China's Intervention in the Central Parity Rate：A Bayesian Tobit Analysis

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ABSTRACT

This paper investigates China's daily foreign exchange intervention through the setting and

adjustment of the central parity rate, using daily data from July 22, 2005 to July 22, 2013.

Applying a Bayes Tobit model, we find evidence that China's daily price intervention

decision is driven by market developments regarding the Chinese currency, international

currency movements and macroeconomic conditions. The results further suggest that the

objectives of China's daily price intervention change not only over time, but also between

high and low interventions.

1. Introduction

Daily intervention is applied by some monetary authorities, such as Germany (Almekinders and Eijffinger, 1994 and 1996), Russia (Tullio and Natarov, 1999) and Pakistan (Shah et al., 2009), in the most of trading days. China is also the country which applies the intervention in the most of trading days. Official daily intervention in the foreign exchange market has been a distinctive feature of China's exchange rate policy. As in other emerging market economies, the primary motivation of China's daily intervention is to align the exchange rate to fundamentals as suggested in the 1985 Plaza Accord (Baillie and Osterberg, 1997), and to stabilize the disorderly foreign exchange market (Szakmary and Mathur, 1997; Disyatat and Galati, 2007; Pontines and Rajan, 2011). However, despite its critical importance, little is understood about the country's intervention operation. This hampers keeping China's exchange rate policy and its global repercussions in perspective, and hence calls for research attention.

In the new managed floating rate regime, the central parity rate plays a key role. On every business day, this rate is published by the authorities before the market opening. It then remains valid for the day and all market transactions are based upon it. This rate also provides an anchor for the system. In addition, the central parity rate is a policy indicator. In the process of setting the parity rate, the central bank takes into account current and expected economic conditions. Through setting the parity rate at different levels, the central bank may affect the benchmark for transactions in the marketplace, anchoring stability of the Chinese foreign exchange market and transmitting policy signals to market participants.

This study is motivated to examine China's intervention in the central parity rate (the Daily Price intervention) because of its primary importance in the nation's intervention nexus; such research will help to achieve a better understanding of China's exchange rate policy, which is increasingly exhibiting global influences. To this end, the first important dimension concerns understanding the determinants of such intervention. The first challenge is to model a reaction function based on a non-linear relationship, because intervention in the central parity rate does not increase or decrease in approximately the same magnitude. Literature has shown that Tobit models are appropriate when the research interest lies in the magnitude of intervention rather than the probability (Humpage, 1999; Brandner and Grech, 2005). However, given the fact that threshold varies depending on individual characteristics (Omori and Miyawaki, 2010; Nakayama et al., 2010), we combine the Tobit analysis with covariate dependent thresholds. This paper begins by using the Bayes Tobit model as the reaction function.

The work contributes to the literature in several ways. First, we develop a Daily Intervention Index that is constructed by comparing the daily central parity rate to the fair value CNY/USD rate in the IFV approach. Analysis based on this index, the current research unearths evidence on how the foundation of China's exchange rate regime, i.e. the parity exchange rate is managed by the authorities. This sheds critical lights on the properties and frequency of Chinese official intervention and hence helps promote a better understanding of the Chinese exchange rate policy which has growing global importance.

Then, the findings by this research confirms the significant effects of three determinants underlying the process of China's setting of the central parity rate reveals the true nature of the Chinese exchange rate regime. These three determining factors include the RMB price in previous trading sessions (proxied by the market makers' offer rate), international currency movements (proxied by the Broad Dollar Index compiled by

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America's Federal Reserves) and macro conditions of the economic environment (proxied by the yield curve spread between China and the USA). For practical purposes, with knowledge of these factors international investors and policy observers in the Chinese financial market can gauge possible changes and their future trend of China's central parity as the benchmark exchange rate changes. Finally, for the traders who are involved in China currency business, a better understanding of how and when China's intervention operations may happen can help them design a better informed trading strategy.

In terms of policy implications, this research shows that China's intervention can be effective under some conditions. This means that it is possible for the Chinese government to operate a middle way between the free floating and the fixed exchange rate system. In turn, China to some extent can manage to mitigate the effects of the monetary policy trilemma. This is important to understand fundamental policy development in China.

The results from the Bayes Tobit models show that, generally, these factors have significant effects on China's Daily Price intervention in the whole sample. Results for the whole sample suggest that China follows a leaning-against-the-wind policy, and conditions of domestic economy and foreign market can impact Daily Price intervention. Furthermore, coefficients on the determinants are found to be time-varying across different subsamples, and between high and low intervention. The evidence indicates that China's Daily Price intervention has multi-facets. With regard to high intervention, the policy objective during all the subsample time periods relates to market exchange rate condition. For low intervention, the policy objective ranges from restraining the domestic economy from overheating before the financial crisis, to a focus on market exchange rate conditions during and after the financial crisis.

The rest of this chapter is organized as follows. Section 2 describes measurement of China's Daily Price intervention and the data deployed in the study. Section 3 estimates the Bayes Tobit models. Section 4 reports the estimation results. Section 5 presents the main findings of the study.

2. Data Description

2.1. Forms and Measures of Foreign Exchange Intervention

2.1.1. Forms of China's intervention

From an operational standpoint, there are three major ways in which the Chinese monetary authorities may intervene in the foreign exchange market:

(1) The central bank (CB) intervenes by directly selling or purchasing foreign currencies in the marketplace. In the case of purchase intervention, the central bank trades foreign currencies with central bank notes; in selling intervention, it pours foreign reserves into the market. We term this type of intervention 'quantity intervention'; it is also called CB intervention, as it involves the central bank participating in market transactions. Only rarely would the Chinese monetary authorities intervene through adjusting the interest rate or changing commercial banks' required reserve rate.

(2) The central bank controls the level and growth of the RMB exchange rate by specifying the central parity rate (CPR) and the range around which the daily trading prices are allowed to fluctuate. We call this 'daily price intervention', since this intervention operation involves the setting and adjustment of the central parity.

(3) Intervention may also take an oral form, including policy briefing, moral persuasion, formal and informal meetings, and telephone conversations. We call this 'Oral

intervention'. It is straightforward for the Chinese central bank to effectuate this form of intervention by instructing or directing the attention of the state-owned banks towards 'things to note', which are dominant forces in the Chinese foreign exchange market.

Of the three forms of Chinese official intervention, this paper concentrates on the Daily Price intervention, due to data availability[1].

