notice that i_t has been replaced with the monetary policy index MPI_t. This variable is intended to represent both the quantitative and qualitative tools available to the PBOC[9]. Another important point to note is the sign of the coefficients. The nature of the MPI's calculation means that an increase in the index corresponds to expansionary monetary policy and a decrease to a contractionary policy. Therefore the expected signs will be the opposite of those observed by the standard theory.

[8] We can consider ϵ_t in this equation to represent a zero mean error term that captures deviations from the monetary policy rule.

[9] While many monetary policy rules for the PRC include a representation of changes in M2 as an intermediate target, this is not included in the monetary policy rule as the monetary policy index is estimated using changes in the money supply and therefore would ultimately provide us with misleading or spurious results due to problems such as autocorrelation and heteroskedasticity

4. Data

4.1 Inflation Gap, Output Gap and Exchange Rate

The estimations in this paper were calculated using quarterly data from 1994Q1 to 2014Q3 The start date was choosen as the Chinese government began to publish inflation targets for the first time in this year as part of their reform of the banking and financial sector. Figure 1 shows the plots all of the variables used in the estimations while Table 2 reports the results of the Augmented Dickey Fuller (ADF) Test[10]. All of the variables with the exception of the lending rate pass the test for integration of order zero (I~ (0)). Official quarterly inflation data is available from the National Bureau of Statistics (NBS) of the PRC. The inflation target data was sourced from targets for CPI inflation mentioned in various publications of the *'Report on the Implementation of the "YEAR" Plan for National Economic & Social Development and on the "YEAR+1" Draft Plan National Economic & Social Development'.* Every year, the National People's Congress (NPC)[11], holds an annual plenary session. For example, the incumbent 12th National People's Conference are scheduled to meet five times, in March of every year from 2013-2018. At these sessions, the National Development & Reform Commission (a macroeconomic management agency under the Chinese State Council, which has broad administrative control over the Chinese economy), submit a report which includes economic updates, forecast and targets including the inflation rate.

[INSERT FIGURE 1 HERE]

For the output gap, there are two approaches available for its calculation; the production function approach and a filtering approach using a HP filter. While the latter of these is easy to implement, it suffers from the drawback that, unlike the former, it provides no economic understanding of the sources of growth. Thus, it is arguably best seen as a complement to the more rigorous production function approach (Gerlach and Peng 2006). Therefore, this papers estimations

[10] Adjustments for seasonality are made where appropriate.

[11] The National People's Congress (NPC) is the supreme organ of state power and the national legislature in China.

use a production function output gap[12]. This is available from the *Oxford Economics Global Economic Databank.*

For the exchange rate, the nominal effective exchange rate is included since the RMB is heavily managed and any change in its parity is likely to affect the monetary policy stance. This quarterly data is available from the IMF International Financial Statistics (IFS). The RMB exchange rate has received a great deal of attention both in the economic literature and in the media. Academics such as Koivu (2009) argue that the foundation of Chinese monetary policy has been a fixed exchange rate, while politicians and policy makers in the US claim that the PRC intentionally suppresses the value of the RMB through massive market intervention to raise the competitiveness of its exports.

As has been mentioned, the PBOC relies on a basket of different policy tools in the conduct of monetary policy. Therefore, a monetary policy index composed of both qualitative and quantitative tools is required to accurately examine the stance of the PBOC. As no data set for qualitative tools exists, this will be calculated using a Kalman filter technique. A monetary policy index can then be composed based on a weighted average of the changes in both qualitative and quantitative tools. Given the importance of this variable for the analysis of the PRC's monetary policy, Section 4.2 describes the theory, rationale and calculations behind the monetary policy index.

[INSERT TABLE 2 HERE]

4.2 A Monetary Policy Index for the People's Republic of China

4.2.1 The Unobserved Components Model

Quantifying unobserved variables is a common problem in empirical research. Often in macroeconomics, we come across variables that play an important role in theoretical models, but which we cannot observe. Unobserved component models (UCMs) have been used in economic

[12] In the interest of robustness, we also estimated an output gap using a HP filter and real GDP data from the NBS to use as a comparison with the production function approach. This series is available on request The two series were found to be very similar.

research in a variety of problems when a variable, supposed to play some relevant economic role, is not directly observable. While a particular variable may not be directly observable, the UCM using a Kalman Filter[13] allows researchers to predict how this unobserved variable might be behaving. For example, unobserved components have been used in modelling agents' reaction to permanent or transitory changes in the price level (Lucas 1976), in modelling credibility of the monetary authority (Weber 1992) and in measuring the persistence (or long-term effects) of economic shocks (Cochrane 1988). The statistical treatment of an unobserved components model is based on the State-Space Model (SSM) form. In the SSM, the unobserved components, which depend on the state vector, are related to the observations by a measurement equation. A transition equation then models the dynamics of the unobserved variables or states. While linear regression models use exogenous variables to distinguish the explained variation from the unexplained variation, SSM's rely on the dynamics of the state variables and the linkage between the observed variables and state variables to draw statistical inference about the unobserved state. This allows us to estimate the unknown parameters of the model. The Kalman filter is the basic recursion for estimating the state, and hence the unobserved components, in a linear State-Space Model (Harvey et al. 2004). The useful thing about the unobserved components model is that if the unobserved variable is closely linked with an observed variable, it is possible to predict the value of that variable from the observed values. The purpose of this technique therefore in this paper, is to make inference about the unobservable policy instruments that the PBOC carry out given a set of observable policy instruments.

