

Examining Monetary Policy Transmission in the People's Republic of China—Structural Change Models with a Monetary Policy Index[†]

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This paper estimates augmented versions of the Investment–Saving curve for the People's Republic of China in an attempt to examine the relationship between monetary policy and the real economy. It endeavors to account for any structural break, nonlinearity, or asymmetry in the transmission process by estimating a breakpoint model and a Markov switching model. The Investment–Saving curve equations are estimated using a Monetary Policy Index, which has been calculated using the Kalman filter. This index will account for the various monetary policy tools, both quantitative and qualitative, that the People's Bank of China has used over the period 1991–2014. The results of this paper suggest that monetary policy has an asymmetric affect depending on the level of output in relation to potential, and that the People's Republic of China's exchange rate policy has restricted the effectiveness of the People's Bank of China's monetary policy response.

Keywords: IS curve, Kalman filter, monetary policy, People's Bank of China, structural change

JEL codes: E12, E42, E58

I. Introduction

The dynamics of monetary policy transmission is arguably the most comprehensive and yet rapidly expanding research area in the discipline of macroeconomics. Taylor (1995) describes the monetary policy transmission channel as the process by which a central bank's monetary policy instruments exert influence on macroeconomic variables such as prices, output, and employment. In most advanced economies, the operating target for the conduct of monetary policy is the interest rate. For example, the United States (US) Federal Reserve has the Fed Funds rate, the European Central Bank has the main refinancing rate, and the Bank

[†]ADB recognizes "China" as the People's Republic of China.

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of England has the base rate. It has been argued, however, that the People's Republic of China's (PRC) central bank, the People's Bank of China (PBOC), uses a variety of policy instruments, both quantitative and qualitative, and so the use of a single interest rate variable may not give an accurate representation of the PBOC's monetary stance (see, for example, Geiger 2008, He and Pauwels 2008, Ma 2014). While some researchers suggest that continued liberalization in the finance sector has improved its effectiveness (Fernald, Hsu, and Spiegel 2014), most studies have found that the interest rate channel in the PRC has been largely ineffective. Since the reforms in 1978, the foundations of the PRC's monetary policy have instead been built on a fixed exchange rate, strict controls on capital flows, and a wide selection of administrative and qualitative policy tools. Over the past 30 years, the PRC's macroeconomic dynamics have been characterized mainly by high gross domestic product (GDP) growth accompanied by erratic business cycle fluctuations. Despite average annual growth of almost 10% per annum over the last 3 decades, the PRC's output volatility has remained consistently high. An IMF (2011) paper states that the PRC's output volatility is twice as high as that of the US. In recovering from the global financial crisis of 2008–2009, the PRC faced serious credit-fueled inflationary concerns. The PRC's monetary authorities addressed this by raising banks' reserve requirement ratios. However, in the pursuit of higher financial openness and exchange rate stability, the PRC is facing the crucial trade-off of having to give up monetary policy independence. This is a perfect example of the trilemma, or impossible trinity problem.¹

With this in mind, understanding the PBOC's instruments of monetary policy is important in examining how the transition mechanisms affect the real economy. To fully analyze what drives business cycle behavior in the PRC, it is important to carry out a robust study of the relationship between monetary policy, the credit market, and the real economy while allowing for PRC-specific characteristics. It is also crucial to examine if these relationships have changed during the estimation period (1991–2014), given the large number of reforms and institutional changes that typified this period. This paper will attempt to do so by estimating different variations of an Investment–Saving (IS) curve—both a traditional interest rate IS curve and a model estimated using a composite policy index that has been calculated using a Kalman filter in a State Space Model (SSM) form. This index may give a more accurate representation of the instruments at the disposal of the PBOC. This paper will also test, and account for where appropriate, structural breaks, nonlinearity, and asymmetry in the time series to determine if the response or effect of monetary policy has changed or switched in any significant way.

¹A fundamental contribution of the Mundell–Fleming framework, the impossible trinity states that an economy may choose two but not all three of the policy goals of monetary policy independence, a fixed exchange rate, and full capital mobility.

The paper presents three main findings. First of all, unlike the majority of the literature in this area, our results find that a standard IS curve equation using a simple PBOC lending rate has a statistically significant impact on the real economy, albeit a small one. Secondly, a composite measure of the monetary policy instruments would seem to give a better explanation of the monetary policy transmission channel once structural breaks, asymmetry, and nonlinearity are accounted for. The breakpoint model finds that the PRC's monetary policy reaction has declined since 1995, and we suggest that this is the result of the adoption of the dollar peg exchange rate regime in 1994. Finally, the results of the Markov switching (MS) model indicate that the PBOC's monetary policy instruments have a stronger effect on the real economy when output is operating at or above potential (positive output gap), but has less of an effect when output is operating below potential (negative output gap). The paper is structured as follows. Section II gives an overview of the literature on monetary policy transmission in the PRC during the reform period (1991–2014). Section III outlines the methodology used in estimating our IS curve. Section IV outlines the data used in our estimations and gives a detailed description of the estimated Monetary Policy Index (MPI). Section V estimates the various IS models and comments on the results of each. Section VI performs robustness tests on our results. Section VII concludes.

II. Literature Review

A number of seminal papers have been written relating the level of aggregate demand to monetary policy. Bernanke and Blinder (1992), Blanchard (1990), and Friedman (1995) are all good examples of the theory that in advanced economies the level of real output is highly responsive to monetary policy. There is, however, a separate branch of research that suggests monetary policy has had little or diminishing impact on the real economy (see, for example, Goodhart and Hofmann 2005). The New Keynesian model of monetary policy has become the standard tool for the analysis of the monetary policy transmission channel. This model consists of a Phillips curve, an IS curve, and a monetary policy rule. According to Goodhart and Hofmann (2005), the IS curve represents the intertemporal Euler consumption equation. It relates the output gap to the expected future output gap and the real interest rate: the higher the interest rate, the lower the output. A great deal of research on this topic in the PRC has focused on understanding the impact of interest rate changes on investment, which accounts for a particularly large share of GDP and growth in the PRC and is an important driver of business cycle volatility (Conway et al. 2010, Liu and Zhang 2010, Kuijs 2006). The PRC's authorities have traditionally relied mainly on administrative instruments and an array of both qualitative and quantitative measures in conducting monetary policy, with interest rates playing a less prominent role (Koivu 2005). So far, the majority of the literature

has supported this argument as macroeconomic evidence of a significant negative relationship between interest rate changes and capital formation in the PRC has been weak. Geiger (2006) argues that changes in interest rates have limited impact on aggregate macro variables and that the transmission of monetary policy via the interest rate channel is distorted. Laurens and Maino (2007) argue that there is no significant link between the PRC's short-term interest rates and movements in GDP. Mehrotra (2007) examines the role of interest rate channels in the PRC; Hong Kong, China; and Japan using a structural vector autoregression model and finds that while there is strong evidence of the interest rate channel as a monetary policy tool for both Japan and Hong Kong, China, the same cannot be said for the PRC. The limited importance of the interest rate channel in the PRC is attributed to the implementation of interest rates by administrative measures rather than market-determined interest rates.

The majority of studies analyzing aggregate demand in the PRC have used standard linear models and found little or no evidence of a relationship between output and monetary policy. Koivu (2009) argues that the reforms and structural breaks during 1998–2007 prevented the estimation of a stable credit demand equation for the PRC. To remedy this, the author estimates the model across two subsample periods, accounting for these structural breaks and reforms. The results seem to support the findings of previous studies that the link from interest rates to the real economy is still quite weak in the PRC. The author did, however, find that the link had strengthened toward the end of the estimation period, suggesting that interest rates have increased in importance along with continued reform in the PRC's finance sector. Qin et al. (2005) find that the overall impact of monetary policy on the real sector of the macroeconomy is small and insubstantial, suggesting that the PRC's monetary policy instruments are not effective tools for controlling output, investment, or employment. In contrast to this, many authors have found that there is a negative link between interest rates and macroeconomic aggregates in the PRC. Girardin and Liu (2007) use a vector autoregression model to investigate the relationship between interest rates and output in the PRC and find that a negative relationship does exist, particularly in the latter half of the sample period 1997–2005. While Conway et al. (2010) argue that an IS equation for the PRC is difficult to estimate, the authors' estimation for 2000–2007 found that both the interest rate and the exchange rate have a statistically significant impact on the real economy in the PRC, even if this impact is relatively small.

There has been very little agreement in the mainstream literature regarding the asymmetric effect of monetary policy; that is, whether monetary policy has a greater effect across different stages of the business cycle. Using US data, Ravn and Sola (2004) and Weise (1999) find that the transmission of monetary policy is very much symmetric. In a more recent paper, Tenreyro and Thwaites (2013) also suggest that monetary policy transmission has asymmetric effects, with the authors finding a greater effect on output (and inflation) in an expansion. Dolado,

Maria-Dolores, and Ruge-Murcia (2005); Peersman and Smets (2001); Aragón and Portugal (2009); and, more recently, Barigozzi et al. (2014) have also investigated the topic of asymmetric monetary policy in eurozone economies. Despite these studies, across advanced economies, no real consensus has been reached in this area of research. As a result, the topic and its policy implications have been largely ignored in the mainstream monetary policy literature.² This paper will add to the body of research by testing and accounting for asymmetry in the PRC's economy over the last 25 years. However, the huge difference between the PRC's economy and that of the US and the eurozone requires innovative and perhaps unconventional tools to investigate the monetary policy transmission channel. The presence of structural breaks, changes, nonlinearity, and asymmetry in the transmission channel may be even more prominent in the PRC. There are many reasons to make this inference. This paper examines the monetary policy reactions of the PBOC since late 1991, which is often regarded as the start of the PRC's second reform era. During this period, the PBOC endeavored to pursue a more market-oriented monetary policy framework, which included greater use of indirect instruments. The period also coincided with other institutional reforms and changes that may have greatly affected the monetary policy transmission channel over time.