2.1.2 Development of the central parity rate

Table 1 shows the process of the development of the central parity rate. The managed float system started on 21st July 2005 (PBOC, 2005). From that date the RMB exchange rate was not simply pegged to the US dollar, and so could better reflect market conditions. On 29th December 2005, the State Administration of Foreign Exchange (SAFE) authorized 13 banks to launch the market maker service (SAFE, 2005). Now there are 35 market makers (SAFE, 2016). Before 4th January 2006, the central parity rate was set by the closing price exchange rate of the previous day. However, with the introduction of the OTC transaction, the PBOC changed the formation of the central parity rate (PBOC, 2006). In this system, the China Foreign Exchange Trade System (CFETS) asks the exchange rate prices from the market makers before the opening time of the foreign exchange market, and these exchange rate prices are used as the calculation sample of the central parity rate. Then, after deleting the highest and the lowest price, the weighted average of these exchange rate prices is calculated. The weighted average price is the central parity rate. The weights are based on the trading volume of market makers and the conditions of exchange rate prices. From Table 1, we can see that the PBOC has tended to increase the width of the exchange rate band. The

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[1] Even in the advanced countries, such as US or Japan, the exact time of a foreign exchange intervention is unavailable (Kitamura, 2016).

band has increased three times: on 21st May 2007 (PBOC, 2007), 16th April 2012 (PBOC, 2012), and 17th March 2014 (PBOC, 2014). This serves the PBOC's purpose, which is to increase the elasticity of the RMB exchange rate.

Table 1

Developments of China's central parity rate policy.

Date	Event
21/07/2005	Launch of the managed float system with reference to a basket of currencies
29/12/2005	13 banks become the market makers
04/01/2006	Central parity rate combines OTC transactions and negotiation
21/05/2007	Exchange rate band changes from 0.3% to 0.5%
16/04/2012	Exchange rate band changes from 0.5% to 1%
17/03/2014	Exchange rate band changes from 1% to 2%

The daily central parity is published by the China Foreign Exchange Trade System (CFETS) at 9:15; this is fifteen minutes before the start of the foreign exchange opening hours, which run from 9:30 to 15:30 Beijing time. The price-setting process for the central parity considers three functions (CFETS, 2013): the prices of central parity of all foreign exchange market makers asked by CFETS before the opening time; the changes in foreign exchange market conditions; and China's macro economy condition. As proxies for these three functions we use CNY/USD exchange rate offers from foreign exchange market makers, broad currency index, and the yield curve spread, respectively. Therefore, this research tests whether or not CNY/USD exchange rate offers, broad currency index and the yield curve spread are determinant factors of Daily Price intervention.

Two evidences used central parity rate to intervene RMB exchange rate movements. First, some Chinese literature argues that the PBOC controls RMB exchange rate through the

central parity rate. For example, Zhao et al. (2012) indicate that if the PBOC never loses control of the central parity rate, then the RMB exchange rate must follow the will of the PBOC. In addition, Zhao et al. (2013) and Shen (2013) also argue that RMB exchange rate is controlled by the PBOC, as the PBOC decides the central parity rate. Secondly, news reports might also provide proof that the central parity rate can influence RMB exchange rate movement. For example, according to reports in *The Wall Street Journal*, the RMB exchange rate followed the guidance of the central parity rate on 12/09/2014, 16/09/2014, and 08/10/2014. However, the literature in English includes very little on Daily Price intervention. This chapter tries to fill this critical void.

2.1.3. Measuring China's daily price intervention

This research constructs a Daily Price intervention ratio by comparing the CPR with the fair value CNY/USD exchange rate estimated by the indirect fair value (IFV) approach. From the fair value exchange rate, we can find out at what level the exchange rate should be.

Over the years, a number of models of currency fair value have been developed. Financial markets have developed formulas and models to derive fair values for futures, bonds, options, swaps and other securities (Aries et al., 2006). Empirical estimations make extensive use of purchasing power parity (PPP) (Officer, 1976), Pen effect (Summers and Heston, 1991), fundamental equilibrium exchange rate (FEER) (Williamson, 1983 and 1994), behavioural equilibrium exchange rate (BEER) (Clark and MacDonald, 1999) and indirect fair value (IFV) (Cenedese and Stolper, 2012) to measure exchange rate misalignment. IFV estimates are based on the assumption that speculative activity is the principal cause of misaligned exchange rates (Cenedese and Stolper, 2012). In comparison with PPP, Pen effect, FEER and BEER, the IFV has some advantages: First, only IFV can focus on daily financial

and macro data, while the other models have to use quarterly or yearly data (Zhang, 2012). Second, the fair value does not require restrictive assumptions on financial market equilibrium to be operational (Clarida, 2013). Third, the IFV model benefits from ease of operability. Like the BEER model, IFV is estimated using co-integration techniques. To our knowledge, this IFV approach has not been previously formalized in the academic literature.

The IFV approach is based on the assumption that misaligned exchange rates are caused by speculative activity (Lyons, 2001). The following equation can express the relation between the exchange rate level and the speculative positioning:

$$e_t = \beta' Z_t + \theta' S_t + \varepsilon_t \tag{1}$$

where e_t is the spot exchange rate observed in the FX market, Z_t is a vector of broadly defined fundamentals, S_t is speculative activity variables, and ε_t is a residual error.

Depending on equation (1), it is possible to use the parameter estimates to calculate fair value in the following equation:

$$\bar{e}_t = \hat{\beta}' Z_t + \hat{\theta}' \bar{S} \tag{2}$$

with the overbar denoting the value of S that is neutral speculative positioning. In most cases the choice of neutral speculative positioning is the sample mean.

If the CPR is contrary to the prediction of the market, and is 1% (0.3% during the period 22nd July 2005 to 21st May 2007; 0.5% before 16th April 2012), that is, 100% of the horizontal band, above/below the benchmark, it is marked as Daily Price intervention. The ratio of Daily Price intervention is estimated as follows:

$$I_t = \frac{CPR_t}{FV_t} \tag{3}$$

where I_t is the Daily Price intervention index, CPR_t is the present central parity rate, and FV_{t-1} is the fair value RMB exchange rate estimated by the IFV approach at day t. High intervention (depreciates the Chinese yuan) means the CPR is 100% higher than the benchmark, but if the Daily Price intervention ratio is 100% lower than the benchmark, it is termed low intervention (appreciates the Chinese yuan); otherwise there is no intervention. This means high intervention is larger than 1, and low intervention is smaller than 1.

For example, on 30/04/2009, the fair value exchange rate was 6.98, but the CPR was 6.83; this is interpreted as an appreciation of the RMB with intervention by the PBOC. Therefore, this date is marked as low intervention. On 03/02/2011, the markets considered the RMB fair value exchange rate should be 6.51, but the PBOC set the CPR at 6.59, indicating a depreciation of the RMB. Accordingly, this date is marked as high intervention.