We can loosely categorize the monetary policy tools of the PBOC into two categories, quantitative and qualitative.

- Quantitative monetary policy tools, often known as *"general tools"*, are the instruments used most often by advanced central banks and monetary authorities. These include bank lending and deposit rates, reserve requirements, open market operations etc. The quantitative instruments

[13]Additional information on this technique can be found in Cuthbertson et al. (1992), Kim and Nelson (1999) & Commandeur and Koopman (2007).

used in this paper were chosen based on information from various PBOC official publications. For example;

"*The monetary policy instruments applied by the PBOC include reserve requirement ratio, central bank base interest rate, rediscounting, central bank lending and deposit rate, open market operations and other policy instruments specified by the State Council"*

PBOC, Monetary Policy Instruments (2015)[14].

- Qualitative monetary policy tools, described as *"selective tools"*, often involves direct administrative pressure on financial players to make them operate consistently with national needs (Geiger 2008). This style of institutional coercion is one of the PBOC's unique characteristics and it reflects the PRC's hierarchical order. It also makes the monetary policy reactions of the PBOC very difficult to quantify and model accurately. The most well-known of these instruments is "window guidance"[15], also known as "moral suasion" or "jawboning". Despite the phrase "guidance", which implies a voluntary aspect in the system, the PBOC have a major influence on the lending decisions especially of the four state-owned commercial banks (Ikeya 2002).

A key consideration of this paper is how to quantify the latter of these two monetary policy tools i.e. how to link the unobserved variables (qualitative) to the observed variables (quantitative)? Let us suppose that the Chinese money supply (M2)[16] changes in a way that would be consistent with a certain monetary policy response. Let's also assume however, that the standard quantitative policy instruments (interest rates, open market operations, reserve requirement rates etc.), that we would expect to influence M2, *cannot* be held accountable for the deviations. It is therefore logical to assume that some unobserved qualitative variables might be responsible for changes in the M2. Of course, this does not mean that all changes in M2 not explained by the measurement equation

[14] Accessed at http://www.pbc.gov.cn:8080/publish/english/979/index.html

[15] There are several other direct control instruments that a central bank can use. These included credit controls, (for example lending ceilings and floors), prudential guidelines (informing commercial banks to exercise particular care in their operations in order that specified outcomes are realized etc.).

[16] M2 is chosen because qualitative instruments are likely to be reflected on to broad money (Petreski and Jovanovic 2013). In this paper, we use quarter on quarter changes in the M2 and this variable is plotted in Figure 2.

variables will be explained by this unobserved variable, as there is probably a lot of noise in the M2 data. There is however, likely to be very useful “signal” or “noise free” data. The Kalman filter is therefore used to separate the best signal from the noise.

4.2.2 Set Up of the Unobserved Components Model (UCM)

First of all, we need to specify the quantitative instruments that will influence M2. The main quantitative policy instruments used by the PBOC are the base (or discount) rate, the reserve requirement ratio (RRR) and open market operations (OMO). Secondly, we include instruments based on the nature of the PRC’s financial system. Since the PRC’s banking and financial institutions are dominated by state owned banks, any rate changes can be treated as a monetary policy response and so we include both the lending and deposit rates of these institutions. We also need to include any other variable that will have a major influence on the level of M2. Therefore, both real GDP and the nominal effective exchange rate are included in the measurement equation[17].

Equation 4 and 5 describe both the measurement and transition equations respectively. Quarter on quarter changes in M2 (ΔM2) is chosen as the dependent variable in the measurement equation because, as mentioned, qualitative instruments are likely to be reflected on to broad money. ΔM2 is then expressed as a function of both the quantitative and the qualitative monetary policy instruments used by the PBOC. The transition equation then models the unobservable qualitative instruments as a first-order autoregressive process (AR (1)). The qualitative instrument series is

[17] We would expect the quantity of money demanded to be effected by the level of real GDP. Higher real income leads to higher expenditure and therefore people hold more money to finance the higher volume of expenditure (See for example Romer 2014). Mundell (1963) stated that the demand for money is likely to depend upon the exchange rate in addition to the interest rate and the level of income. Also, we would expect the huge build-up of foreign exchange reserves to be a central factor affecting M2 (see for example Kawai and Laberte 2010). While there is no variable explicitly included to account for the change in foreign reserves, the change in these reserves in China is associated with a change in the NEER. For example, in the period 2008-2009, the increase in reserves was associated with a decline in the nominal effective exchange rate, indicating that reserve accumulation may have been used to prevent an appreciation of the RMB. Therefore, the changes in the nominal effective exchange rate should capture changes in the foreign reserves.

obtained by a Kalman filter estimation of this money demand function. The two equations are written in the following form;

Measurement equation: $\Delta M2 \quad = \quad \beta_1 + \beta_2\ exchange\ rate + \beta_3\ base\ rate + \beta_4 reserve\ requirement + \beta_5 lending\ rate + \beta_6\ deposit\ rate + \ \beta_7 GDP + \beta_8 Qual + e_{t1}$ (4)

