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Optimal Renminbi Exchange Rate Policy under Depreciation Anticipation

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Mei Li *

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Abstract

We establish formal models to study optimal foreign exchange intervention policy for a currency under depreciation pressure when a central bank aims both to discourage speculative capital flows and to reduce exchange rate misalignment. In particular, we study two cases where speculators have complete and incomplete information about the central bank's long-run equilibrium exchange rate target and arrive at the following results: (1) With complete information, the central bank is better off pre-committing to a specific exchange rate level than deciding it discretionarily. (2) With incomplete information, the central bank cannot credibly reveal its exchange rate target to speculators through "cheap talk". (3) With incomplete information, any action taken by the central bank will send a signal to speculators about the central bank's preferences, causing a change in the speculators' beliefs and subsequently in capital flows.

Journal of Economic Literature Classification: F31, F32

Keywords: foreign exchange intervention, depreciation anticipation, renminbi exchange rate

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1 Introduction

On August 11, 2015, the People's Bank of China announced to reform the midpoint value determination mechanism of the renminbi and leave it to be determined by market makers. The same day midpoint value dropped by 1.9% against the previous day value. This move is no doubt an important step towards a more market-determined renminbi exchange rate. However, the announcement accompanied with the large depreciation of the renminbi on the same day also triggered sudden enormous capital outflows. On July 1st, 2015 before the announcement, China's international reserves stood at 3.65 trillion U.S. dollars. On January 4th, 2016, this number was reduced to around 3.23 trillion U.S. dollars. That is, there was a capital outflow of more than 400 billion U.S. dollars within half a year following the announcement.

This example vividly demonstrates that the renminbi exchange rate management has become much more challenging with an anticipation of renminbi deprecitation. Before 2014, the renminbi was considered undervalued by the market and expected to appreciate over time. It is relatively easy to maintain a stable renminbi exchange rate under an appreciation anticipation, because the monetary authorities could prevent a rapid appreciation of the renminbi simply by buying foreign currencies from speculators with the renminbi. The major concerns in such a situation are inflation pressure and asset price bubbles caused by speculative capital *inflows*.[1] However, since 2014, with the economic slow-down in China and economic recovery in the U.S., an anticipation of renminbi depreciation has been developed. It has become much more challenging to maintain a stable renminbi exchange rate with such an anticipation reversal. This is because a renminbi depreciation anticipation may cause a large amount of speculative capital *outflows*. In order to stabilize exchange rates, the monetary authorities have to rely on limited international reserves to intervene in the foreign exchange market. Once the monetary authorities run out of international reserves, the renminbi exchange rate will be determined by market forces. A large renminbi depreciation may happen, causing huge economic and financial turbulence. That is, China may face a currency crisis.

[1] See Li and Qiu (2011, 2013).

We establish formal models to study optimal exchange rate policy for a central bank with a currency under depreciation pressure. More specifically, we study two cases where speculators have complete and incomplete information about the central bank's long-run equilibrium exchange rate target. In both cases, we introduce a sequential game with two players: a continuum of speculators and a central bank. The central bank chooses the future exchange rate both to discourage speculative capital outflows and to reduce exchange rate misalignment. According to the central bank's preferences, the speculators form their rational expectations about the central bank's exchange rate policy, and make profits from currency speculation. The major results that our models produce are as follows:

First, in the complete information case, because the speculators have complete information about the central bank's preferences, they can always rationally form correct expectations about the central bank's future exchange rate policy. In such a situation, we find that the central bank is better off pre-committing to a specific future exchange rate level than deciding the future exchange rate discretionarily. This is because in the commitment case, the central bank can use its future exchange rate policy to affect the speculators' current decision on their speculative capital flows and benefits from this effect that is missing in the discretionary case. Additionally, we find that in the commitment case, the central bank will devalue the currency less than in the discretionary case, due to its additional incentive to use its future exchange rate policy to discourage capital outflows.

Second, in the incomplete information case, the central bank is unable to credibly reveal its long-run equilibrium exchange rate target to the speculators. We find that no matter what the central bank's true target is, it always has an incentive to claim a target that induces a zero speculative capital outflow. Thus in our model, a central bank cannot affect speculators' beliefs about its preferences through "cheap talk". We find that this result differs from that found by Stein (1989). In Stein (1989), a central bank also has an incentive to lie, but not to lie too much. As a result, the central bank can credibly reveal the true range of its exchange rate target to speculators. However, in our model, a central bank always has an incentive to claim a target exactly equal to the one inducing a zero speculative capital outflow. As a result, in our model it is impossible for the central bank to credibly reveal its type to the market through "cheap talk".