While there has been a great deal of literature chronicling the PRC's economic policy, in particular the effect of changes in exchange rate policy, less attention has been paid to estimating an indicator for the monetary policy stance and very few studies have accounted for the asymmetric affect that these policies have had on the level of output. Xiong (2012) computes a monetary policy index using an ordered probit model, but stops short of differentiating between asymmetric responses to the PBOC's actions due to changes in the state of the economy, stating that this warrants further investigation.³ Girardin, Lunven, and Ma (2014) build on the work of He and Pauwels (2008) and Xiong (2012) by constructing an aggregate measure of the PRC's monetary policy stance using price, quantitative, and administrative measures. Finally, Petreski and Jovanovic (2013) create their own MPI using a weighted average of quantitative and qualitative instruments, which is in turn included in the model instead of the interest rate. The estimation of the PRC's monetary policy instruments in this paper is based on this work as it also uses a Kalman filter to extract the qualitative variables. While these papers may have focused on finding an appropriate measurement of monetary policy in the PRC, one oversight in this area of the literature has been the failure to account for structural breaks, asymmetry, and nonlinearity in the transmission process. As has been discussed, this could be particularly relevant to an economy like the PRC's, which has undergone significant change and reform. To our knowledge, this research is the first to apply both a

²This argument was made by Tenreyro and Thwaites (2013), who pointed to examples such as Christiano, Eichenbaum, and Evans (2005); and Woodford (2003).

³An ordered probit model in this case assigns a number depending on the type of policy that is observed or believed to have been carried out: -1 is contractionary, 0 is neutral, and 1 is expansionary.

linear model with structural breaks and a nonlinear technique (MS model) to the transmission process, as well as a composite index of the monetary policy stance.

III. Methodology

The traditional IS curve takes the form of Equation 1:

$$\bar{y}_t = E_t(\bar{y}_{t+1}) - c[i_t - E_t(\pi_{t+1})] + v_t \quad (1)$$

where \bar{y}_t is the output gap, $(i_t - E_t(\pi_{t+1}))$ is the real interest rate, v_t is a demand-side shock, and c is the response of output to changes in the real interest rate.

Equation 1 is a purely forward-looking equation and relates the output gap to the expected future output gap and the real interest rate. In empirical applications, however, purely forward-looking models have been found to be inconsistent with the dynamics of aggregate demand (Estrella and Fuhrer 2002). Therefore, a backward-looking specification is often preferred in order to match the lagged and persistent responses of output to monetary policy measures that are found in the data (Rudebusch 2002). Backward-looking specifications have been used in many empirical studies, including Fuhrer and Moore (1995), Rudebusch and Svensson (1998), and Goodhart and Hofmann (2005). We can therefore rewrite the equation as

$$\bar{y}_t = a + b(\bar{y}_{t-1}) - c[(i_{t-1}) - (\pi_{t-1})] + dv_t + \varepsilon_t \quad (2)$$

This purely backward-looking specification of the PRC's IS equation can be used in our estimations to obtain dynamics that match those of available economic data most consistently. Macroeconomic data usually shows a high degree of persistence in both inflation and output (Estrella and Fuhrer 2002). According to Ball (1999, 128), the advantage of the backward-looking specification is that it "is similar in spirit to the more complicated macro econometric models of many central banks."

Since the PBOC has adopted a wide range of monetary policy instruments over the last 3 decades, the use of a single variable to adequately capture a monetary policy stance may not be appropriate. A good measure of the monetary policy stance should be able to indicate, either qualitatively or quantitatively, whether policy is becoming contractionary, expansionary, or remaining unchanged (Xiong 2012). Most studies in this area focus on the movement of a single policy variable such as the lending or the deposit interest rate (Xie and Xiong 2003, Conway et al. 2010) or the M2 money supply (Burdekin and Silkos 2008, Koivu 2008). It is commonly accepted that monetary policy in the PRC consists of both quantitative instruments (interest rates, deposit rates, reserve requirement) and qualitative instruments. Qualitative instruments include persuasion and specific directives such as telling banks which

companies to lend to, a practice that is often referred to as window guidance. This policy uses benevolent compulsion to persuade banks and other financial institutions to stick to official guidelines. Central banks put moral pressure on financial players to make them operate consistently with national needs (Geiger 2008). This usually involves influencing market participants through announcements rather than a set of strict rules. Many authors—including Goodfriend and Prasad (2006); Bell and Feng (2013); and Girardin, Lunven, and Ma (2014)—have emphasized the importance of these qualitative instruments with regard to the conduct of the PRC's monetary policy, but the problem from a modeling point of view is that there is no data available for such instruments. How can one model or quantify whether the PBOC informs a particular industry or company to follow their instructions? Therefore, this qualitative instrument variable must be calculated. Once predicted, this series can be used to create an index composed of both the changes in quantitative and qualitative instruments that would more accurately represent the monetary policy stance of the PBOC. The technique of building an index for monetary policy using a variety of techniques has been carried out by Gerlach (2007); Petreski and Jovanovic (2013); and Girardin, Lunven, and Ma (2014).

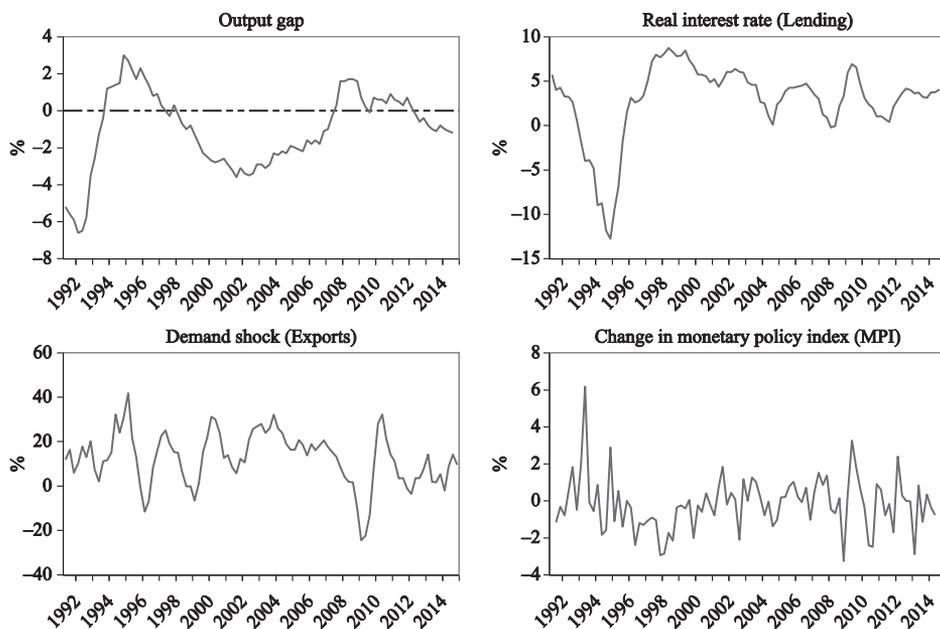
IV. Data

A. Interest Rate and Demand Shock

All variables used in the IS curve estimations are plotted in Figure 1. Seasonal factors have been adjusted for where appropriate. The time period of Q1 1991–Q3 2014 corresponds with the start of the second reform era and was chosen to capture the dynamics of this period of structural changes and institutional reforms. Table 1 reports the unit root tests for all the variables used in our estimations. The results confirm that all variables pass the test for integration of order zero ($I \sim [0]$) and are therefore stationary.

The real interest rate is calculated as $(i_t - \pi_t)$ where i_t is the lending interest rate and π_t is the annual change in quarterly Consumer Price Index. Both of these series are available in the International Monetary Fund's (IMF) *International Financial Statistics* and the PRC's National Bureau of Statistics. For the demand shock, the PRC's seasonally adjusted export data, also found in the IMF's *International Financial Statistics*, is used. The huge importance of the PRC's exports to its growth model over the last 2 decades has been discussed extensively in the literature (Liu, BurrIDGE, and Sinclair 2002; Guo and N'Diaye 2009; Amiti and Freund 2010), and therefore this is the most logical and appropriate demand shock for the PRC's economy. As has been mentioned, the PBOC relies on a basket of different policy tools in the conduct of monetary policy. Therefore, an MPI is required to accurately examine the stance of the PBOC. As no dataset for such an index exists, it will be calculated using the Kalman filter technique. Given the

Figure 1. IS Curve Estimation Variables, Q1 1991–Q3 2014



IS = Investment–Saving.

Sources: National Bureau of Statistics. <http://www.stats.gov.cn/english/>; International Monetary Fund. International Financial Statistics. <http://data.imf.org/?sk=5DABAFF2-C5AD-4D27-A175-1253419C02D1>; and Oxford Economics. Global Economic Databank. <http://www.oxfordeconomics.com/forecasts-and-models/cities/china-cities-and-regional-forecasts/overview> (all accessed January 2015); and authors' calculations.