Transition equation: $Qual = \ \beta_9\ Qual(-1) + e_{t2}$ (5)

In the above model, the measurement equation, Equation 4, links the quantitative variables *($\beta_3\ base\ rate + \beta_4 reserve\ requirement + \beta_5 lending\ rate + \beta_6\ deposit\ rate$)*[18] and changes in the exchange rate and real GDP *($\beta_2\ exchange\ rate\ + \beta_7 GDP$)* to an unobserved state variable ($\beta_8 Qual$). The transition equation then describes the dynamics of this qualitative instrument[19]. This $Qual$ variable in both Equations 4 and 5 is the vector of the unobserved variables and describe how these variables evolve over time. The error terms e_{t1} and e_{t2} are the monetary policy shock and the shocks to the qualitative instruments respectively. The set-up of this UCM assumes that the only variable affecting the quarter on quarter change in M2 that can have an AR (1) structure is the unobserved variable, and treats all other factors as shocks. While using this assumption to define our series for the qualitative variable may at first seem slightly naive, it is justified for the simple reason that the key variables which may have an AR (1) structure and still effect changes in M2 have already been included in the measurement equation. Therefore, it is logical to assume that the only important variables that remains for changes in M2 is this qualitative variables. The qualitative variable is intended to capture PBOC actions such window guidance, bank directives, credit guidance and other instructions which are widely regarded to be very important to the PRC's banking sector. We expect that it would influence M2 as it involves the central bank persuading commercial banks to take certain steps without itself making any changes to benchmark rates.

[18] Note the omission of the open market operations (OMO) variables. The variable for OMO moved almost exactly with the base (or discount rate). They deviated at the same periods and by the same magnitude and, therefore, all the dynamics will be already captured by the base rate.
[19] The starting values for the parameters in the measurement equation were chosen from OLS regression which is the standard procedure for an estimation of this type.

4.2.3 Estimating the Qualitative Variable

The results of the estimations are as follows;

$$\text{Measurement equation: } \Delta M2 = 7.5^{***} - 0.04\ exchange\ rate + 0.32\ base\ rate + 0.10\ reserve\ requirement - 1.4^{*}\ lending\ rate + 0.95^{***}\ deposit\ rate + 0.05 GDP + Qual \quad (6)$$[20]

$$\text{Transition equation: } Qual = -0.02\ Qual(-1) \quad (7)$$

The measurement equation results show that while the GDP growth rate and changes to the exchange rate are correctly signed, their coefficients are not significant. The base rate and the reserve requirement ratio (RRR) are insignificant and also incorrectly signed. In fact, of all the monetary policy tools included in the equation, only the deposit rate is correctly signed and significant. This would suggest that, for the most part, the quantitative variables have played a limited role on the Chinese money supply. This equation would obviously suffer from multicollinearity problems however, and so the interpretation of its results must be treated with caution.

The transition equation on the other hand will give the prediction of the qualitative instruments used by the PBOC. Technically speaking, the transition equation identifies latent autoregressive process of order 1 (i.e. AR(1)) that affects money growth. The predicted series calculated from the estimation can be seen in the bottom centre panel of Figure 2 *(Changes in Qualitative Instruments)*. This series should, broadly speaking, correspond to the “selective” monetary policy actions of the PBOC. As a simple example, the marked increase and decline in the 1992-95 periods may be accredited to Deng Xiaoping’s southern tour. The spike in the 2008-09 periods on the other hand may have captured the stimulus package the PBOC undertook to prevent the effects of the financial crisis in the PRC. Therefore, from a simple observation of the series, it would

[20] ***,** and* denote significance at the 1%, 5% and 10% level of significance respectively.

appear that our *'qualitative'* variable measure has succeeded in capturing some of the important "unobservable" Chinese monetary policy movements.

4.2.4 Calculating the Index

Having obtained an estimated series of the qualitative variable, the monetary policy index (MPI) can be constructed. Firstly, the coefficient of variance of the five instruments[21], both qualitative and quantitative, is calculated and their sum normalised to unity. The coefficient of variance is a statistical measure of the dispersion of data points in a data series around the mean. It is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different from each other. This technique allows us to examine and compare the degree of variation of the five series. The coefficient of variance for the five variables can be seen in Table 3. We can clearly see that the main monetary policy tools mentioned by the PBOC – deposit rate, lending rate discount rate and reserve requirement –play a comparatively minor role and seem to change infrequently when compared to our qualitative instrument. The addition of the qualitative instrument variable clearly shows its importance in its role as a monetary policy tool.

[INSERT TABLE 3 HERE]

This is confirmed by examining the changes in all policy variables (Figure 2) which clearly shows that the qualitative instrument variable changes far more frequently than the other four quantitative variables. The final monetary policy index (MPI) is then calculated as a weighted average of the changes in the five policy instruments using the coefficient of variance values (see Table 3) as weights. Figure 3 plots the final MPI which will be used in the estimations that follow. It should be noted that an increase in this index corresponds to an expansionary monetary policy stance and a decrease to a contractionary stance. This is due to the setup of the weightings of each of the variables.