Third, in the incomplete information case, a public signal sent by the central bank about its long-run equilibrium exchange rate target can greatly affect speculators' beliefs and trigger large capital outflows. This is particularly true if the central bank implements an opaque exchange rate policy and intentionally hide its preferences from speculators. More specifically, we find that a public signal can affect speculators' beliefs about the distribution of the future exchange rate, their expected profits from capital outflows, and eventually the size of capital outflows. In particular, the higher the precision of the public signal relative to that of speculators' prior belief, the larger the change in speculators' beliefs and subsequently in capital outflows.

This paper is closely related to Li and Qiu (2011, 2013), who study the optimal renminbi exchange rate policy when the renminbi is expected to *appreciate*. Similar to this paper, they also study the strategic interactions between the central bank and speculators. However, they focus on the optimal appreciation path of the renminbi with a renminbi *appreciation* anticipation. More generally, this paper is in line with the literature on currency attacks with a focus on strategic interactions between the central bank and speculators. This literature can date back to the first and second generation currency attack models developed in the 1970's and 1980's. The related seminal work includes Krugman (1979), Flood and Garber (1984), and Obstfeld (1986). More recent work includes Morris and Shin (1998), Corsetti et al. (2004), Angeletos, Hellwig, and Pavan (2006, 2007), and Li and Milne (2014) among many others.

This paper is also related to Stein (1989) and Vitale (2003), both of which study optimal foreign exchange intervention when a central bank cannot credibly reveal its true preferences. In particular, Stein (1989) studies "cheap talk" or oral intervention, whereas Vitale (2003) studies actual intervention which is used as a costly signal of the central bank's preferences. Our model is constructed to study a specific situation faced by the Chinese exchange rate policy makers since 2014, where a renminbi depreciation anticipation has been developed under capital controls. As a result, the central bank's objective function in this paper differs from those in these two papers. As mentioned previously, in our model a central bank cannot credibly reveal a range of its preferences as suggested by Stein (1989).

Finally, this paper is related to the general literature on foreign exchange intervention.[2] This literature focuses on two channels through which sterilized foreign exchange intervention influence the exchange rate: (1) the portfolio balance channel (Dominguez and Frankel (1993)); and (2) the signaling or more generally information channel (Mussa (1981)). The portfolio balance channel theory posits that domestic and foreign assets are imperfect substitutes. Thus sterilized foreign exchange intervention will affect the composition of market participants' portfolios and, consequently, the exchange rate. The signaling channel theory posits that foreign exchange intervention signals the future policy stance, affecting market participants' expectations on the exchange rate and, consequently, the exchange rate. This study is in the same vein as the information channel theory, because we focus on examining how foreign exchange rate policy affects speculators' beliefs on the exchange rates.

The rest of the paper is organized as follows. Section 2 establishes a model where speculators have complete information about the central bank's long-run equilibrium exchange rate target to study optimal exchange rate policy. Section 3 establishes a model where speculators have incomplete information. Section 4 provides a discussion on the renminbi exchange rate policy, using the framework of our models. Section 5 concludes.

2 A Model with Complete Information

2.1 The Model

Consider a one-period sequential game with two players: a continuum of atomically small speculators and a central bank. Assume that speculators are identical and the first mover. They form their rational expectations about the future log exchange rate, denoted by s_1, and chooses their position on the foreign currency, denoted by b, to maximize their

[2] The related works include Sarno and Taylor(2001), King (2003) and Chutasripanich and Yetman (2015) among many others.

expected profits. Here the exchange rate is denoted by units of domestic currency, say the renminbi, per unit of foreign currency, say the U.S. dollar. Thus a higher s_1 implies a depreciation of the renminbi.