2.2 Data Description

2.2.1 The dataset

The dataset analysed in this study contains daily intervention over an 8-year period starting on 22nd July 2005 and ending on 22nd July 2013, which represents a total of 2087 trading days excluding official holidays. To further understand the determinants of China's intervention, we additionally divide the whole sample into three subsamples: 15th July 2008 and 23rd June 2010 are two time points. From Figure 1, it can be seen that the movements of the RMB exchange rate were flat during the period from 15th July 2008 to 23rd June 2010, when, in response to the global financial crisis, China re-pegged its currency. We also use the $\sup_\gamma(F(\gamma))$ test (Andrews, 1993) to confirm that the structural break dates are 15th July 2008 and 23rd June 2010. Based on the Andrews (1993), the variable contained in the $\sup_\gamma(F(\gamma))$ test should no unit root. Table 3 shows that there is no unit root in RMB exchange rate based

on the ADF and PP tests. The F-statistic at each break candidate (γ) can be obtained by the standard Chow test. From Figure 2 we find that the largest (4.86) F-statistic is in July 2008. While the second largest (3.63) F-statistic is in September 2010, we still choose June 2010 (2.73), because it was in that month that the PBOC announced the change of China's exchange rate regime from a peg to a managed float. We reject the null hypothesis, which is that there is no break, at 5% significance. Therefore, 15th July 2008 and 23rd June 2010 are the structural break dates. Figure 3 presents the time series of daily intervention index.
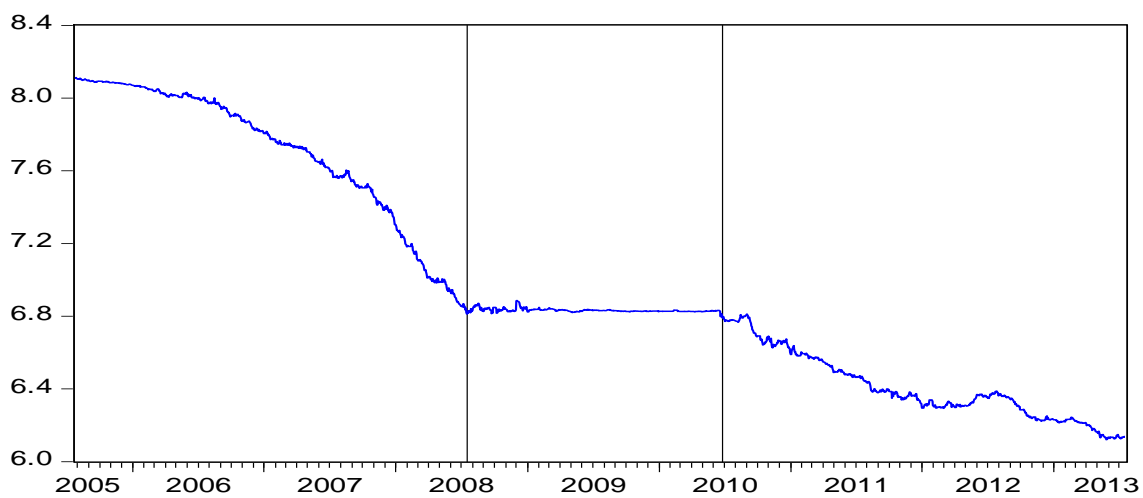

Fig. 1. Movements of CNY/USD exchange rate.

Table 3

ADF and PP tests

Methods	t-Statistic
ADF	-3.423***
PP	-4.574***

Note: *** significant at 1%, ** at 5%, * at 10% level; the null hypotheses for ADF and PP tests is that the variable follows a unit root process.
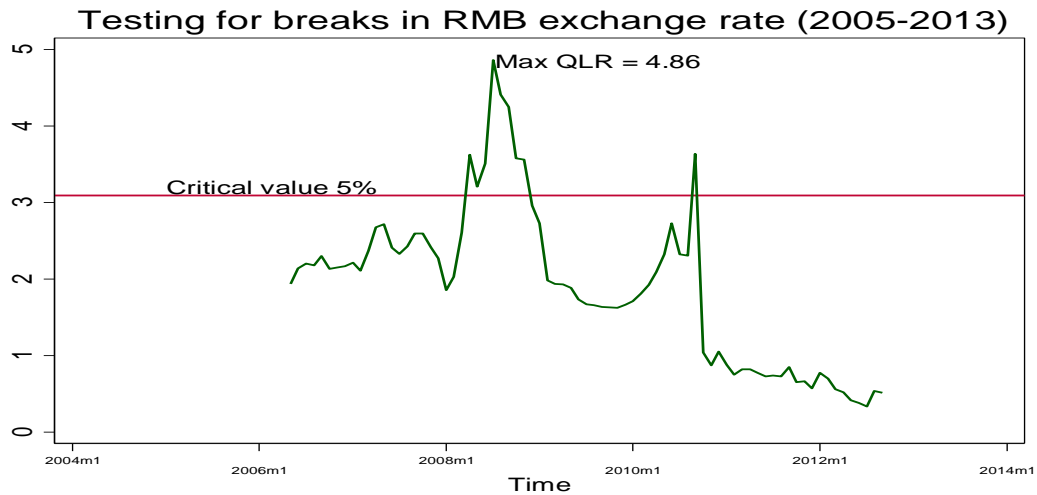
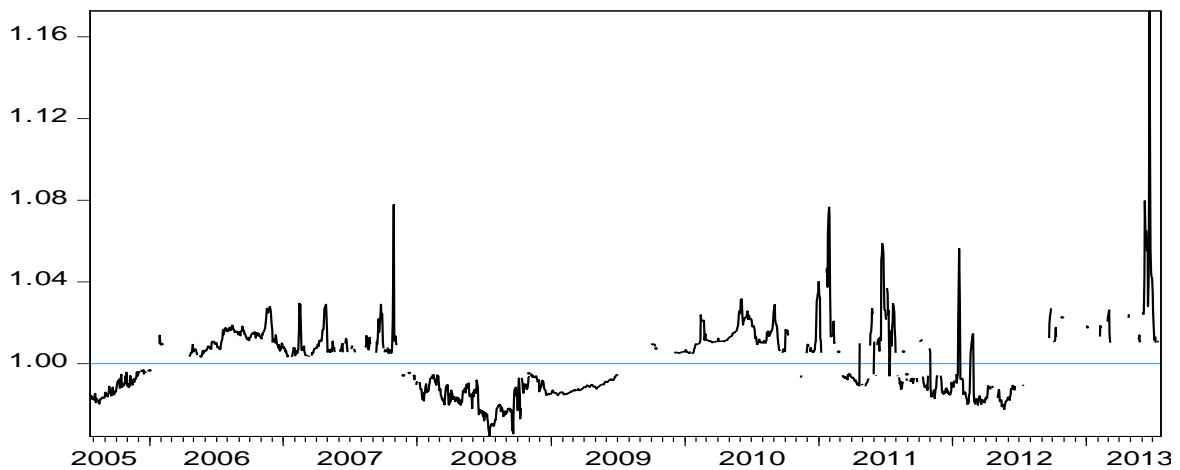**Fig. 2.** Regime breaks in the RMB exchange rate (2005-2013).