[21] The five instruments are the four quantitative (deposit rate, lending, base and reserve requirement rate) and the estimated qualitative variable. The estimations in Section 5 begin in 1994 due to the earliest available official inflation target. Due to data availability of all variables involved, both the qualitative instruments and monetary policy index are estimated from 1991 however.

Therefore, we would expect to see a negative sign on the monetary policy reaction coefficient in the monetary policy rule in our estimation.

[INSERT FIGURE 2 HERE]

[INSERT FIGURE 3 HERE]

5. Estimations

5.1 Standard OLS Estimations

The standard OLS monetary policy rule estimation (Equation 2) can be seen in Table 4. The results are not particularly compelling. Both the deviation in inflation and output from the target and potential level respectively are only significant at the 10% level and even then, the coefficients are small. The sign of the inflation gap is also incorrectly signed. The change in the exchange rate does not have a significant bearing on the dependent variable. Furthermore, the R^2 is low a 0.1 suggetsing that this specification is a poor fit to model the PBOC's monetary policy reaction to deviations in their target levels. The equation, however does appear to be stable as the *SupF* test fails to detect the presence of structural breaks over the time period. These results would reiterate the arguments of He and Pauwels (2008), Xiong (2012) and Girardin et al. (2014) who all infer that a single interest rate rule would not appropriately represent the monetary policy reactions of the PBOC.

Using the same standard OLS estimation technique, we can examine if the monetary policy index (MPI) improves on the specification of the PRC's monetary policy rule estimation. This index contains a weighted average of the policy instruments that are used by the PBOC. It includes both quantitative and qualitative instruments. The results of this estimation (Equation 3) can be seen in the right hand column of Table 4. The results of these estimations are also not very compelling. The reaction of the policy index to a deviation in inflation from its target level is again only significant at the 10% level and its coefficient is small at 0.11. The sign on the coefficient is also incorrect. The exchange rate is once again insignificant, however the R^2 is marginally higher than in our previous model at 0.17.

[INSERT TABLE 4 HERE]

The validity of the results are however compromised by the presence of a structural break. This is observed by the highly significant value of the *SupF* test, which indicates a structural break in 2009Q1.

5.2 Markov Switching Model

Many economic time series occasionally exhibit dramatic breaks in their behaviour, associated with events such as financial crises or abrupt changes in government policy (Hamilton 2005). The PRC, in particular, has experienced tremendous structural changes in recent decades, associated with the gradual opening of the economy. Prices have been liberalised, trade has increased extensively, companies have been privatised and the economy has been transformed from one that was centrally planned prior to 1978 to a market economy (Brandt and Rawski 2008). It has also experienced several economic shocks, some of which were related to policy measures to liberalise the economy (Gerlach and Peng 2006). The breaks in the time series associated with these events may make linear models inappropriate for analysing macroeconomic variables over time. To account for structural breaks, asymmetry and non-linearity, the Chinese monetary policy rule is examined using the Markov switching (MS) model of Hamilton (1989, 1990 and 1994). The MS model is so called because the switching mechanism is controlled by an unobserved state variable, s_t, that follows a first order Markov chain process. An interesting feature of the MS model is that the filtered probabilities can be interpreted as the agent's belief that the economy is in one of the possible states that describe the economy. It is also a very useful technique as the unobserved or latent state variable can be linked (or at least possibly linked) to an observable event, policy or characteristic. Another key point is that the Markov switching model is relatively easy to implement because it does not assume any *a priori* knowledge of an arbitrary time period or event. Instead, the regime classification in this model is probabilistic and determined by the data (Kuan 2002).

By fitting the linear monetary policy rule equation to the Markov switching framework, we get:

$$MPI_t = a_{st} - b_{st}(\pi_t - \pi_t^*) - c_{st}(y_t - y_t^*) + d_{st}\Delta er_t + \epsilon_{t_{st}} \quad (8)$$

Where e_t~i.i.d. N (0,$\sigma^2_{e,st}$) and with unobserved state s_t, which is assumed to follow a Markov chain of order 1 with transition probabilities p_{ij}. The transition probability p_{ij} gives the probability that state *i* will be followed by state *j*.

$$P_{ij} = \Pr[\, s_t = j \mid s_{t-1} = i\,], \quad \sum_{i-1}^{M} p_{ij} = 1, \quad \forall i, j = 1, \ldots\ldots M \quad (9)$$

This is often then written in an *(M x M)* matrix P, called a transition matrix:

$$\mathrm{P} = \begin{bmatrix} p_{11} & p_{21} & \cdots & p_{M1} \\ p_{12} & p_{22} & \cdots & p_{M2} \\ \vdots & \vdots & \cdots & \vdots \\ p_{MM} & p_{2M} & \cdots & p_{MM} \end{bmatrix} \quad (10)$$

The row *i*, column *j* element of *P* is the transition probability p_{ij}. To demonstrate, in the above matrix (10), the row 2 column 1 element gives the probability that *State 1* will be followed by *State 2*. Let us for example, say that at time *t* , the state of the economy s_t is classified as contractionary monetary policy in s_t= 1 or expansionary monetary policy in s_t = 2. In our estimation, let us assume that the model gives us a probability of 95% of being p_{11} and 5% of being p_{21}. What these values tell us is that if the economy is in a state of expansionary monetary policy the previous period, it tends to stay in a expansionary monetary policy state with a very high probability of 95%. On the other had the probability of being in a expansionary monetary policy state in the previous period and switching to a contractionary monetary policy state is low at just 5%.