More specifically, a representative speculator's expected profit is given by:

$$E_0(\Pi_1) = b(E_0(s_1) - s^{IP}) - \frac{1}{2}cb^2. \tag{1}$$

Here $E_0(s_1)$ is the speculator's expected log future exchange rate. s^{IP} is the log future exchange rate that induces the interest parity to hold. That is,

$$s^{IP} = s_0 + i_0 - i_0^*, \tag{2}$$

where s_0 is the spot log exchange rate, i_0 is the current domestic interest rate, and i_0^* is the current foreign interest rate. Thus $E_0(s_1) - s^{IP}$ is the speculator's expected rate of return from buying one U.S dollar. Note that if $E_0(s_1) = s^{IP}$, the speculator will expect the interest parity to hold, and there will be no speculative capital flows.

Additionally, we use the second term, $\frac{1}{2}cb^2$, where c is a positive constant, to capture the cost that the speculator incurs to circumvent capital controls. Note that it is in the quadratic form, implying that the speculative cost for each additional unit of capital flows increases as capital flows increase.

Given the above profit function, we find that the first-order condition implies that the speculator will optimally choose

$$b^* = \frac{E_0(s_1) - s^{IP}}{c}. \tag{3}$$

Thus the speculator's realized gross profit without the cost deducted after the central bank chooses s_1 is given by

$$\frac{(E_0(s_1) - s^{IP})(s_1 - s^{IP})}{c}, \tag{4}$$

which is equivalent to the capital loss of the central bank. Intuitively, the term $s_1 - s^{IP}$ gives the speculator's realized rate of return for one dollar he buys. On the other hand, $\frac{E_0(s_1) - s^{IP}}{c}$ is the total amount of U.S. dollars that the speculator buys, which is proportional to $E_0(s_1) - s^{IP}$, the speculator's expected rate of return for one dollar he buys.

Note that in a general case, a positive b implies that speculators are selling the renminbi for the U.S. dollar (capital outflows), whereas a negative b implies that speculators are selling the U.S. dollar for the renminbi (capital inflows). Later we will explain that because we focus on a case where the renminbi is anticipated to depreciate, b will always be positive in our model. That is, the central bank always faces a capital outflow.

Assume that the central bank is the second mover, who chooses s_1 to minimize its loss function as follows, after observing capital flows, b.

$$L = b(s_1 - s^{IP}) + \frac{1}{2}\lambda(s_1 - s^E)^2, \tag{5}$$

where $\lambda > 0$ is a positive constant, indicating the relative weight the central bank places on the second term. Additionally, s^E is the central bank's long-run equilibrium exchange rate target. Because we focus on the case where the domestic currency is under the depreciation pressure, we assume that $s^E > s^{IP}$ throughout the paper. Our later analysis shows that this assumption implies that $s_1 > s^{IP}$ and b is always positive in equilibrium.

This loss function indicates that the central bank aims to achieve two objectives when implementing its exchange rate policy. First, the central bank aims to minimize capital gains of speculators, which are equivalent to the loss of the central bank. Second, the central bank also aims to minimize the misalignment cost caused by the deviation of the actual exchange rate from its long-run equilibrium target, which is given by $\frac{1}{2}\lambda(s_1 - s^E)^2$.

This loss function reveals that when $s^{IP} \neq s^E$, the central bank has two conflicting objectives: In order to minimize speculative profits, the central bank would like to set s_1 at s^{IP}. On the other hand, in order to minimize the misalignment cost, the central bank would like to set s_1 at s^E.

We first look at the complete information case where speculators have complete information about the central bank's loss function. In particular, they know perfectly the central bank's long-run equilibrium exchange rate target, s^E. Backward induction is used to find the Subgame Perfect Nash Equilibrium in this sequential game.

We start with the second mover, the central bank, who will choose s_1 to minimize its loss function, given the amount of capital outflows, $b = \frac{E_0(s_1)-s^{IP}}{c}$, or equivalently, speculators' expected future exchange rate, $E_0(s_1)$. The first-order condition gives us the optimal level of s_1 that the central bank will choose:

$$s_1^* = s^E - \frac{E_0(s_1) - s^{IP}}{\lambda c} \tag{6}$$

Now we move back to the first mover of the game, the speculators, who rationally form their expectation about s_1 based on the best response of the central bank. Thus

$$E_0(s_1) = E_0(s_1^*) = s^E - \frac{E_0(E_0(s_1)) - s^{IP}}{\lambda c}. \tag{7}$$