Table 1. IS Curve Unit Root Test (augmented Dickey-Fuller)

Variable	1 lag	2 lags	3 lags	4 lags	5 lags
Output gap, \bar{y}_t	-2.60* (0.09)	-3.23* (0.04)	-3.50** (0.03)	-5.76** (0.04)	-3.05** (0.04)
Real interest rate, $i_t - E_t(\pi_{t+1})$	-2.60* (0.09)	-3.14** (0.03)	-2.99** (0.05)	-2.19 (0.14)	-2.73** (0.05)
Demand shock (Δ Exports), v_t	-4.54*** (0.00)	-4.82*** (0.00)	-5.69*** (0.00)	-3.92** (0.02)	-3.19** (0.05)
Monetary Policy Index, MPI_t	-5.07*** (0.00)	-4.35*** (0.00)	-4.84*** (0.00)	-3.76*** (0.00)	-2.87* (0.09)

IS = Investment–Saving.

Notes: Rejection of the unit root hypothesis at the 10%, 5%, and 1% level is indicated with *, **, and ***, respectively. P-values are in parentheses. Critical values for test with constant are -2.5, -2.8, and -3.4.

Source: Authors' calculations.

importance of this variable for the analysis of the PRC's monetary policy, section IV.C describes the theory, rationale, and calculations behind the MPI. Finally, for the excess demand variable, the output gap is used. As the output gap variable is key to this paper and is the dependent variable for almost all econometric estimations, the next section discusses its calculation and interpretation.

B. The People's Republic of China's Output Gap

The IMF (2015) defines the output gap as the deviation of actual from potential output as a percentage of potential. In the equation below, y denotes actual output (measured by real GDP) and y^* represents potential output, which is defined as the output an economy could produce if all factors of production were operating at their full employment rates of capacity. The output gap can then be represented as $\bar{y} = \frac{y-y^*}{y^*} \times 100$.

Gerlach and Peng (2006) identify two broad approaches to estimating potential output, and thus the output gap, for the PRC:⁴

- a production function approach, which makes use of information regarding the sources of growth (i.e., factor accumulation and the state of total factor productivity); and
- by identifying the trend in real GDP with potential output and using time series techniques, such as filtering, to estimate it.

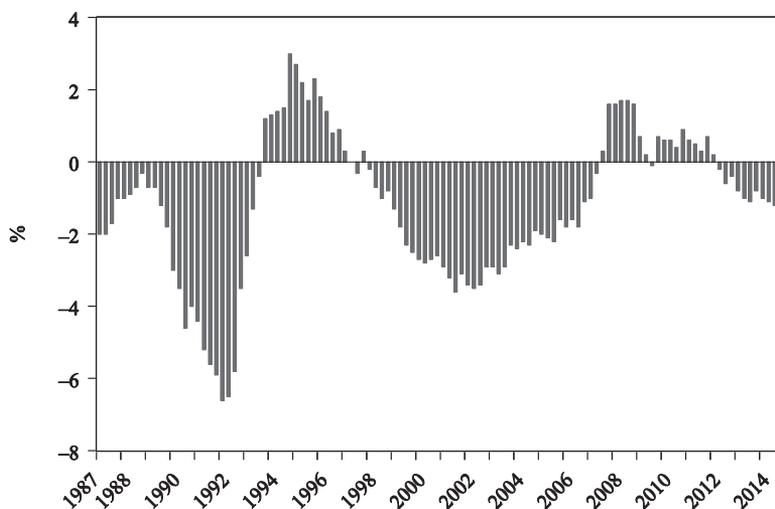
We will examine these two techniques for our output gap data for the PRC.

1. Production Function

The main advantage of the production function approach is that it provides an understanding of the sources of growth. However, to estimate a level of potential output in this way requires high-quality data on the capital stock and labor force. The reasons that this may be an issue for the PRC have been well documented (see, for example, Holz 2014). Scheibe (2003) devotes an entire paper to the calculation of the PRC's output gap. The author points out the many issues in estimating potential output for the PRC, ranging from the limited number of postreform observations, badly measured data, absence of proxies for capacity utilization or hours worked, no reliable inventory data, and significant structural changes.

This paper considers a production function output gap calculated by the Oxford Economics Global Economic Databank (Figure 2), given that this organization has access to data that are not widely available. This variable is estimated as follows: "We construct our measure of potential output bottom-up by looking at the inputs into the production function ([labor] supply, capital accumulation, and the components of [total factor productivity]). Subsequently, we benchmark this against actual GDP to a period where we feel the economy was

⁴More recently Zhang and Murasawa (2011, 2012) and Zhang et al. (2013) have estimated a measure of the output gap for the PRC based on a multivariate dynamic model.

Figure 2. **Production Function Output Gap**

Source: Oxford Economics. Global Economic Databank. <http://www.oxfordeconomics.com/forecasts-and-models/cities/china-cities-and-regional-forecasts/overview> (accessed January 2015).

operating at potential to ensure the level of actual and potential GDP at that moment is equal and the output gap is zero.”⁵

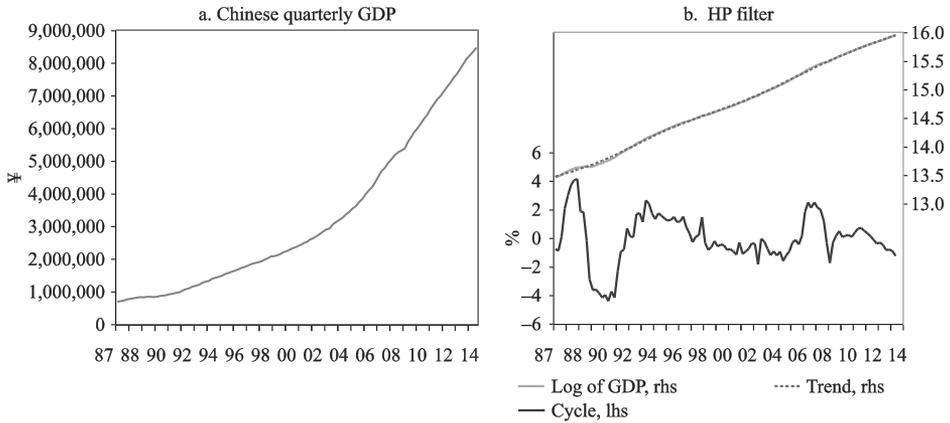
2. Filtering

A frequently used tool in macroeconomics is the Hodrick–Prescott (HP) filter, which decomposes actual output into a long-run trend and cyclical components. This statistical method does not use any information regarding the determinants of each of the components, but provides a useful approximation of potential output growth. While the time series approach is easy to implement, it suffers from the drawback that 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, we will calculate an HP filter output gap using GDP data from the PRC’s National Bureau of Statistics to compare to Oxford Economics’ estimations.

To get a complete comparison for as long a period as possible, we use the earliest available data and calculate an HP filter output gap from 1987 to 2014. The PRC’s quarterly GDP data can be seen in Figure 3(a) and the HP filter applied to this series in Figure 3(b). The calculated output gap is presented in Figure 4.

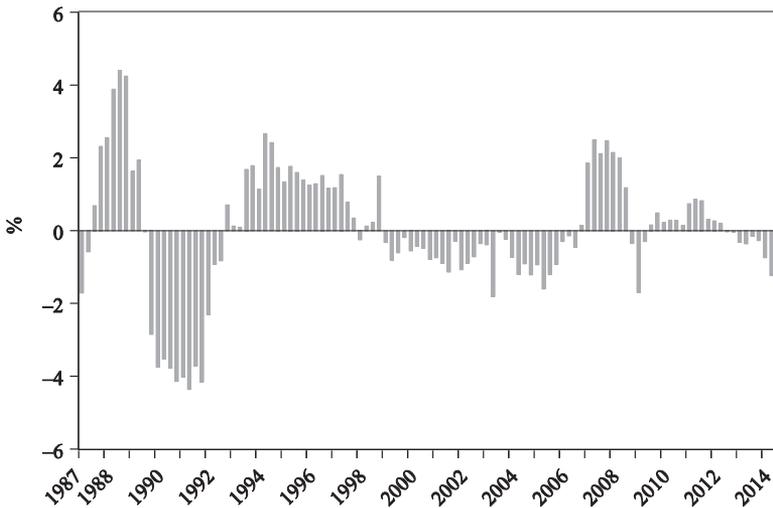
⁵This includes data on wages; labor; primary, secondary, and tertiary activities; employment; income and consumer spending; retail sales; and other series of importance. Oxford Economics, Global Economic Databank. <http://www.oxfordeconomics.com/forecasts-and-models/cities/china-cities-and-regional-forecasts/overview> (accessed January 2015).

Figure 3. Hodrick-Prescott Filter of the PRC's GDP Data



GDP = gross domestic product, HP = Hodrick-Prescott, PRC = People's Republic of China.
 Sources: National Bureau of Statistics; and authors' calculations.

Figure 4. Hodrick-Prescott Filter Output Gap

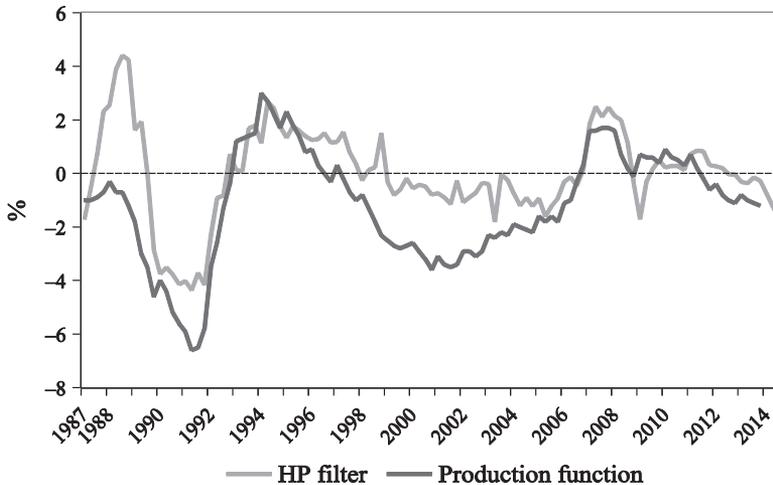


Sources: National Bureau of Statistics; and authors' calculations.