The estimation of the model depends on maximum likelihood. The maximization of likelihood function of the model requires an iterative estimation technique to obtain estimates of the parameters of the model and the transition probabilities[22]. With the parameters identified, it is then possible to estimate the probability that the variable of interest is following a particular regime. It is also possible to derive the smoothed state probabilities which indicate the probability of being in a particular regime or state. Before estimating the Markov switching monetary policy rule, the

[22] For more details on these technique and the maximum likelihood see Hamilton (1989, 1994) and Kim and Nelson (1999)

number of states or regimes to be included in the model must be chosen. As there are often relatively few transitions among states, it is difficult to estimate strictly exogenous explanatory variables accurately. For this reason, most applications assume only two or three states (Hamilton 2005). Tests for both a two-state and three-state Markov switching IS curve were carried out. The three-state specification was rejected against the two-state specification since the data points are detected only in the first and second states.

Table 5 presents the results of the Markov switching monetary policy rule and Figure 4 plots the states recognised by the model with the three monetary policy target variables used in the estimation. The model characterises the monetary policy reaction into two different states – *State 1* and *State 2*. In *State 1*, as in the previous estimations of this paper, the inflation gap seems to play no significant role in the monetary policy reaction of the PBOC. The coefficient is only significant at the 10% level and is incorrectly signed. Changes in the exchange are also not statistically significant in *State 1*. The output gap on the other hand is highly significant with a coefficient of -0.54. A 1% S.D. in the output gap results in a 0.55% deviation in the monetary policy index. The summary statistics in the Appendix indicate that *State 1* is, for the most part, characterised by a negative output gap (with a mean of -0.5%) and a positive or appreciating exchange rate (with a mean of 3.7%).

In *State 2*, the inflation gap is again insignificant and incorrectly signed. The output gap has now switched from being significant and correctly signed to being insignificant and incorrectly signed. What is perhaps most interesting is that the exchange rate is now highly significant with a coefficient of 0.05. A 1% S.D. in the exchange rate results in a 0.34% deviation in the monetary policy index. The summary statistics in the Appendix show that *State 2* is characterised *mostly* by a negative output gap (with a mean of -0.9%) and *mostly* a negative or depreciating exchange rate (with a mean of -0.2%).

The results of our MS estimations paint an interesting picture about the monetary policy reaction function in the PRC. First of all, the PBOC seem to have been very accommodative of inflation over the estimation period as the inflation gap was not found to have any significant effect on the monetary policy index across either state. This can be attributed to the fact that the inflation gap was predominately negative over the estimation period. The output gap is only significant in *State 1*, when the exchange rate is appreciating and not targeted by the PBOC's basket of policy instruments. On the other hand, in *State 2* the output gap is no longer significant. During this state, changes in the exchange rate are highly significant and, on average, the exchange rate is depreciating. As it is almost universally accepted that the RMB was undervalued over the entire estimation period[23], any depreciation of the RMB could possibly be viewed as an intervention by the PBOC to maintain the RMB at a desired level. When the exchange rate is "managed" in this way, adjustments in terms of trade or exchange rate cannot be used to mitigate the impact of external shocks. Under this regime, increases in the cost of sterilization[24] following a sudden decline in foreign interest rates further constrain the central bank's ability to stabilize the economy (Chang et al. 2014).

Based on the results of the estimations in this section, it is quite reasonable to suggest that when the PBOC do not intervene heavily in the foreign exchange market and allow the RMB to appreciate it retains its ability to stabilise the level of output through its monetary policy instruments. However, when the PBOC intervene in the foreign exchange market to maintain the RMB at a desired level, they surrender this stabilisation channel. This loss is possibly linked to the cost of the sterilisation process. The surrender of an effective output stabilisation channel could have a profound effect on the stability of the Chinese economy, particularity as it enters a new era of reform intended on introducing a more balance domestic led growth model. The current policy could cause the PBOC to react in an inappropriate or counterproductive manner to certain shocks to aggregate demand due to the constraints caused by the exchange rate policy. This can be examined further by looking at the state coefficients and summary statistics in Table 5 and the Appendix respectively. In *State 1*, the PBOC actually operated a paradoxical monetary policy response i.e. adopted contractionary monetary policy (mean of MPI of -1%) when output was below potential and the economy was operating below capacity, in favour of maintaining the exchange rate at the desired level. This trade-off that the PBOC face between maintaining a stable level of output and maintaining the exchange rate at a

[23] Chang and Shao (2004), Coudert and Couharde (2007) and Tang (2015) all discuss the nature and extent of China's currency undervaluation.
[24] Sterilisation is a process by which a monetary authority seeks to limit the effect of inflows and outflows of capital on the money supply

desired level is a classic example of the impossible trinity problem which has been widely discussed in the literature (see for example Goodfriend and Prasad 2006, Prasad 2009, Aizenman et al. 2010)

[INSERT TABLE 5 HERE]

[INSERT FIGURE 4 HERE]

6. Robustness Test

In this section, we undertake a robustness test to add reliability and credence to the findings of our Markov switching model. We attempt to do this by estimating a more simple, if not arbitrary, examination of the Chinese monetary policy rule. This is done by estimating a breakpoint model. The seminal work of Chow (1960) and Quandt (1960) developed the testing procedure for structural changes in a time series at a single specified (hence known) break date. Bai and Perron (1998), (2003) developed this technique further and attempted to develop methods that allow for estimation and testing of structural change at unknown break dates. While this technique lacks many of the advantages of the MS model[25], it is none the less a useful robustness check of the validity of our findings and interpretations.