Fig. 3. Daily CPR intervention index in Chinese foreign exchange market during 2005-2013.

Note: High intervention is larger than 1; low intervention is smaller than 1.

2.2.2 Determining factors

CNY/USD exchange rate offers. Similar to the London Gold Fix and European Currency Unit (ECU) concertation procedure, the RMB exchange rate central parity process involves CNY/USD exchange rate offers from foreign exchange market makers. Because the

price of central parity provided by different makers is confidential, the makers' RMB

exchange rate offer is the best proxy for central parity price. Data on exchange rate prices is

available for only 6 banks, and we cannot know the weights. In addition, we use the

CNY/USD exchange rate in the US market to be the proxy for foreign banks' offers. The

offers from foreign banks are less controlled by the Chinese government and should follow

the exchange rate in the US foreign exchange market. Moreover, although we do not know

the weights, we know that the Bank of China occupies the greatest weight, as the majority of

foreign reserves are in the Bank of China. Therefore, this research first uses the average mean

of the 5 banks' exchange rate prices and exchange rate in the US market, and then sums the

exchange rate price from the Bank of China to be the price of central parity from foreign

exchange market makers. The equation for CNY/USD exchange rate offers is as follows:

$$ERO = 60\%EROBC + 40\%EROM$$

$$EROM = ER - ERO \tag{4}$$

where ERO is the CNY/USD exchange rate offers, EROBC is the exchange rate offer from

the Bank of China, and EROM is the average mean of the 5 banks' exchange rate prices and

exchange rate in the US market. In addition, EROM is the exchange rate offers deviation,

equalling RMB exchange rate minus exchange rate offers.

Broad currency index. Unlike the London Gold Fix and the ECU concertation

procedure, China's central parity also considers the changes in foreign exchange market

conditions. We use broad currency index as the proxy for foreign exchange market condition.

The broad currency index is a weighted average of the foreign exchange values of the US

dollar against the currencies of a large group of major US trading partners, including China.

It is an appropriate measure for the foreign exchange market condition, as we can use it to get

the situations of the basket currencies relevant to the RMB exchange rate movement.[2] The change of broad currency index is estimated as follows:

$$BCI_t = Index_t - Index_{t-1} \tag{5}$$

where BCI_t is the change of broad currency index, which is calculated by broad currency index on day t minus index on day t-1. Poor foreign exchange market condition would trigger Daily Price intervention by the PBOC. Therefore, we assume that the relation between the Daily Price intervention and the change of broad currency index should be negative.

The yield curve spread. The PBOC also needs to consider the condition of China's macro economy. The yield curve spread is a proxy for China's macroeconomic condition. Based on studies by Harvey (1988), Estrella and Hardouvelis (1991), and Rudebusch and Williams (2009), it can play a useful role in macroeconomic prediction. The yield curve spread used in this research is the 10-year government bond yield minus the 12-month government bond yield, gained through the following equation:

$$YC_t = 10YGB_t - 1YGB_t \tag{6}$$

where YC_t is the yield curve spread, $10YGB_t$ is the 10-year government bond yield, and $1YGB_t$ is the 12-month government bond yield. The relation between the yield curve and the economy should be positive (Estrella and Mishkin, 1998). From Figure 4, we can see that the yield curve has co-movement with the GDP growth.

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[2] On 28th January 2011, PBOC Governor Zhou Xiaochuan stated that the RMB exchange rate refers to a basket of almost 20 currencies (PBOC, 2011).
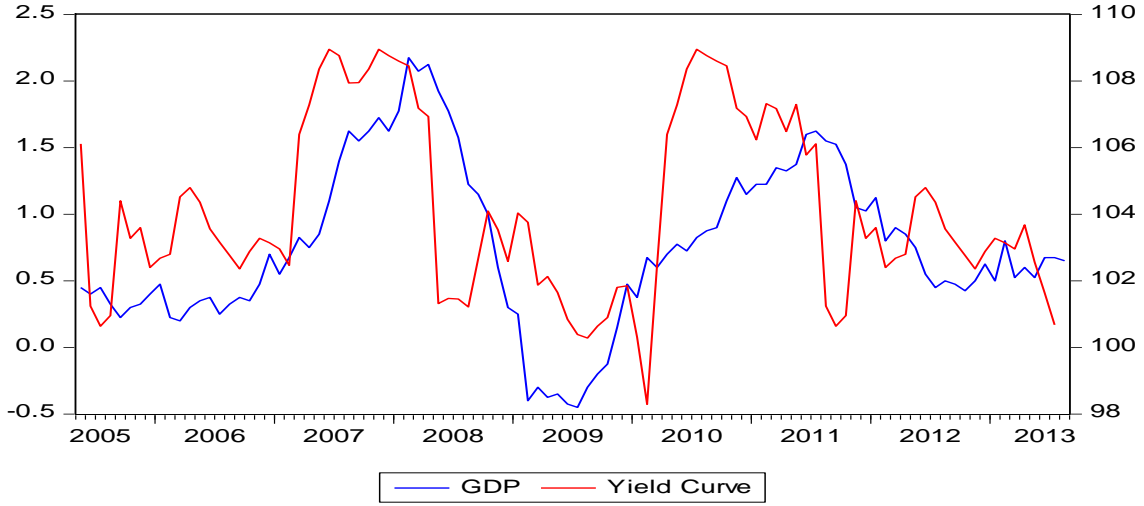
Fig. 4. China's GDP and yield curve.

3. Tobit Model with Covariate Dependent Thresholds

The Tobit model with covariate dependent thresholds is a development of the standard Tobit model. Although Tobit models can overcome the problem whereby the dependent variable takes a value of zero most of the time, the coefficients cannot be estimated when the deterministic thresholds[3] can vary with individuals depending on their characteristics (Omori and Miyawaki, 2010; Nakayama et al., 2010). In such a model with covariate dependent thresholds, the ith response variable y_i is observed if it is greater than or equal to a threshold $d_i = w_i'\delta$ where w_i' and δ are a $J \times 1$ covariate vector and a corresponding coefficient vector, respectively. The vector w_i' consists of the covariates that impact the decision whether to engage in Daily Price intervention. Using a Bayesian approach, we describe a Gibbs sampler algorithm to estimate parameters.