3. Comparison of Both Series

Both the production function output gap and the HP filter output gap are plotted together in Figure 5. There is a noticeable difference between the two in the 1987–1989 period: the HP filter estimation shows a highly positive output gap, while the production function gap shows a negative value. The significant difference in the HP filter estimation in this period may be explained by the arguments of Giorno,

Figure 5. Comparison of the PRC's Output Gaps, 1987–2014



HP = Hodrick-Prescott, PRC = People's Republic of China.

Sources: Oxford Economics. Global Economic Databank. <http://www.oxfordeconomics.com/forecasts-and-models/cities/china-cities-and-regional-forecasts/overview> (accessed January 2015); and authors' calculations.

Roseveare, and Van Den Noord (1995), who suggest the HP filter method often falls victim to an endpoint problem. In part, this reflects the fitting of a trend line symmetrically through the data. If the beginning and the end of the dataset do not reflect similar points in the cycle, then the trend will be pulled upward or downward toward the path of actual output for the first and last few observations. For example, for those economies that have been slower to emerge from a recession, an HP filter will tend to underestimate trend output growth for the current period. Other than this discrepancy, the two series seem to follow a similar pattern of output operating above or below potential in similar periods.

What is striking about both series is that despite GDP growth, which has averaged almost 10% since 1987, the PRC's output gap has remained negative for the majority of the review period. This point has also been made by the IMF (2012). This problem of excess capacity can be highlighted by examining both estimates of the PRC's output gap.⁶ It is indicative of a growth model that has relied on high levels of investment and exports combined with surplus labor. In the past, the PRC's high levels of investment created capacity beyond its ability to consume. The excess capacity has often been absorbed outside its borders by the exceptionally strong global demand for the PRC's exports (IMF 2014). As the 2008–2009 global financial

⁶Several factors are believed to contribute to the problem of excess capacity in the PRC. These include very high rates of saving and investment, a massive transfer of unskilled labor from the agriculture to urban nonagriculture sectors, cheap labor costs, low levels of education, and low levels of technical innovation (Wang, Fan, and Liu 2008). In addition, there is the PRC's institutional and political environment, which often results in central and regional governments propping up largely inefficient state-owned enterprises.

crisis highlighted, however, the PRC can no longer rely on the same blistering level of demand for its exports that it enjoyed in the early and mid-2000s.

The similarity of these two techniques using two different datasets adds robustness to the use of the PRC's output gap in our empirical estimations. Given that the production function is often seen as the optimal methodology in estimating an economy's potential output, we use the production function estimate of potential output measure as calculated by Oxford Economics Global Economic Databank.

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

1. 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 have been used in economics research in a variety of problems when a variable that is supposed to play some relevant economic role is not directly observable. While a particular variable may not be directly observable, the unobserved component model using a Kalman filter allows researchers to predict how this unobserved variable might be behaving.⁷ For example, unobserved components have been used in modeling agents' reaction to permanent or transitory changes in the price level (Lucas 1976), modeling the credibility of the monetary authority (Weber 1992), and measuring the persistence (long-term effects) of economic shocks (Cochrane 1988). The statistical treatment of an unobserved components model is based on the 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, SSMs 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 SSM (Harvey, Koopman, and Sheppard 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 using this technique in this paper is to make inferences about the unobservable policy instruments that the PBOC carry out given a set of observable policy instruments.

⁷Additional information on this technique can be found in Cuthbertson, Hall, and Taylor (1992); Kim and Nelson (1999); and Commandeur and Koopman (2007).

We can categorize the monetary policy tools of the PBOC as either quantitative or qualitative:

- Quantitative monetary policy tools, often known as general tools, are the instruments used most often by central banks and monetary authorities in advanced economies. These include bank lending and deposit rates, reserve requirements, and open market operations. The quantitative instruments 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.”⁸
- Qualitative monetary policy tools, described as selective tools, often involve 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, also known as moral suasion or jawboning.⁹ Despite the word “guidance,” which implies a voluntary aspect in the system, the PBOC has had a major influence on the lending decisions of financial institutions, especially 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; that is, how to link the unobserved variables (qualitative) to the observed variables (quantitative)? Let us suppose that the PRC’s money supply (M2) changes in a way that would be consistent with a certain monetary policy response.¹⁰ Let us also assume, however, that none of the standard quantitative policy instruments (e.g., interest rates, open market operations, and reserve requirement ratios) 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 M2. Of course, this does not mean that all changes in M2 not explained by the measurement equation variables will be explained by this

⁸PBOC. Monetary Policy Instruments. <http://www.pbc.gov.cn:8080/publish/english/979/index.html> (accessed January 2015).

⁹There are several other direct control instruments that a central bank can use. These include credit controls (lending ceilings and floors) and prudential guidelines (informing commercial banks to exercise particular care in their operations in order that specified outcomes are realized).

¹⁰M2 is chosen because qualitative instruments are likely to be reflected onto the broad money supply (Petreski and Jovanovic 2013).

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.

2. Setup of the Unobserved Components Model

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 (discount) rate, reserve requirement ratios, and open market operations. 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. Finally, we need to include any other variable that will have a major influence on the level of M2. Therefore, we include changes in the level of real GDP as this will obviously affect M2 growth. Finally, we include the nominal effective exchange rate as the exchange rate is heavily managed and any deviation in its level will also affect growth in M2. While the renminbi was pegged to the US dollar without any movement between 1994 and 2005, the variable used, the nominal effective exchange rate, varies throughout the estimation period. Therefore, we can account for the effect that these nominal appreciations and depreciations, caused by changes in the exchange rate policy or regime, had on the growth of M2.

Equation 3 and 4 represent the measurement and transition equations, respectively. The quarterly change in M2 is chosen as the dependent variable in the measurement equation because, as mentioned, qualitative instruments are likely to be reflected onto broad money. $\Delta M2$ 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 obtained by a Kalman filter estimation of this money demand function. The two equations are written in the following forms:

Measurement equation

$$\Delta M2 = \beta_1 + \beta_2 \text{ exchange rate} + \beta_3 \text{ base rate} + \beta_4 \text{ reserve requirement} \\ + \beta_5 \text{ lending rate} + \beta_6 \text{ deposit rate} + \beta_7 \text{ GDP} + \beta_8 \text{ Qual} + \epsilon_{t1} \quad (3)$$

Transition equation

$$\text{Qual} = \beta_9 \text{ Qual}(-1) + \epsilon_{t2} \quad (4)$$

The measurement equation links the quantitative variables (β_3 base rate + β_4 reserve requirement + β_5 lending rate + β_6 deposit rate) and changes in the exchange rate and GDP (β_2 exchange rate + β_7 GDP) to an unobserved state variable

$(\beta_8 Qual)$.¹¹ The transition equation then describes the dynamics of this qualitative instrument.¹² This *Qual* variable in both Equations 3 and 4 is the vector of the unobserved variables and describes how these variables evolve over time. The error terms e_{t1} and e_{t2} are the monetary policy shock and shocks to the qualitative instruments, respectively. The setup of this unobserved component model assumes that the only variable affecting the quarterly growth rate of 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 that 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 variable that remains for the quarterly change in M2 is this qualitative variable. The qualitative variable is intended to capture PBOC actions such as window guidance, bank directives, credit guidance, and other instructions that are widely regarded to be very important to the PRC's banking sector. We expect that the qualitative variable would influence M2 as it involves the central bank persuading commercial banks to take certain steps without the PBOC making any changes to benchmark rates.

3. Estimating the Qualitative Variable

The results of the estimations are as follows:

Measurement equation

$$\Delta M2 = 7.5^{***} - 0.04 \text{ exchange rate} + 0.32 \text{ base rate} + 0.10 \text{ reserve requirement} - 1.4^* \text{ lending rate} + 0.95^{***} \text{ deposit rate} + 0.05 \text{ GDP} + Qual^{13} \quad (5)$$