The breakpoint model of Bai-Perron can be used to estimate multiple structural changes in a linear model estimated by least squares. It treats the number of breakpoints and their locations as unknown. Applying this procedure to the augmented monetary policy rule with the calculated index, again used as the dependent variable, gives us the following equation with m breaks;

[25] For example, it does not allow for switching between different states of the economy. Therefore breakpoint model can tell us how the dynamics of a particular variable are changing over time. However, macroeconomic relationships do not just change over time, but may also display distinct patters under different states or regimes. Therefore this technique should be used as a complement to the MS model.

$$MPI_t = a_1 - b_1(\pi_{t-1} - \pi_t{}^*) - c_1(\bar{y}_{t-1}) - d_1\Delta er_t + \epsilon_t \quad t = 1, \ldots\ldots, T_1 \tag{11}$$

$$\vdots$$

$$MPI_t = a_m - b_m(\pi_{t-1} - \pi_t{}^*) - c_m(\bar{y}_{t-1}) - d_m\Delta er_t + \epsilon_t \quad t = T_{m+1}, \ldots\ldots, T \tag{12}$$

[INSERT TABLE 6 HERE]

The results of the breakpoint test can be found in Table 6. As in the results in Table 4, the test detects a single breakpoint at 2009Q1[26].

The breakpoint model results seem to confirm the findings of the MS model that the PBOC seem to have been very accommodative of inflation over the estimation period as the inflation gap was not found to have any significant effect on the monetary policy index. In *Period 1* (1994Q2-2009Q1), the coefficient on the output gap is high in both significance and magnitude. However, the sign on this coefficient is incorrectly found to be positive which would indicate that the PBOC actually undertook paradoxical monetary policy responses in this period. While this logic seems counter intuitive, the coefficient on the exchange rate may provide an explanation for this. Changes in the nominal effective exchange rate are highly significant with a coefficient of 0.23. A 1% S.D. in the exchange rate leads to a very strong change of 2.1% in the monetary policy index. This suggests that the PBOC responded very strongly to any deviations in the level of exchange rate during this period. This is an interesting finding as it suggests that the PBOC's preference for controlling the movements in the exchange rate may have limited an appropriate response to deviations in the level of output. This is in line with our findings from Section 5. In *Period 2* (2009Q2-2014Q3) the exchange rate variable has gone from being highly significant in *Period 1* to insignificant. What is interesting is that the coefficient on the output gap is now highly significant and correctly signed. A 1% S.D. in the output gap leads to a 0.16% change in the monetary policy index. At first glance, one could argue that this structural break points to a more traditional central bank reaction function that targets the level of output and puts less emphasis on the exchange rate and may even point to a more independent and autonomous monetary authority. This may not be the case however. First of all, in early 2009, the

[26] Although the multiple breakpoint model is designed to pick up several breaks, only one is detected at 2009Q1.

size of China's foreign exchange intervention and reserve accumulation fell sharply as capital inflows slowed and the trade surplus narrowed due to the effects of the Global Financial Crisis. This meant that maintaining the RMB at a certain level was no longer the main focus of the monetary policy reaction.

7. Conclusion

The motivation of this paper was to examine the monetary policy reaction in the PRC by estimating a selection of augmented "Taylor type" monetary policy rules. The standard OLS estimation with the lending interest rate set by the PBOC as the dependent variable seems to be a very poor fit to the monetary policy reaction function of the PBOC. This result is not surprising and seems to support the arguments that the PBOC use a mixture of quantitative and qualitative monetary policy instruments. The inclusion of the monetary policy index as the dependent variable improves the specification slightly, but this estimation was found to contain structural breaks.

Therefore, a non-linear model which allows dynamic switching between different states is employed to the augmented monetary policy rule. The Markov switching model characterised the PBOC's monetary policy reaction into two states, First of all, the results indicated that the PBOC were accommodative of inflation over the entire estimation period of 1994-2014. This is in line with Mehrotra and Sanchez-Feng (2010) who argue that as the inflation gap has been mostly negative over the last twenty years, inflationary pressure has not been of huge concern to the PBOC. In *State 1* of the model, the PBOC reacts strongly and appropriately to deviations in output from its potential level. Changes in the exchange rate do not have a significant effect on the monetary policy index in this state. In *State 2*, the PBOC no longer reacts appropriately to the output gap but instead responds to deviations in the nominal effective exchange rate. What is most interesting about the results of the MS estimations is that in *State 1*, the NEER appreciates while it *State 2* it depreciates. As the RMB was considered undervalued throughout the estimation period, a depreciation in its value can be seen as intervention on behalf of the PBOC.