First, we describe a Gibbs sampler for a standard Tobit model (Chib, 1995). The prior distributions of (α, τ^2) are assumed to be a conditionally multivariate normal distribution and an inverse gamma distribution, respectively:

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[3] Threshold is quite often used to check the effects of monetary policies in the different levels (Aleem and Lahiani, 2014; Chkili and Nguyen, 2014)

$$\alpha|\tau^2 \sim N(\alpha_0, \tau^2 A_0), \quad \tau^2 \sim \lg\left(\frac{n_0}{2}, \frac{S_0}{2}\right), \tag{10}$$

where α_0 is a $K \times 1$ known constant vector, A_0 is a $K \times K$ known constant matrix, and n_0, S_0 are known positive constants. To implement a Markov chain Monte Carlo method, we use a data augmentation method by sampling an unobserved latent response variable y_i^*. Using y^*, standard Tobit model reduces to an ordinary linear regression model, $y^* = X\alpha + \epsilon$, where $y^* = (y_1^*, y_2^*, \dots, y_n^*)', X' = (x_1, x_2, \dots, x_n)$ and $\epsilon = (\epsilon_1, \epsilon_2, \dots, \epsilon_n)' \sim N(0, \tau^2 I_n)$. Given y^*, the conditional posterior distributions of (α, τ^2) are

$$\alpha|\tau^2, y^* \sim N(a_1, \tau^2 A_1), \quad \tau^2 \sim \lg\left(\frac{n_1}{2}, \frac{S_1}{2}\right), \tag{11}$$

where $A_1^{-1} = A_0^{-1} + X'X, a_1 = A_1(A_0^{-1}a_0 + X'y^*), n_1 = n_0 + n$, and $S_1 = y^{*'}y^* + a_0'A_0^{-1}a_0 + S_0 - a_1'A_1^{-1}a_1$. Let $y_0 = (y_{0,1}, y_{0,2}, \dots, y_{0,m})'$ and $y_c^* = (y_{c,1}^*, y_{c,2}^*, \dots, y_{c,n-m}^*)'$ denote $m \times 1$ and $(n - m) \times 1$ vectors of observed (uncensored) and censored dependent variables, respectively. Then, we can sample from the posterior distribution using a Gibbs sampler:

(1) Initialize α and τ^2.

(2) Sample $y_c^*|\alpha, \tau^2 \sim TN_{(-\infty,d)}(x_i'\alpha, \tau^2), i = 1,2, \dots, n - m$, for censored observations, where $TN_{(a,b)}(\mu, \sigma^2)$ denotes a normal distribution $N(\mu, \sigma^2)$ truncated on the interval (a, b).

(3) Sample $(\alpha, \tau^2)|y_c^*, y_0$

    (a) Sample $\tau^2|y_c^*, y_0 \sim \lg(n_1/2, S_1/2)$,

    (b) Sample $\alpha|\tau^2, y_c^*, y_0 \sim N(a_1, \tau^2 A_1)$.

(4) Go to 2.

Next, we extend the above sampler by adding another step, whereby we can derive the Gibbs sampler for the Tobit model with covariate dependent thresholds. The threshold In the standard Tobit model is assumed to be known and a constant. However, it is usually unknown and may vary with the individual characteristics. Thus we extend it to allow unknown but covariate dependent thresholds as follows:

$$y_t^* = x_t' b + \varepsilon_t$$

$$y_t = y_t^* = x_t' b + \varepsilon_t \ \ if \ y_t^* \geq w_i' \delta,$$

$$y_t = 0 \quad if \ y_t^* < w_i' \delta. \tag{12}$$

where (w_i, x_i) are $J \times 1$ and $K \times 1$ covariate vectors and (δ, α) are corresponding $J \times 1$ and $K \times 1$ regression coefficient vectors. The known constant threshold d in (26) and (27) is replaced by the unknown but covariate dependent threshold, $w_i' \delta$.

To conduct a Bayesian analysis of the proposed Tobit model (12), we assume that prior distributions of (α, τ^2) are given by (11). A prior distribution of δ is assumed to be $\delta | \tau^2 \sim N(d_0, \tau^2 D_0)$, since we often use independent variables for w_i's similar to those for x_i's, and the magnitude of the dispersion is expected to be similar. If there is little prior information with respect to δ, we take large values for the diagonal elements of D_0, which will result in a fairly flat prior for δ.

$$\alpha | \delta, \tau^2, y^* \sim N(a_1, \tau^2 A_1), \quad \tau^2 | \delta, \alpha, y^* \sim \lg\left(\frac{n_1}{2}, \frac{S_1}{2}\right),$$

$$\delta | \alpha, \tau^2, y^* \sim TN_{R_0 \cap R_c}(d_0, \tau^2 D_0), \tag{13}$$

where $n_1 = n_0 + n + J, S_1 = y^{*'} y^* + a_0' A_0^{-1} a_0 - a_1' A_1^{-1} a_1 + S_0 + (\delta - d_0)' D_0^{-1}(\delta - d_0), A_1^{-1} = A_0^{-1} + X'X, a_1 = A_1(A_0^{-1} a_0 + X'y^*), R_0 =$

$\{\delta | w_i'\delta \le y_i \ for \ uncensored \ i\}, R_c = \{\delta | w_i'\delta \le y_i \ for \ censored \ i\}$. The Gibbs sampler is implemented in three blocks as follows:

(1) Initialize $\delta, \alpha \ and \ \tau^2$ where $\delta \in R_0$.

(2) Sample $y_c^* | \alpha, \tau^2, \delta, y_0$. Generate $y_{c,i}^* | \delta, \alpha, \tau^2 \sim TN_{(-\infty, w_i'\delta)}(x_i'\alpha, \tau^2), i = 1,2, \dots, n-m$, for censored observations.

(3) Sample $(\alpha, \tau^2) | \delta, y_c^*, y_0$

    (a) Sample $\tau^2 | \delta, y_c^*, y_0 \sim \lg(n_1/2, S_1/2)$,

    (b) Sample $\alpha | \tau^2, \delta, y_c^*, y_0 \sim N(a_1, \tau^2 A_1)$.

(4) Sample $\delta | \alpha, \tau^2, y^* \sim TN_{R_0 \cap R_c}(d_0, \tau^2 D_0)$.

(5) Go to 2.