Since $E_0(E_0(s_1)) = E_0(s_1)$, we have

$$E_0(s_1) = \frac{\lambda c}{1+\lambda c} s^E + \frac{1}{1+\lambda c} s^{IP} \tag{8}$$

in equilibrium. The intuition behind this result is that speculators form their expected future exchange rate based on the central bank's preferences. Because the central bank cares about both the speculative profits and misalignment cost, speculators (correctly) believe that the central bank will choose s_1 as a weighted average of s^E and s^{IP}. Note that $E_0(s_1)$ increases in λ. This is because with a higher λ, the central bank cares more about the misalignment cost relative to speculative profits. Hence speculators believe that s_1 will be closer to s^E.

Additionally, in equilibrium the central bank will indeed set

$$s_1 = \frac{\lambda c}{1+\lambda c} s^E + \frac{1}{1+\lambda c} s^{IP} = s^E - \frac{1}{1+\lambda c}(s^E - s^{IP}). \tag{9}$$

That is, the central bank will not fully devalue its currency to the long-run equilibrium value. Instead, the central bank will devalue less due to its concern for speculative profits.

2.2 Policy Implications

Here we examine the implications that the model produces for the renminbi exchange rate policy. We find that with complete information, the central bank will be better off if it can pre-commit to a specific exchange rate level, rather than deciding it discretionarily.

To see this, consider the case where the central bank can commit to a specific level for s_1. Thus the central bank's loss function becomes

$$L = \frac{(s_1 - s^{IP})^2}{c} + \frac{1}{2}\lambda(s_1 - s^E)^2. \tag{10}$$

The first-order condition w.r.t. s_1 yields

$$s_1^c = \frac{2}{2+\lambda c}s^{IP} + \frac{\lambda c}{2+\lambda c}s^E. \tag{11}$$

Thus in equilibrium of this commitment case, the central bank's loss would be

$$L^c = \frac{(s_1^c - s^{IP})^2}{c} + \frac{1}{2}\lambda(s_1^c - s^E)^2 = [\frac{1}{c}(\frac{\lambda c}{2+\lambda c})^2 + \frac{1}{2}\lambda(\frac{2}{2+\lambda c})^2](s^E - s^{IP})^2. \tag{12}$$

Recall that in the discretionary case, the central bank's optimal solution for s_1 is given by $\frac{1}{1+\lambda c}s^{IP} + \frac{\lambda c}{1+\lambda c}s^E$. As a result, in equilibrium of the discretionary case, the central bank's loss is given by

$$L^d = \frac{(s_1^* - s^{IP})^2}{c} + \frac{1}{2}\lambda(s_1^* - s^E)^2 = [\frac{1}{c}(\frac{\lambda c}{1+\lambda c})^2 + \frac{1}{2}\lambda(\frac{1}{1+\lambda c})^2](s^E - s^{IP})^2. \tag{13}$$

It is straightforward to prove that the central bank's loss is lower under the commitment policy, because[3]

$$L^d - L^c = \frac{\lambda^2 c + \frac{1}{2}\lambda^3 c^2}{(1+\lambda c)^2(2+\lambda c)^2}(s^E - s^{IP})^2 > 0. \tag{14}$$

Thus the central bank will attain a higher welfare level if it can pre-commit to a specific exchange rate level. The intuition behind this result is that if the central bank can commit to a specific exchange rate level, it will be able to use the exchange rate to influence speculators' decision on capital flows, rather than taking them as given. As a result, the central bank will have an additional incentive to set the exchange rate low to discourage capital flows, and place a higher weight on $s^{IP}(\frac{2}{2+\lambda c} > \frac{1}{1+\lambda c})$.

However, we should take this result with caution. A key assumption that leads to this result is that speculators have complete information about the central bank's objective function, including the central bank's relative weight on the misalignment cost, λ, and its

[3]See the Appendix for the proof.

exchange rate target, s^E. As a result, speculators can always correctly form their rational expectation about s_1 in equilibrium. This commitment policy will make the central bank better off only in such a situation. Later in the case where speculators have incomplete information about s^E, speculators will not know s_1 for sure. Their uncertainty about s_1 will reduce capital outflows. In this case, the commitment policy eliminates speculators' uncertainty about s_1, encouraging more capital outflows. Thus the commitment policy should be applied only to the situation where speculators have accurate information about the central bank's preferences.