A robustness test in the form of a breakpoint model was estimated to test the validity of our findings. A single breakpoint was detected in 2009Q1. Prior to this breakpoint (i.e. 1994Q2-2009Q1), the PBOC seemed to adopt counterintuitive monetary policy responses i.e. they expanded (contracted) monetary policy when output was operating above (below) potential. While this policy seems illogical, the highly significant reaction of the policy index to changes in the NEER in the same period seem to indicate that the PBOC's exchange rate policy may have prevented the appropriate policy response to deviations in output from its potential level. After the breakpoint (2009Q2-2014Q4) this dynamic changed however. The exchange rate no longer had a significant effect on the MPI while changes in the level of output did. This is not attributed to the increased independence of the PBOC but instead to the slowdown in capital inflows as a result of the financial crisis and the fiscal stimulus package introduced in 2008 by the state council which was strongly linked to monetary policy. The empirical results of this paper therefore seem to indicate that the PBOC lose the monetary policy transmission channel in terms of output stabilisation during periods when they intervene in the foreign exchange market to maintain the exchange rate at a desired level. This argument points to the impossible trinity problem.

While the estimations in this paper by no means provide a definitive model of Chinese monetary policy, some constructive conclusions can still be drawn from the empirical results of the estimations. First of all, in agreement with Goodfriend and Prasad (2006), Goldstein and Lardy (2007) and Chang et al. (2014), the results would suggest that China's quasi-fixed exchange rate regime has the potential to restrain the PBOC from conducting independent and appropriate monetary policy. As the PBOC would have to increase the money supply to maintain the exchange rate at a desired level, it may cause them to avoid reacting to deviations in the output gap in an appropriate manner. This could ultimately lead to the Chinese economy being exposed to significant risk of macroeconomic instability. The main policy recommendation from the results suggest that the PBOC should be granted increased monetary policy independence to mitigate against the adverse effects of external shocks which would disrupt macroeconomic stability. This would be complimented by continued reform in the financial and banking sector in China and, perhaps most importantly, further flexibility of the RMB.

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APPENDIX – SUMMARY STATISTICS

	OLS Estimations	Markov Switching Model		Robustness Test	
	1994Q2-2014Q3	State 1	State 2	Period 1 (1994Q2-2009Q1)	Period 2 (2009Q2-2014Q3)
Mean of output gap	-0.7%	-0.5%	-0.9%	-0.9%	-0.2%
Standard deviation of output gap	1.7%	1.4%	1.8%	1.9%	0.7%
Mean of inflation gap	-0.7%	-1.5%	-0.7%	-0.6%	-0.4%
Standard deviation of inflation gap	1.7%	2.4%	3.8%	3.8%	1.3%
Mean of monetary policy index	-0.3%	-1.0%	0.2%	-0.4%	-0.4%
Standard deviation monetary policy index	1.3%	1.4%	1.1%	1.2%	1.3%
Mean of Δ in nominal effective exchange rate	0.3%	3.7%	-0.2%	-0.5%	1.6%
Standard deviation of nominal effective exchange rate	9.7%	5.5%	7.4%	10.9%	4.1%

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Tables

Table 1. Monetary Policy Tools of the People's Bank Of China

(a) Price Based Instruments

Interest rates on bank deposits & lending	The People's Bank of China's (PBOC) benchmark deposit rate is the "ceiling" interest rates bank pay for deposits. The lending rate is the "floor" of the rates banks earn from loans. In recent years, the PBOC has made plans to further liberalize the interest rates by gradually phasing out the benchmark deposit and lending rates. This would allow for a more market-based monetary policy implementation framework.
Refinancing to commercial banks	In its earlier years, the PBOC lent to specialized banks (see *Section 5.1*) and the PBOC also allocated a borrowing quota for each bank every year. In recent years, the PBOC began to use the refinancing policy instrument to ensure financial stability and help economic transformation during the "Second Reform Era".

(b) Quantity Based Instruments

Reserve Requirement Ratio (RRR)	Introduced by the PBOC in 1984, the RRR has been increasingly used in recent years as a key policy instrument to control liquidity in the financial system and restrict relatively rapid growth of monetary and credit aggregates in the economy.
Open Market Operations (OMO's)	OMOs, the purchase and sale of securities on the open market by the PBOC, were first introduced as a monetary instrument in 1993. Since 1998, with actions taken by the PBOC to develop the interbank bond markets, OMO's have represented a critical instrument for the conduct of monetary policy in China.
Capital Controls	This is related to foreign exchange intervention (below). The aim of this policy instrument differs in that its aim is not to control credit allocation, but instead to quantitatively limit the financial flows between China and the rest of the world.