Steps 2 and 3 are similar to those in the simple Tobit model. To sample from the conditional posterior distribution of δ in Step 4, we generate one component δ_j of $\delta = (\delta_1, \delta_2, \dots, \delta_j)'$ at a time, given other components $\delta_{-j} = (\delta_1, \dots, \delta_{j-1}, \delta_{j+1} \dots, \delta_J)'$. Since δ should lie in the region $R_0 \cap R_c$, the δ_j is subject to the constant $L_j \le \delta_j \le U_j$ where $w_{i,-j} = (w_{i1}, \dots, w_{ij-1}, w_{ij+1}, \dots, w_{iJ})'$,

$$L_j = \max_i L_{ij}, \quad L_{ij} = \begin{cases} w_{ij}^{-1}(y_i - w_{i,-j}'\delta_{-j}) & if \ w_{ij} < 0 \ for \ uncensored \ i, \\ w_{ij}^{-1}(y_i^* - w_{i,-j}'\delta_{-j}) & if \ w_{ij} > 0 \ for \ censored \ i, \\ -\infty, & otherwise, \end{cases}$$

$$L_j = \min_i U_{ij}, \quad U_{ij} = \begin{cases} w_{ij}^{-1}(y_i - w_{i,-j}'\delta_{-j}) & if \ w_{ij} < 0 \ for \ uncensored \ i, \\ w_{ij}^{-1}(y_i^* - w_{i,-j}'\delta_{-j}) & if \ w_{ij} > 0 \ for \ censored \ i, \\ -\infty, & otherwise, \end{cases} \quad (14)$$

Let $d_{0,-j} = (d_{01}, \dots, d_{0,j-1}, d_{0,j+1}, \dots, d_{0J})'$ and let $D_{0,j,j}$, $D_{0,j,-j}$ and $D_{0,-j,-j}$ denote a prior variance of δ_j, for $j = 1,2, \dots, J$, using the conditional truncated normal posterior distribution,

$$\delta_j \big| \delta_{-j}, \alpha, \tau^2, y^* \sim TN_{(L_j, U_j)}(m_j, s_j^2 \tau^2),$$

$$m_j = d_{0j} + D_{0,j,-j} D_{0,-j,-j}^{-1} (\delta_{-j} - d_{0,-j}),$$

$$s_j^2 = D_{0,j,j} - D_{0,j,-j} D_{0,-j,-j}^{-1} D_{0,j,-j}'. \tag{15}$$

Note that this reduces to $TN_{(L_j, U_j)}(d_{0j}, \tau^2 D_{0,j,j})$ for a diagonal D_0.

We estimate a Tobit model with covariate dependent thresholds to test whether the three factors (CNY/USD exchange rate bank offers, broad currency index and the yield curve) could be the determinants of China's Daily Price intervention:

$$I_t^* = x_t' b + \varepsilon_t, I_t^h = I_t^* \ \ if \ I_t^* > w_i' \delta, and \ I_t^h = 0 \ \ if \ I_t^* \leq w_i' \delta,$$

Or

$$I_t^* = x_t' b + \varepsilon_t, I_t^l = I_t^* \ \ if \ I_t^* < w_i' \delta, and \ I_t^l = 0 \ \ if \ I_t^* \geq w_i' \delta,$$

$$where \ x_t' b = b_0 + b_1 EROM_t + b_2 BCI_t + b_3 YC_t$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2), \tag{16}$$

where I_t^* is the latent variable; I_t^h (I_t^l) is the observed censored value of high (low) intervention; x_t' is the vector of exogenous explanatory variables at time t; $EROM_t$ is the CNY/USD exchange rate offers deviation; BCI_t means the broad currency index; YC_t is the yield curve between the 10-year and the 12-month China government bond yields.

4. Empirical Results

4.1 The Fair Value RMB Exchange Rate

Following the IFV approach, we estimate the fair value for the RMB exchange rate. The Z_t is the difference between US and Chinese 2-year swap rates, as well as linear, quadratic and cubic time trends. We use 1-month 25-delta risk reversals as a measure of speculative positioning in the regression (1). Before cointegration analysis, it is necessary to test unit roots in the time series in order to avoid spurious regression (Wang et al., 2007). Table 6 shows the results of Augmented Dickey-Fuller test. We find evidence that risk reversals are stationary, while the exchange rate and interest rate differential show a unit root. In fact, Figure 5 shows that risk reversals behave as a stationary time series with a sample mean, which is very close, but not equal, to zero.

Table 6

Augmented Dickey-Fuller tests for the IFV model.

ADF test	*ER*	*Z*	*S*
t-Statistic	-0.524	-2.540	-4.148***

Note: *significant at 10% level; **significant at 5% level; ***significant at 1% level.
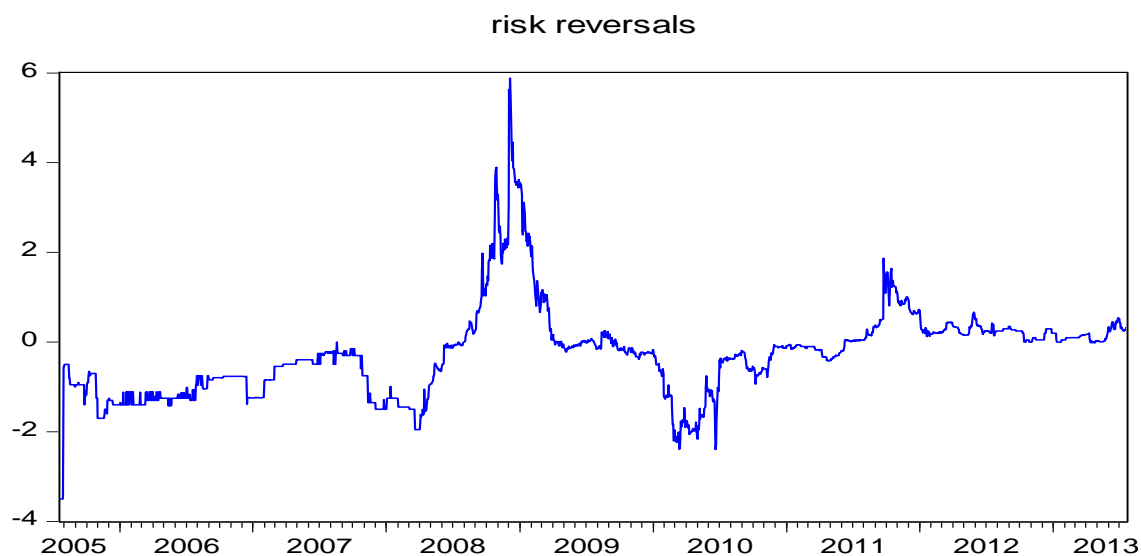

risk reversals

Fig. 5. China's risk reversals.