Transition equation

$$Qual = -0.02 Qual(-1) \quad (6)$$

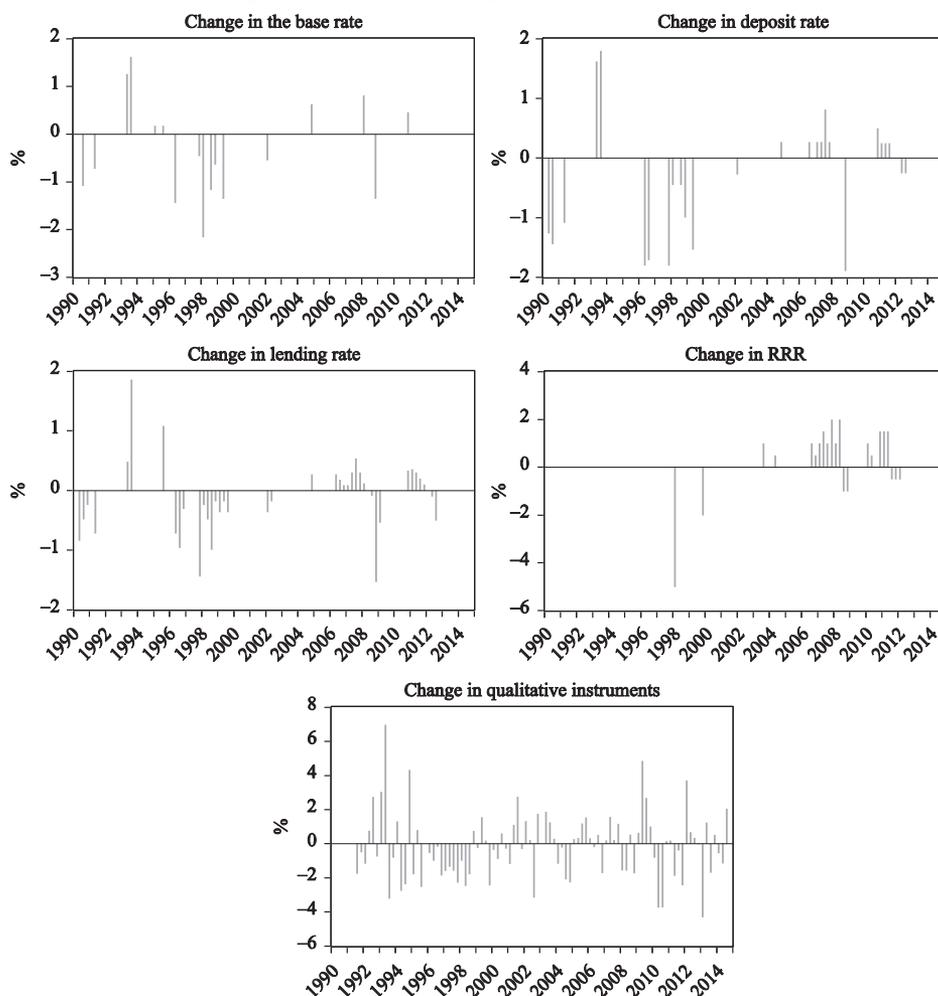
The measurement equation results show that while the GDP growth rate and changes to the exchange rate are correctly signed, their coefficients are not significant. The base rate and the reserve requirement ratio are insignificant and also incorrectly signed. In fact, of all the monetary policy tools included in the equation, only the deposit rate is correctly signed and significant. This suggests that for the

¹¹Note the omission of the open market operations variables. The variable for the open market operations variable moved almost exactly with the base (discount) rate. They deviated at the same periods and by the same magnitude; therefore, all the dynamics are already captured by the base rate.

¹²The starting values for the parameters in the measurement equation were chosen from an ordinary least squares (OLS) regression, which is the standard procedure for an estimation of this type.

¹³***, **, and * denote significance at the 1%, 5%, and 10% level of significance, respectively.

Figure 6. PBOC Monetary Policy Index Variables



PBOC = People's Bank of China, RRR = reserve requirement ratio.

Sources: National Bureau of Statistics. <http://www.stats.gov.cn/english/>; International Monetary Fund. International Financial Statistics. <http://data.imf.org/?sk=5DABAFF2-C5AD-4D27-A175-1253419C02D1> (both accessed January 2015); and authors' calculations.

most part the quantitative variables have had a limited impact on the PRC's money supply. This equation obviously suffers 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 the latent AR(1) that affects growth in M2. The predicted series calculated from the estimation can be seen in the bottom center panel of Figure 6 (Changes in Qualitative Instruments). This series should, broadly speaking,

Table 2. **Coefficient of Variance of Policy Instruments**

Index	Deposit	Lending	Base	RRR	Qualitative
MPI_t	0.20	0.09	0.16	0.12	0.43

MPI = Monetary Policy Index, RRR = reserve requirement ratio.

Note: The coefficients have been normalized.

Source: Authors' calculations.

correspond to the selective monetary policy actions of the PBOC. As a simple example, the marked increase and decline in the 1992–1995 period may be accredited to Deng Xiaoping's southern tour. The spike in the 2008–2009 period may have captured the stimulus package the PBOC undertook to mitigate the domestic impacts of the global financial crisis. From a simple observation of the series, it would appear that our qualitative variable measure has succeeded in capturing some of the important “unobservable” in the PRC's monetary policy movements.

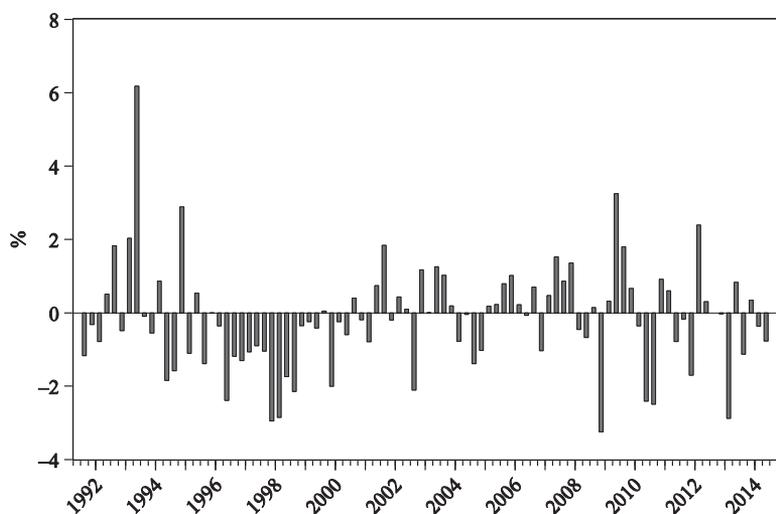
4. Calculating the Index

Having obtained an estimated series of the qualitative variable, the monetary policy index can then be constructed. Firstly, the coefficient of variance of the five instruments, both qualitative and quantitative, is calculated and their sum normalized to unity.¹⁴ 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 2. We can see that the main monetary policy tools mentioned by the PBOC—deposit rate, lending rate, discount rate, and reserve requirement ratio—play a relatively minor role and seem to change infrequently when compared to our qualitative instrument. The addition of the qualitative instrument variable clearly shows the importance of its role as a monetary policy tool.

This is confirmed by examining the changes in all policy variables (Figure 6), which show that the qualitative instrument variable changes far more frequently than the other four quantitative variables. The final MPI is then calculated as a weighted average of the changes in the five policy instruments, using the coefficient of variance values as weights (Table 2). Figure 7 plots the final MPI that will be used in the estimations that follow. 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. Therefore, we would expect to see a positive sign on the monetary policy reaction coefficient in the IS curve estimation.

¹⁴The five instruments are the four quantitative variables (deposit rate, lending rate, base rate, and reserve requirement ratio) and the estimated qualitative variable.

Figure 7. Calculated Monetary Policy Index



Source: Authors' calculations.

V. Estimations and Results

A. Standard Ordinary Least Squares Estimation

Table 3 reports the results of the traditional IS curve equation for the PRC that uses a standard single policy variable (lending rate) as a measure of the monetary policy stance of the central bank. Both a forward-looking (Equation 1) and backward-looking (Equation 2) IS curve are estimated. While these are the specifications most often used to examine monetary policy transmission in advanced economies, the literature has suggested that they may not provide an accurate representation of the monetary policy transmission channel in the PRC. The left-hand column of Table 3 provides the results of the forward-looking IS curve. The findings seem to support the arguments made in section III that forward-looking transmission equations of this kind perform poorly when tested empirically. First of all, the real interest variable, $i_t - E_t(\pi_t)$, is incorrectly signed and only significant at the 10% level. The demand shock, represented as a change in exports, is also insignificant and incorrectly signed. Finally, the estimations fail to satisfy tests for both autocorrelation and stability.¹⁵ The center column of Table 3 provides the results of the backward-looking IS curve (Equation 2). This specification seems to provide a better fit for the data. The lag of the output gap is large and highly significant, indicating that shocks to the output gap are quite persistent. The real interest rate is correctly signed and highly significant, which suggests that the lending rate set

¹⁵This can be seen by examining the LM F Statistic and the SupF Statistic.

Table 3. IS Curve Estimation—OLS Estimation, Q2 1991–Q3 2014

Variable	Forward-Looking IS Curve (1)	Backward-Looking IS Curve (2)	Monetary Policy Index IS Curve (7)
Dependent Variable: PRC Output Gap, \bar{y}_t			
Constant	-0.01	0.01***	-0.01
<i>a</i>	(0.01)	(0.00)	(0.01)
Output gap lag	—	0.90***	0.98***
\bar{y}_{t-1}		(0.03)	(0.03)
Output gap expect.	1.02***	—	—
\bar{y}_{t+1}	(0.03)		
Real interest rate (Lending)	0.03*	-0.06***	—
$i_t - E_t(\pi_t)$	(0.02)	(0.01)	
Monetary Policy Index	—	—	0.12**
<i>MPI_t</i>			(0.04)
Demand shock (Exports)	-0.01	-0.01	0.01***
<i>v_t</i>	(0.11)	(0.10)	(0.01)
R ²	0.93	0.94	0.94
LM F-Stat	4.46**	2.26	2.11
SupF-Stat	28.12***	14.51	17.39***
	(Q4 1994)	(no break)	(Q4 1994)

HAC = heteroscedasticity and autocorrelation-consistent, IS = Investment–Saving, OLS = ordinary least squares, PRC = People’s Republic of China.

Notes: *** = 10% level of statistical significance, ** = 5% level of statistical significance, * = 1% level of statistical significance. HAC standard errors are in parentheses.