(c) Less observable instruments

Foreign exchange intervention	In simple terms, this involves controlling the level of the RMB through selling the domestic currency and buying foreign currencies to keep the foreign-exchange value lower than it would otherwise be. This policy has received a huge amount of attention, particularly from the US, who have labelled the process "currency manipulation".
Window Guidance	This is the policy of the Chinese government persuading the PBOC and financial institutions to follow official guidelines. This can involve directing financial institutions on who and how much to lend. e.g. lending to certain sectors or industries, state owned enterprises etc.
Admin measures	This would include set limits on the price (interest rate controls) or the quantity (credit ceilings) of bank borrowing and lending operations. There has been a degree of liberalisation in this area however. For example limits on lending rates were removed in 2004 and 2013 leaving the ceiling deposit rate as the only remaining regulated interest rate.

Source: Frankel (2006), PBOC website, Bell and Feng (2013), Geiger (2008) and author's research.

Table 2. Monetary Policy Rule Unit Root Test (Augmented Dickey-Fuller)

Variable	1 lag	2 lags	3 lags	4 lags	5 lags
Output Gap	-2.60*** (0.00)	-2.35 * (0.02)	-2.04** (0.04)	-2.26** (0.02)	-2.36** (0.02)
Inflation Target	-3.88*** (0.00)	-5.55*** (0.00)	-7.77*** (0.00)	-3.78 ** (0.01)	-3.33 ** (0.02)
Interest Rate (Lending)	-1.35 (0.60)	-1.40 (0.58)	-1.42 (0.57)	-1.33 (0.61)	-1.47 (0.54)
Δ Interest Rate (Lending)	-4.63*** (0.00)	-4.08*** (0.00)	-4.07*** (0.00)	-3.20** (0.02)	-3.22** (0.02)
Monetary Policy Index	-5.28*** (0.00)	-4.53*** (0.00)	-4.77*** (0.00)	-3.09** (0.03)	-2.6* (0.09)
Δ in Exchange Rate	-4.99*** (0.00)	-6.36*** (0.00)	-9.71*** (0.00)	-2.80* (0.06)	-4.44 (0.00)

Notes: 1% and 5% P-values are -3.52 and -2.90 for test with a constant. Rejection of the unit root hypothesis at the 10, 5 & 1% level is indicated with *, ** & ***. P-values are in parenthesis.

Table 3. Coefficient of Variance of Policy Variables

Index	Deposit	Lending	Base	RRR	Qualitative
$\boldsymbol{MPI_t}$	0.20	0.09	0.16	0.12	0.43

Source: Author's calculations. Notes: The coefficients have been normalised.

Table 4. Monetary Policy Rule Estimation - OLS Estimation (1994Q2-2014Q3)

Variable	Interest Rate (2)	Monetary Policy Index (3)
Dependent Variable: Δ Interest Rate (24) and MPI (25)		
Constant	-0.01	-0.01
	(0.01)	(0.01)
Inflation Gap	0.03*	0.11*
	(0.02)	(0.07)
Output Gap	-0.04*	-0.20**
	(0.02)	(0.09)
Δ in Exchange Rate	0.01	0.03
	(0.01)	(0.02)
$\mathbf{R^2}$	0.1	0.17
DW Statistic	1.4	1.7
SupF Stat	14.8	28.0***
	(no break)	(2009Q1)

Notes: ***,** and * denotes significance at the 1, 5 and 10% respectively. HAC standard errors are in parenthesis.

Table 5. Monetary Policy Rule with Markov Switching Model (1991Q2-2014Q3)

Variable	State 1	State 2
Dependent Variable: Estimated Monetary Policy Index (MPI)		
Constant	-0.01***	-0.01*
	(0.01)	(0.01)
Inflation Gap	0.29*	0.01
	(0.17)	(0.16)
Output Gap	-0.54***	0.11
	(0.19)	(0.13)
Δ in Exchange Rate	-0.01	0.05***
	(0.05)	(0.03)
$\mathbf{p_{11}}$	0.63	
$\mathbf{p_{12}}$	0.37	
$\mathbf{p_{21}}$		0.28
$\mathbf{p_{22}}$		0.72
Duration of State	2.7 quarters	3.5 quarters

Notes: ***,** and * denotes significance at the 1, 5 and 10% respectively. Standard errors are in parenthesis

Table 6 – Robustness Test Monetary Policy Rule (MPI) with Multiple Breakpoints (1991Q2-2014Q3)

Variable	Period 1 (1994Q2-2009Q1)	Period 2 (2009Q2-2014Q3)
Dependent Variable: Monetary Policy Index (MPI). Break Date 2009Q1		
Constant	-0.08***	-0.15***
	(0.01)	(0.01)
Inflation Gap	-0.07	0.15*
	(0.12)	(0.07)
Output Gap	1.06**	-0.29***
	(0.40)	(0.04)
Δ in Exchange Rate	0.23***	0.02
	(0.01)	(0.02)

Notes: ***,** and * denotes significance at the 1, 5 and 10% respectively. HAC standard errors are in parenthesis

Figure 1.   All Relevant Estimation Variables

Source: National Bureau of Statistics (NBS), IMF International Financial Statistics, Oxford Economics & author's calculations

Figure 2. Changes in PBOC Policy Instruments

Source: National Bureau of Statistics (NBS) & authors calculations

Figure 3. Estimated Monetary Policy Index (MPI)

Source: Authors Calculations

Figure 4. Monetary Policy Targets & State Classification

Source: National Bureau of Statistics (NBS), Oxford Economics & author's calculations

All figures – EViews 9 /PC