Figure 6 illustrates the results. The green line is the observed daily RMB exchange rate. The red line represents the fitted value of the regression using the raw data of all variables. Finally, the blue line displays the fair value exchange rate, which the exchange rate would have been without the impact of speculative activity. We use equation (2) to get the fair value, that is, as the fitted exchange rate but using the sample mean of the risk reversals instead of the observed values.
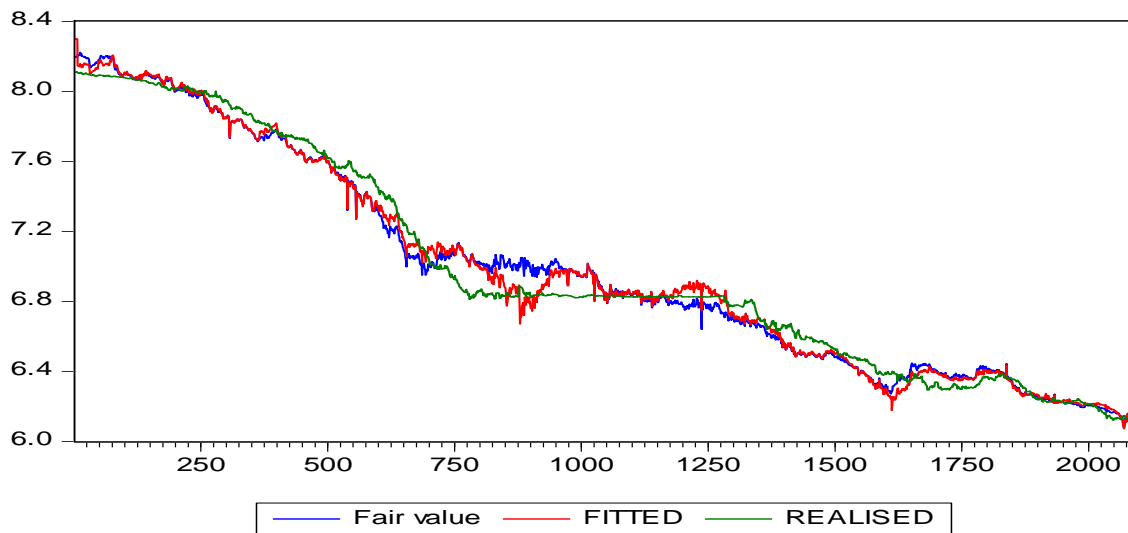
Fig. 6. Movements of Renminbi's fair value, fitted value and realised value.

4.2 Results for the Whole Sample Period

Table 7 presents the results for the whole sample period tested using the Tobit model with covariate dependent thresholds. In the models for the subsample periods, the initial 1,000 variates are discarded as the burn-in period and the subsequent 30,000 values are recorded to conduct an inference. The number of Daily Price interventions in the whole sample is 1515, among which 43.6% of high interventions and 29% of low interventions are censored. Like Daily intervention by the Bundesbank and Federal Reserve (Almekinders and

Eijffinger, 1994 and 1996), China's Daily Price intervention happened on more than half of all trading days.

The estimates do not reject the hypothesis that the PBOC followed a leaning-against-the-wind policy by reverting to its bank exchange rate offers. The 95% intervals for bank exchange rate offer variables do not include zero, which means coefficients are significant at 5% level. The coefficient on bank exchange rate offers b_1 is negative (positive) and significant for high (low) intervention in the Tobit model with covariate dependent thresholds, which means that when the exchange rate offers appreciate (depreciate), the PBOC sets a higher (lower) central parity rate to reverse this appreciation (depreciation). This gives empirical evidence for the leaning-against-the-wind hypothesis.

The coefficients on broad currency index b_2 are negative and significant for high intervention, and are positive and significant for low intervention at 5% level in the Tobit model with covariate dependent thresholds, as the 95% intervals for broad currency index variables do not include zero. The broad currency index reflects the foreign exchange market conditions. Evidence shows that poor (good) foreign exchange market conditions would trigger Daily Price high (low) intervention by the PBOC. Through the use of Daily Price intervention, the PBOC makes efforts to improve foreign exchange market conditions.

Results in the Bayes Tobit model indicate that China's macro economy has negatively significant effect on low intervention, but has no effect on high intervention. The yield curve spread is the proxy for China's macro economy condition. Based on studies by Harvey (1988), Estrella and Hardouvelis (1991), and Rudebusch and Williams (2009), the relation between the yield curve and the economy should be positive. The coefficients on the yield curve b_3 are negatively significant for low intervention at 5% level. The low yield curve spread means that China's macro economy condition is bad. Then, the RMB exchange rate

depreciates, reflecting the poor economic condition. Low intervention is used to offset the depreciation of the RMB exchange rate. Therefore, the low yield curve spread triggers intervention.

Referring to the magnitude of determinant coefficients in Table 8, the numbers for the yield curve spread for both high (0.017) and low (-0.017) interventions are smallest. The difference between numbers for the yield curve spread variables and other variables shows that the yield curve spread represents the least important factor in the PBOC's intervention decision. The broad currency index is the most important factor.

Table 7

Tobit model results with covariate dependent thresholds for whole period.

Full sample: 22/07/2005-22/07/2013						
	High intervention			Low intervention		
	Mean	Stdev	95% Interval	Mean	Stdev	95% Interval
Cons	26.92	3.298	(20.50,33.36)	-40.65	4.082	(-48.74,-32.72)
ERO_t	-12.85	3.636	(-20.12,-5.79)	6.242	1.781	(2.755,9.727)
BCI_t	-13.40	1.660	(-16.63,-10.16)	20.092	2.047	(16.12,24.14)
YC_t	0.017	0.048	(-0.078,0.11)	-0.225	0.060	(-0.34,-0.11)
τ^2	0.981	0.054	(0.882,1.091)	1.320	0.089	(1.16,1.51)

Note: ERO_t is the bank RMB exchange rate offers, BCI_t is the broad currency index, YC_t is the yield curve spread.

Table 8

Marginal effects for the whole time period.

Full sample: 22/07/2005-22/07/2013		
	High intervention	Low intervention
ERO_t	-13.099***	4.729***
	(-3.534)	(3.505)
BCI_t	-13.660***	15.221***

	(-8.072)	(9.815)
YC_t	0.017	-0.170***
	(0.354)	(-3.750)

Note: The significance levels are displayed as *** for 1%, ** for 5%, and * for 10%. ERO_t is the bank RMB exchange rate offers, BCI_t is the broad currency index, YC_t is the yield curve spread.

4.3 Results for Subsamples: Before, During and After the Global Financial Crisis

The results for the three subsamples are reported in Table 9. In the subsample models, as in the model for the whole sample, the initial 1,000 variates are discarded as the burn-in period and the subsequent 30,000 values are recorded to conduct an inference. The number of Daily Price interventions in subsample 1 is 606, among which 51.7% of high interventions and 26.3% of low interventions are censored. There are 367 observations for Daily Price intervention in subsample 2, in which 27.2% of high interventions and 52.8% of low interventions are censored. In subsample 3, the number of interventions is 594, in which 68.4% of high interventions and 23.4% of low interventions are censored.

In subsample 1, 22nd July 2005 to 14th July 2008, only the broad currency index factors have significant impacts on high and low intervention, as the 95% credible intervals do not include zero. The broad currency index variables are negative and significant for both high and low intervention. These results indicate that when making intervention decisions the PBOC considers the foreign exchange market conditions; that is, the PBOC tries to improve poor foreign exchange market conditions. For the yield curve spread, the coefficient b_3 is positive and significant for low intervention only. This suggests that the PBOC tries to cool down the overheating of economic growth by using low intervention.