Source: Authors’ calculations.

by the PBOC did have an effect on the real economy. While the coefficient of 0.06 indicates that the magnitude of this effect is quite small, it can be examined further by estimating the standard deviation (SD) of variables.¹⁶ This will give a more precise indication of the magnitude of the relationship between monetary policy and the real economy. A 1% SD in the interest rate results in a 0.12% change in the output gap. The effect of a shock to demand, represented in this paper as a change in exports, has no significant effect on the output gap during the estimation period. The presence of structural breaks can also be tested by applying the Quandt–Andrews SupF statistic (Quandt 1960 and Andrews 1993). Table 3 shows that the model passes the tests for structural breaks, which suggests that this standard IS curve for the PRC is characterized by a stable and linear relationship. This is an interesting finding and is at odds with the majority of research in the area. The result suggests that a standard IS curve may be an appropriate model for examining the monetary policy transmission channel in the PRC. There are explanations one can offer as to why the magnitude of this relationship is quite small. The underdevelopment of the banking system, market segmentation, and the ineffectiveness of the credit channel,

¹⁶These are calculated throughout the paper using the summary statistics that are provided in the Appendix. The SD is calculated by multiplying the coefficient given for the independent variable by the SD of that variable divided by the SD of the dependent variable.

as well as the fact that the PBOC has also relied on many different tools in the conduct of monetary policy, are all possible explanations.

As the PBOC has been known to use a variety of different policy instruments, an index representing these may give a better and more accurate representation of the PRC's monetary policy stance. The augmented IS curve model, estimated using the MPI that was estimated in section IV.C, then takes the following form:

$$\bar{y}_t = a + b(\bar{y}_{t-1}) + c(MPI_t) + dv_t + \varepsilon_t \quad (7)$$

The estimation of this augmented IS curve can also be seen in Table 3 (right-hand column).

Again, the persistence of a shock to the output gap is very high. The results, a coefficient of 0.12, seem to indicate that changes in this combined index have a stronger effect on the real economy than the interest rate. The positive sign suggests that an increase in the index corresponds to looser monetary policy and a decrease to tighter monetary policy. As before, we can examine more rigorously the relationship between the output gap and the MPI by examining the SD of the variables. A 1% SD in the MPI leads to only a 0.08% change in the output gap, a change that is actually smaller than that calculated by the interest rate IS curve. 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 in Table 3. In an attempt to remedy this problem, the next section of the paper estimates the MPI–IS curve using models that allow for structural breaks and switching between different states or regimes.

B. Breakpoint Model

The standard linear regression model assumes that the parameters of the model do not vary across observations. Despite this assumption, structural change, which is the changing of parameters at dates in the sample periods, plays an empirically relevant role in applied time series analysis. This is particularly true of economies such as the PRC that have experienced reform and institutional change. With this in mind, a linear regression model that is subject to structural change is estimated. There has been a large volume of work targeted at developing testing and estimating methodologies for regression models that allow for change. The seminal work of Chow (1960) and Quandt (1960) developed the testing procedure for structural changes in a time series at a single specified (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.¹⁷ An important feature of this test is that it allows us to test for multiple breaks

¹⁷Details of the multiple breakpoint regression model were sourced from Bai (1997); Bai and Perron (1998); Demers (2003); and Carlson, Craig, and Schwarz (2000).

Table 4. Monetary Policy Index IS Curve with Multiple Breakpoints, Q2 1991–Q3 2014

Variable	Period 1 (Q2 1991–Q4 1994)	Period 2 (Q1 1995–Q3 2014)
Dependent Variable: PRC's Output Gap, \bar{y}_t (breakdate: Q4 1994)		
Constant	-0.01	0.01*
a	(0.01)	(0.01)
Output gap lag	0.99***	0.96**
\bar{y}_{t-1}	(0.04)	(0.03)
Monetary Policy Index	0.24***	0.07*
MPI_t	(0.08)	(0.04)
Demand shock (Exports)	0.04*	0.01
v_t	(0.04)	(0.02)

HAC = heteroscedasticity and autocorrelation-consistent, IS = Investment–Saving, PRC = People's Republic of China.

Notes: *** = 10% level of statistical significance, ** = 5% level of statistical significance, * = 1% level of statistical significance. HAC standard errors are in parentheses.

Source: Authors' calculations.

at unknown dates. It is well documented that the effects of financial liberalization and economic reform are difficult to model using standard ordinary least squares (OLS) regressions, often due to the structural breaks that such events can cause in the time series (Blangiewicz and Charemza 1999). The Bai–Perron procedure is useful in such a case as it allows the user to find the number of breaks implied by the data and estimate the timing of the breaks and the parameters of the processes between breaks. The methodology can be used to estimate multiple structural changes in a linear model estimated by OLS. It treats the number of breakpoints and their locations as unknown.

Applying this procedure to the augmented IS curve with the calculated policy index, this gives us the following IS curve equation with m breaks:

$$\bar{y}_t = a_1 + b_1\bar{y}_{t-1} + c_1 MPI_t + d_1 v_t + \varepsilon_t \quad t = 1, \dots, T_1 \tag{8}$$

⋮

$$\bar{y}_t = a_m + b_m\bar{y}_{t-1} + c_m MPI_t + d_m v_t + \varepsilon_t \quad t = T_{m+1}, \dots, T \tag{9}$$

where the breakpoints (T_1, \dots, T_{m+1}) are treated as unknown. The Bai–Perron estimation is based upon OLS estimates of $a_i, b_i, c_i,$ and d_i .

The results of the multiple breakpoint regression, which can be seen in Table 4, confirm the presence of a structural break in Q4 1994. In Q2 1991–Q4 1994 (Period 1), the lag of the output gap is very high at 0.99 and significant at the 1% level. This indicates that shocks to the output gap are very persistent in this period. The index representing the monetary policy changes of the PBOC is highly significant in Period 1 with a coefficient of 0.24. A 1% SD in the policy index results in a 0.15%

change in the output gap. Finally, the demand shock is significant (if only at the 10% level) in this period, but has a small magnitude with a coefficient of 0.04. Examining the SD, a 1% shock to demand in Period 1 shows it causes a 0.13% change in the output gap.

In Q1 1995–Q3 2014 (Period 2), the lagged coefficient of the output gap is again highly significant at 0.96. The MPI is only significant at the 10% level with a coefficient value of 0.07. Again, we can evaluate the magnitude of the relationship by examining the effect of a 1% SD on the output gap. A 1% change in the policy index in this period leads to only a 0.05% deviation in the output gap. There is no significant effect of the demand shock on the output gap in Period 2.

C. Markov Switching Model

While the estimations in section V.B provide a better insight into the monetary policy transmission process in the PRC than the standard linear model, the breakpoint regression is limited in that it does not allow us to switch between different regimes or states. Many economic time series occasionally exhibit dramatic breaks in their behavior that are associated with events such as financial crises or abrupt changes in government policy (Hamilton 2005). The PRC, in particular, has experienced tremendous structural change in recent decades associated with the gradual opening of the economy. Prices have been liberalized, trade has increased extensively, companies have been privatized, and the economy has been transformed from one that was centrally planned prior to 1978 to a market economy (Brandt and Rawski 2008). The PRC has also experienced several economic shocks, some of which were related to policy measures to liberalize the economy (Gerlach and Peng 2006). The breaks in the time series associated with these events make linear models inappropriate for analyzing macroeconomic variables over time. To fully capture nonlinearity, the PRC's monetary policy transmission channel is examined using the MS model of Hamilton (1989, 1990, 1994). This technique has been used extensively to examine monetary policy transmission in advanced economies such as the United Kingdom, the US, and the eurozone. Dolado, Maria-Dolores, and Ruge-Murcia (2005); Peersman and Smets (2001); and Aragón and Portugal (2009) have all carried out similar studies for advanced economies, but the technique has seldom been applied to the PRC or other emerging market economies. This gives us a unique opportunity to examine any asymmetry or nonlinearity in the PRC's monetary policy transmission channel. 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

MS 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 IS curve equation to the MS framework, we get the following.¹⁸

$$\bar{y}_t = a_{st} + b_{st}(\bar{y}_{t-1}) + c_{st}(MPI_t) + dv_{tst} \tag{10}$$

where $e_t \sim \text{i.i.d. } N(0, \sigma_{e,st}^2)$ 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 .

$$P_{ij} = \Pr[s_t = j \mid s_{t-1} = i], \quad \sum_{i=1}^M p_{ij} = 1, \quad \forall i, j = 1, \dots, M \tag{11}$$

This is often then written in an $(M \times M)$ matrix P , called a transition matrix:

$$P = \begin{bmatrix} p_{11} & p_{21} & \dots & p_{M1} \\ p_{12} & p_{22} & \dots & p_{M2} \\ \vdots & \vdots & \dots & \vdots \\ p_{MM} & p_{2M} & \dots & p_{MM} \end{bmatrix} \tag{12}$$

The row i , column j element of P is the transition probability p_{ij} . To demonstrate, in the above matrix (12), the row 2 column 1 element gives the probability that State 1 will be followed by State 2. For example, at time t the state of the economy s_t is classified as having either a positive output gap ($s_t = 1$) or a negative output gap ($s_t = 2$). In our estimation, we 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 a negative output gap in the previous period, it tends to stay in this state at a very high probability of 95%. On the other hand, the probability of being in a negative output gap state in the previous period and switching to a positive output gap state is 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.¹⁹ 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

¹⁸In the interest of robustness, estimations were carried out using both the MS estimation function in Eviews 8 and the MS_Regress_Fit package developed by Perlin (2012) in Matlab. The results were very similar.

¹⁹For more detail on this technique and the maximum likelihood see Hamilton (1989, 1994) and Kim and Nelson (1999).

Table 5. Monetary Policy Index IS Curve with Markov Switching Model, Q2 1991–Q3 2014

Variable	State 1	State 2
Dependent Variable: PRC's Output Gap, \bar{y}_t		
Constant	-0.01***	0.01***
a	(0.01)	(0.01)
Output gap lag	0.91***	0.70***
\bar{y}_{t-1}	(0.03)	(0.04)
Monetary Policy Index	0.05	0.25***
MPI_t	(0.05)	(0.06)
Demand shock (Exports)	0.01***	0.04***
v_t	(0.01)	(0.01)
p_{11}	0.96	
p_{12}	0.04	
p_{21}		0.11
p_{22}		0.89
Duration of state	32.9 quarters	8.8 quarters

HAC = heteroscedasticity and autocorrelation-consistent, IS = Investment–Saving, PRC = People's Republic of China.

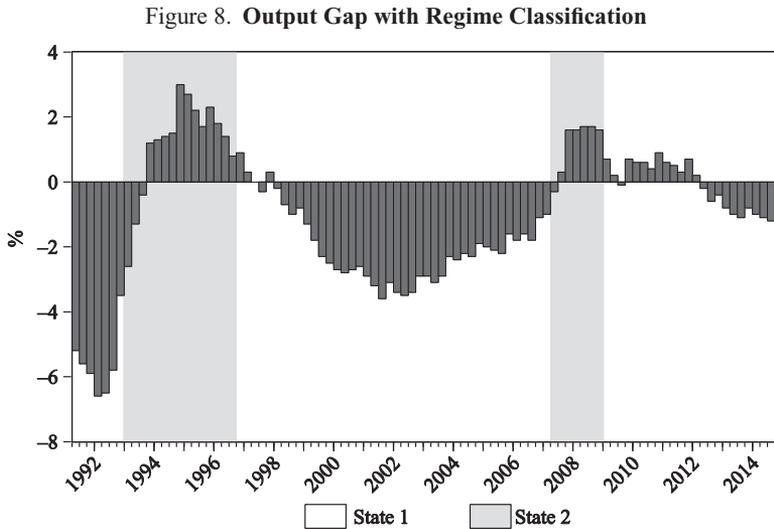
Notes: *** = 10% level of statistical significance, ** = 5% level of statistical significance, * = 1% level of statistical significance. HAC standard errors are in parentheses.

Source: Authors' calculations.

possible to derive the smoothed state probabilities that indicate the probability of being in a particular regime or state. For example, the MS model may highlight the effectiveness of the PBOC's monetary policy depending on whether the PRC's economy is operating above or below potential (positive or negative output gap). Before estimating the MS–IS curve, the 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 MS–IS curves were carried out. The three-state specification was rejected against the two-state specification since the data points were detected only in the first and second states.

The results of the MS estimation of the IS curve can be seen in Table 5 and the two identified states plotted against the output gap can be seen in Figure 8.

In State 1, the autoregressive coefficient of the output gap is high at 0.91. This indicates that shocks to the output gap are quite persistent (i.e., output will increase if output was high in the previous period). The MPI has no significant effect on the output gap in this state. The effect of the demand shock (change in exports), while significant, is very small. We can examine the relationship of the significant independent variables to the output gap further by examining a 1% SD in the demand shock, which has only a 0.09% effect. By examining both Figure 8 and the summary statistics in the Appendix we can see that State 1 can be mostly



Sources: Oxford Economics. Global Economic Databank. <http://www.oxfordeconomics.com/forecasts-and-models/cities/china-cities-and-regional-forecasts/overview> (accessed January 2015); and authors' calculations.

characterized by a period when output was operating below potential (i.e., negative output gap).²⁰

In State 2, the persistence of shocks to the output gap is again high but has decreased from State 1. The MPI is correctly signed and highly significant with a coefficient of 0.25. This indicates that changes to the various policy instruments used by the PBOC had a significant effect on the real economy. The demand shock (change in exports) is also highly significant with a coefficient of 0.04. A 1% SD in the MPI leads to a 0.33% change in the output gap. The effect of a demand shock is much stronger in State 2 than in State 1. A 1% SD in the PRC's exports leads to a 0.44% change in the output gap. Figure 8 and the summary statistics in the Appendix indicate that State 2 can be described as a period when output was mostly operating at or above potential (i.e., neutral or positive output gap).

D. Summary of Results

From the results of the various estimations in this section, several important characteristics of the monetary policy transmission channel in the PRC have been identified. Contrary to the majority of the literature in the area, the results find that a single policy instrument—the lending rate set by the PBOC—can have a significant effect on the real economy. However, the magnitude of this relationship between the interest rate and the output gap is small. The results also found that the traditional

²⁰As mentioned, this seems unusual for an economy that has grown at 9% per year. The issue of the PRC's excess capacity is discussed in detail in IMF (2012).

IS curve specification was linear and stable over the estimation period. An IS curve estimated using a composite index of the policy tools employed by the PBOC, including a measure of qualitative instruments, does not improve on the standard model. However, this specification was found to contain structural breaks.

An IS curve using the breakpoint model of Bai and Perron (1998, 2003) and an MPI consisting of both quantitative and qualitative policy instruments was then estimated. The results suggested that there was a breakpoint in Q4 1994. This breakpoint corresponds to key institutional changes and reforms in the PRC's economy. These include reforms to the banking sector; reforms regarding price liberalization; and, crucially, the adoption of the dollar peg exchange rate regime. These events therefore seem to have had a distinct effect on the PRC's monetary policy transmission channel. During the period prior to this breakpoint (Period 1: Q2 1991–Q4 1994), the MPI exerted a significant influence on the real economy. In the period after the breakpoint (Period 2: Q1 1995–Q3 2014), the same instruments played a less significant role in changes to the level of output. This is an important finding as Period 2 included continued reform of the banking and finance sector which, in theory, should have improved both the transmission channel and mechanisms of monetary policy, as well as the influence and autonomy of the PBOC. A possible explanation for this counterintuitive finding is the adoption of the dollar peg.²¹ It is possible that the maintenance of this quasifixed exchange rate regime has served to hinder the ability of the PBOC to influence the real economy through the monetary policy transmission channel.

The final model estimated was an MS–IS curve. This model differs from the breakpoint model in that it allows switching between states. It classified the PRC's economy into two states. The majority of the estimation period is characterized by State 1, in which the MPI had no significant effect on the output gap. This state is mostly characterized by periods of below potential output (i.e., negative output gap). State 2, on the other hand, is characterized by mostly positive output gaps. The index for PBOC monetary policy changes was highly significant in this state. These results suggest that monetary policy in the PRC is much more effective when output is stronger relative to potential (operating at or above potential) than when it is weaker relative to potential (operating below potential). This finding has similarities to the “pushing on a string” hypothesis, which states that when the economy is weak (operating below its potential level), a central bank can do little to remedy the situation.²² The high significance of the PRC's growth in exports in affecting whether the economy is operating above potential is also an important finding. For

²¹While the dollar peg, introduced in 1994, was officially abandoned in 2005, Morrison (2012) argues that the PRC's exchange rate mechanism remains, in practice, a tightly managed currency peg against the US dollar. In July 2015, the Financial Times reported that despite reform progress since 2005, intervention remains a daily reality (Wildau 2015).

²²This metaphor, attributed to John Maynard Keynes, maintains that using monetary policy to fight a severe recession is like pushing on a piece of string (Blyth 2012).

many years, the PRC's high levels of investment created capacity beyond its ability to consume. This excess capacity was often absorbed outside its borders given the exceptionally strong global demand for the PRC's exports (IMF 2014). Therefore, our results would seem to emphasize the reliance of the PRC on exports in closing the gap between potential and actual output.

VI. Robustness Tests

In this section, we undertake robustness tests to add reliability and credence to the findings of both our breakpoint model and our MS model.

A. Breakpoint Model

The results of our breakpoint model found that prior to 1994, the index calculated to model changes in the PBOC's monetary policy exerted a significant influence on the real economy. However, in the period after the breakpoint date (Q1 1995–Q4 2014), the same instruments played less of a significant role in changes to the level of output. This result is surprising as the post-1994 period was characterized by historic monetary reforms toward a more modernized and financially liberated monetary system. We suggested that the PRC's controversial exchange rate regime may have served to hinder the ability of the PBOC to influence the real economy through the monetary policy transmission channel. This theory can be tested empirically by estimating a simple monetary policy reaction function.²³ Along with the standard monetary policy rule variables of the inflation and output gap, we include the nominal effective exchange rate as a target variable. The monetary policy reaction function, therefore, takes the following form:

$$MPI_t = a - b(\pi_{t-1} - \pi_t^*) - c(\bar{y}_{t-1}) - d\Delta\text{neer}_t + \varepsilon_t \quad (13)$$

As before, MPI_t is our calculated monetary policy index, $\pi_{t-1} - \pi_t^*$ is the inflation gap (inflation rate minus the inflation target), \bar{y}_t is the output gap, and Δneer_t is the change in the nominal effective exchange rate.²⁴ We then estimate this reaction

²³As in our IS curve estimations, the interest rate is replaced with our MPI.

²⁴All variables in Equation 13 were found to be I(0) and available by request. For the inflation gap variable ($\pi_{t-1} - \pi_t^*$), the Consumer Price Index inflation rate is available from the PRC's National Bureau of Statistics. An official target is also available from various publications at <http://english.gov.cn/archive/>. For the exchange rate target, changes in the nominal effective exchange rate are used. The nominal effective exchange rate is defined in foreign currency unit per renminbi (i.e., an increase in this variable corresponds to an appreciation of the renminbi). These data are available in the IMF's *International Financial Statistics*. As mentioned in section IV, the setup of the MPI implies that an increase corresponds to an expansionary monetary policy action. This changed the sign of the monetary policy response coefficient from minus to plus in our IS curve equation. Similarly, an increase in inflation or output over its target, potential, or natural level will lead to a contractionary monetary policy reaction. Therefore, we would expect to see negative signs for both the inflation and output gap coefficients.