In the financial crisis period, which is subsample 2, the aim of Daily Price intervention is to keep the RMB following the US dollar. The exchange rate regime during the financial crisis was a pegging regime, and therefore the main objective of Daily Price

intervention was to stabilize the exchange rate movements. Therefore, the coefficients on broad currency index b_2 are significant on both high and low intervention. The bank exchange rate offers variable influences high intervention only. The coefficient on the bank exchange rate offers b_1 is negative for high intervention. As with the result for subsample 1, the PBOC did use leaning-against-the-wind intervention. With regard to the yield curve spread, the coefficient on the yield curve spread b_3 is negative and significant for low intervention. This suggests that in order to turn the economy from bad to good, the Chinese monetary authorities use low intervention, because low intervention can boost the import volume.

For subsample 3, all determinant factors, except yield curve spread, have significant impact on high and low intervention, as the 95% credible intervals do not include zero. The coefficient on exchange rate offers b_1 is negatively and positively significant for high and low intervention respectively. Similar to the result for the whole sample, this suggests that the PBOC uses leaning-against-the-wind intervention, and wants the RMB exchange rate to be impacted more by market conditions. Both high and low intervention decisions consider the foreign exchange market condition. The negative and positive significances of the coefficient on the broad currency index b_2 for the low and high intervention are at 5% level, respectively. For the yield curve spread, the coefficients b_3 are positive and significant for high intervention, but not significant for low intervention. This means that the PBOC tries to boost economic growth through high intervention, because high intervention can boost the export volume.

According to the significance and magnitude of variables (Table 10) in these three subsamples, we find that the main objective of the Daily Price intervention is different in each case. For high intervention, the main objective across the subsamples is to focus on

market exchange rate condition. For low intervention, the main objective before the financial crisis is to prevent the domestic economy overheating, while during and after the financial crisis the focus is upon market exchange rate condition.

Table 9 (1)

Results of Bayes Tobit models for subsample 1 (22/07/2005-14/07/2008).

	High Intervention			Low Intervention		
	Mean	Stdev	95% Interval	Mean	Stdev	95% Interval
Cons	17.785	5.491	(7.115,28.661)	30.600	11.279	(9.272,53.335)
ERO_t	-2.893	5.096	(-12.963,7.005)	8.067	9.452	(-10.514,26.745)
BCI_t	-8.638	2.753	(-14.093,-3.293)	-16.006	5.683	(-27.456,-5.262)
YC_t	-0.087	0.070	(-0.224,0.052)	0.747	0.164	(0.439,1.088)
τ^2	0.763	0.064	(0.649,0.897)	1.685	0.209	(1.321,2.137)

Note: ERO_t is the bank RMB exchange rate offers, BCI_t is the broad currency index, YC_t is the yield curve spread.

Table 9 (2)

Results of Tobit-GARCH models for subsample 2 (15/07/2008-22/06/2010).

	High Intervention			Low Intervention		
	Mean	Stdev	95% Interval	Mean	Stdev	95% Interval
Cons	53.625	13.808	(27.883,82.054)	-52.492	4.156	(-60.895,-44.528)
ERO_t	-40.742	21.409	(-84.215,-0.390)	9.110	6.023	(-2.616,21.037)
BCI_t	-27.208	6.915	(-41.483,-14.366)	26.440	2.070	(22.485,30.632)
YC_t	0.079	0.170	(-0.249,0.419)	-0.457	0.052	(-0.561,-0.356)
τ^2	2.264	0.414	(1.580,3.195)	0.469	0.047	(0.386,0.569)

Note: ERO_t is the bank RMB exchange rate offers, BCI_t is the broad currency index, YC_t is the yield curve spread.

Table 9 (3)

Results of Bayes Tobit models for subsample 3 (23/06/2010-22/07/2013).

	High Intervention			Low Intervention		
	Mean	Stdev	95% Interval	Mean	Stdev	95% Interval
Cons	53.954	6.527	(41.343,67.018)	-69.18	14.984	(-99.684,-40.761)
ERO_t	-7.844	3.783	(-15.884,-1.405)	5.423	2.234	(1.075,9.817)
BCI_t	-27.193	3.281	(-33.767,-20.851)	34.15	7.504	(19.896,49.428)
YC_t	0.665	0.104	(0.465,0.873)	-0.0002	0.216	(-0.422,0.422)
τ^2	0.731	0.60	(0.625,0.858)	1.853	0.245	(1.432,2.393)

Note: ERO_t is the bank RMB exchange rate offers, BCI_t is the broad currency index, YC_t is the yield curve spread.

Table 10

Marginal effects for subsamples.

	Subsample 1 (22/07/2005-14/07/2008)		Subsample 2 (15/07/2008-22/06/2010)		Subsample 3 (23/06/2010-22/07/2013)	
	High intervention	Low intervention	High intervention	Low intervention	High intervention	Low intervention
ERO_t	-3.792	4.788	-21.163**	19.424	-10.731**	2.927**
	(-0.568)	(0.853)	(-1.903)	(1.513)	(-2.073)	(2.427)
BCI_t	-11.321***	-9.499***	-12.018***	56.375***	-37.200***	18.430***
	(-3.138)	(-2.816)	(-3.935)	(12.773)	(-8.288)	(4.551)
YC_t	-0.114	0.443***	0.035	-0.974***	0.910***	-0.0001
	(-1.243)	(4.555)	(0.465)	(-8.788)	(6.394)	(-0.0009)

Note: The significance levels are displayed as *** for 1%, ** for 5%, and * for 10%. ERO_t is the bank RMB exchange rate offers, BCI_t is the broad currency index, YC_t is the yield curve spread.

5. Conclusions

This paper evaluates the influences that drive China's central parity rate intervention in a Bayes Tobit approach. In order to estimate a proxy for Daily Price intervention data, we

use the present central parity rate and daily fair value CNY/USD exchange rate estimated following the IFV approach.

In general, the results show that the bank RMB exchange rate offers, the broad currency index and the yield curve spread have significant effects on Daily Price intervention. The PBOC follows a leaning-against-the-wind policy by reverting to its bank exchange rate offers. In addition, both bad (good) foreign exchange market and macro economy condition can trigger high (low) intervention.

With regard to the time-varying determinants of Daily Price intervention, results show that determinant factors vary not only between different subsamples, but also between the high and low interventions. We find evidence that across the different subsamples the main objective for high intervention is to focus on market exchange rate condition, while the main objective for low intervention ranges from restraining the domestic economy from overheating before the financial crisis, to a focus on market exchange rate condition during and after the financial crisis.

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