Table 6. Two-Period OLS Monetary Policy Reaction Function

Variable	Period 1 (Q2 1991–Q4 1994)	Period 2 (Q1 1995–Q3 2014)
Dependent Variable: Monetary Policy Index, MPI_t		
Constant	-0.03	-0.01
a	(0.01)	(0.01)
Inflation gap	0.29	0.04
$\pi_{t-1} - \pi_t^*$	(0.19)	(0.06)
Output gap	-0.67*	-0.10
\bar{y}_{t-1}	(0.35)	(0.08)
Exchange rate	-0.01	-0.18***
$\Delta neer_t$	(0.06)	(0.07)
R ²	0.28	0.14
DW-Stat	2.10	1.70

HAC = heteroscedasticity and autocorrelation-consistent, OLS = ordinary least squares.

Notes: *** = 10% level of statistical significance, ** = 5% level of statistical significance, * = 1% level of statistical significance. HAC standard errors are in parentheses.

Source: Authors' calculations.

function before and after the breakpoint in 1994. The results, which are presented in Table 6, are interesting.

First of all, the inflation gap is incorrectly signed and insignificant across both time periods, suggesting that it does not appear to be an important factor in the monetary policy response of the PBOC across the entire estimation period. This is in line with Mehrotra and Sánchez-Fung (2010), who find the same result over a similar period (1994–2008). The authors of this paper argue that as the inflation gap was mostly negative in their estimation period, with the exception of brief periods in 1994/1995 and 2008, inflationary pressures may not have been a major concern for the PBOC. What is perhaps most interesting is that the output gap is correctly signed and significant in Period 1, if only at the 10% level, while the exchange rate is not significant. In Period 2, however, the coefficient of the output gap has decreased substantially and is no longer significant, while changes in the exchange rate have now become highly significant. This switch from a policy index that was responsive to deviations in output from its natural level to deviations in the level of the renminbi exchange rate seems to verify the results and interpretation of our breakpoint model. In other words, the PBOC's exchange rate policy of maintaining the renminbi at a desired level may have hindered the appropriate response to deviations in the level of output.

B. Markov Switching Model

We can also test the results of our MS model. The main finding of our model was that the PRC's monetary policy is more effective when output is operating above

Table 7. **Monetary Policy Transmission with Positive and Negative Output Gaps, Q2 1991–Q3 2014**

Variable	Negative Output Gap (14)	Positive Output Gap (15)
Dependent Variable: PRC's Output Gap		
Constant	−0.01 (0.01)	0.01 (0.01)
Output gap lag	0.98*** (0.05)	0.88*** (0.03)
Monetary Policy Index	0.13*** (0.05)	0.11** (0.06)
Demand shock (Exports)	0.01 (0.01)	0.01** (0.01)

HAC = heteroscedasticity and autocorrelation-consistent, PRC = People's Republic of China.

Notes: *** = 10% level of statistical significance, ** = 5% level of statistical significance, * = 1% level of statistical significance. HAC standard errors are in parentheses.

Source: Authors' calculations.

potential and less effective when operating below potential. The MS estimations detected two states, which we labeled State 1 and State 2. While these states were roughly defined as mostly operating below (State 1) or above (State 2) potential, it is obvious from Figure 8 that not all positive and negative periods correspond exactly to the states detected by the model. Therefore, we can undertake a much more simple, if not arbitrary, examination of this dynamic. This is done by running two separate linear regressions:

$$\bar{y}_{tNEGATIVE} = a + b(\bar{y}_{t-1}) + c(MPI_t) + dv_t + \varepsilon_t \quad (14)$$

$$\bar{y}_{tPOSITIVE} = a + b(\bar{y}_{t-1}) + c(MPI_t) + dv_t + \varepsilon_t \quad (15)$$

These correspond exactly to periods of positive and negative output gaps.²⁵ While this technique lacks many of the advantages of our MS estimation (section V.C), it is nonetheless a useful robustness check of the validity of our findings and interpretations. The results are presented in Table 7 below. The coefficient of the output gap does not differ greatly across the positive and negative output gap periods, with coefficients of 0.11 and 0.13, respectively. In fact, contrary to our MS estimation, the reaction appears to be stronger, if only marginally, in the negative output gap period. However, as mentioned in section V.A, it is important to examine the relationship in terms of the SD of variables. Using the summary statistics in the Appendix, we find that a 1% SD in the MPI results in a 0.12% SD in \bar{y}_t during the negative output gap period. The same deviation in the policy index

²⁵The negative output gap periods are Q1 1991–Q2 1993, Q2 1997, Q4 1997–Q1 2007, Q2 2009, and Q1 2012–Q3 2014. The positive output gap periods are Q3 1993–Q1 1997, Q3 1997, Q2 2007–Q1 2009, and Q3 2009–Q4 2011.

results in a 0.23% deviation in \bar{y}_t during the positive or neutral output gap period. This indicates a stronger reaction of the output gap to changes in policy variables during periods of a positive output gap, which is concurrent with the results of our MS estimations. The coefficients of the demand shock are also not significantly different over the two periods, with a coefficient of 0.012 and 0.010 for the positive and negative output gap periods, respectively. However, a 1% SD in the demand shocks leads to a 0.05% change in \bar{y}_t in the negative gap period and a 0.24% change in the positive gap period. This confirms the relative importance of exports in the closing of the PRC's output gap. This also concurs with our findings in section V.C.

From the results of these simple robustness tests, it appears that the results and the findings from our Bai–Perron and MS estimations are fairly robust.

VII. Conclusion

In examining the link between monetary policy and the real economy in the PRC using different variations of the IS equation, this paper has made several interesting findings. The results of the traditional OLS model indicate that there is a significant and stable link between the lending interest rate set by the PBOC and aggregate demand in the PRC's economy. This is at odds with the majority of studies on the topic that suggest it is difficult to estimate a stable and robust aggregate demand equation for the PRC. It is important to note, however, that the size of the effect is small. This can be attributed to the underdevelopment of the banking system, market segmentation, the ineffectiveness of the credit channel, and the fact that the PBOC relies heavily on many different tools in the conduct of monetary policy. Given these findings, we then estimated an IS curve with an MPI comprising the tools used by the PBOC between 1991 and 2014. This index is a composite measure of the relevant variables observed to be at the disposal of the PBOC, both quantitative and qualitative, and therefore was expected to give a much better representation of the monetary policy stance of the PRC's central bank. The presence of structural breaks indicates that there is asymmetry between monetary policy action and output depending on the state of the economy and the time period.

A monetary policy index IS curve using a breakpoint model was estimated. The results confirmed the presence of a break in late 1994. The results of this model suggest that the monetary policy instruments of the PBOC have had less of an effect on the level of output since this breakpoint. While this seems counterintuitive, due to increased reforms in the finance sector, as well as measures that have promoted greater PBOC independence, the result is attributed to the adoption of the US dollar peg exchange rate regime in 1994.

Finally, an MS–IS curve using our MPI was estimated. This technique provided us with a different perspective on the monetary policy transmission channel as it allowed for switching between different regimes or states. This nonlinear

technique allows us to examine asymmetry in the monetary policy transmission channel. Testing for this type of asymmetry is important due to the underdeveloped nature of the PRC's financial system and the huge amount of reform and structural change that the economy has experienced. Our results suggest that there is a significant link between the monetary policy tools used by the PBOC and the real economy in State 2 of our model, when output is mostly operating at or above its potential level. This relationship breaks down when the economy switches to periods that are characterized by output that is mostly below potential. Finally, our MS model seems to suggest that demand shocks have a much greater effect in State 2 (mostly positive output gap) than in State 1 (mostly negative output gap). This points to the importance of exports in closing the gap between potential and actual output in the PRC.

The results of the paper seem to suggest that the PRC's exchange rate policy has restricted the effectiveness of the PBOC's monetary policy response. While there have been some significant developments in recent years, further liberalization of the exchange rate regime would facilitate greater monetary policy independence and effectiveness. If monetary policy is less effective, or even ineffective, when output is operating below potential, as our results suggest, then the PBOC will need to resort to alternative monetary policy tools to continue to achieve its goal of maintaining economic growth. This could be aided by further reform of the finance and banking sectors to help reduce output volatility and allow for greater symmetry in the transmission of monetary policy.

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*ADB recognizes "China" as the People's Republic of China and "Hong Kong" as Hong Kong, China.

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APPENDIX: Summary Statistics

	OLS	Breakpoint Model		Markov Switching Model		Robustness Test	
	Estimations	Period 1	Period 2			Positive	Negative
	Q2 1991– Q3 2014	(Q2 1991– Q4 1994)	(Q1 1995– Q3 2014)	State 1	State 2	Output Gap	Output Gap
Mean of output gap	–1.0%	–1.5%	–0.8%	–1.4%	0.7%	1.1%	–2.1%
Standard deviation of output gap	2.1%	3.4%	1.6%	2.6%	1.5%	0.8%	1.5%
Mean of real interest rate	2.8%	—	—	—	—	—	—
Standard deviation of real interest rate	4.3%	—	—	—	—	—	—
Mean of Monetary Policy Index	–0.2%	0.5%	–0.3%	–0.3%	0.4%	–0.4%	–0.1%
Standard deviation Monetary Policy Index	1.5%	2.1%	1.3%	1.1%	2.0%	1.5%	1.4%
Mean of demand shock (exports)	12.5%	17.4%	11.6%	13.6%	9.4%	10.3%	13.8%
Standard deviation of demand shock (exports)	12.1%	10.9%	12.2%	10.4%	16.6%	15.2%	9.8%

OLS = ordinary least squares.

Source: Authors' calculations.