An interesting observation from this model is that if the central bank weighs the misalignment cost less (a smaller λ), speculative capital flows will be lower, because speculators realize that the central bank has a strong incentive to discourage speculative capital flows, even at a cost of suffering a large deviation of the exchange rate from its target level. The policy implication of this observation is that if the central bank can establish a reputation of caring less about the misalignment cost, it will help the central bank to deter more capital flows.

Another observation from this model is that with a higher c, capital outflows will be lower and the central bank will choose an exchange rate closer to its long-run exchange rate target. Meanwhile, the equilibrium central bank loss is decreasing in c.[4] The policy implication of this observation is straightforward: tighter capital controls can effectively deter capital outflows and help the central bank to achieve a higher level of welfare. Actually in the recent renminbi depreciation episode, the Chinese monetary authorities indeed relied heavily on capital controls to fight speculative capital outflows.

3 A Model with incomplete information

3.1 The Model

Now we consider a more realistic scenario where speculators have incomplete information about the central bank's objective function. More specifically, assume that speculators

[4] The first order derivative of equilibrium L^d w.r.t. c is equal to $\frac{-\lambda c - \lambda^2 c^2}{(1+\lambda c)^4}$, which is negative.

do not have complete information about the central bank's exchange rate target, s^E. Instead, they have a prior belief that $s^E \sim N(\bar{s}, \bar{\sigma}^2)$. That is, they believe that s^E is normally distributed with a mean of $\bar{s}$ and variance of $\bar{\sigma}^2$. Assume that $\bar{s} > s^{IP}$, implying that the currency is anticipated to depreciate on average. In order to model speculators' behavior in an uncertain environment, following Carlson and Osler (2000) with some small modifications, we now assume that speculators are risk averse and have the following utility function:

$$U = -exp[-\theta(b\pi - \frac{1}{2}cb^2)], \tag{15}$$

where $\theta > 0$ is the absolute risk aversion of speculators, b again denotes the size of position that a speculator takes, and $\pi = s_1 - s^{IP}$ denotes speculators' profit from buying one U.S. dollar. Again, $\frac{1}{2}cb^2$ is the cost that speculators incur to circumvent capital controls that the monetary authorities impose, where $c > 0$ is a positive constant. Provided that speculators' expected future profits, π, are normally distributed (later we will verify it), speculators' expected utility function could be reduced to

$$W = bE_0(\pi) - \frac{1}{2}cb^2 - \frac{\theta}{2}b^2V(\pi), \tag{16}$$

where $V(\pi)$ is the variance of π believed by speculators.[5]

The first-order condition of speculators' expected utility maximization problem gives us the optimal position a speculator takes as follows

$$b = \frac{1}{c + \theta V(\pi)}[E_0(s_1) - s^{IP}]. \tag{17}$$

Note that no matter b is positive or negative, a positive c always leads to a lower absolute value of b. That is, the introduction of c discourages the size of position that speculators take. The intuition of this result is straightforward: the introduction of c makes speculation in both directions more costly, discouraging both speculative outflows and inflows. Additionally, the absolute value of capital flows also decreases in both θ and $V(\pi)$. That is, if speculators are more uncertain about the future profits or more risk averse, speculative capital flows will be lower.

[5]See the appendix for the proof.

Equation (17) implies that the condition to induce a zero b is given by

$$E_0(s_1) - s^{IP} = 0. \tag{18}$$

That is, if speculators expect that the interest parity holds ($E_0(s_1) = s^{IP}$), then there will be no speculative capital flows. For example, suppose that the domestic currency is the renminbi, and the foreign currency is the U.S. dollar. The current one-year government bond interest rate in China and the U.S. are around 2.3 percent and 0.5 percent respectively. Thu if speculators believe that the renminbi will depreciate against the U.S. dollar by 1.8 percent after one year, there will be no speculative flows. However, if speculators believe that the renminbi will depreciate against the U.S. dollar by more than 1.8 percent, there will be capital outflows. On the other hand, if speculators believe that the renminbi will depreciate against the U.S. dollar by less than 1.8 percent, or even appreciate against the U.S. dollar, there will be capital inflows.

Based on the above assumptions, the central bank's objective function with incomplete information becomes

$$L = \frac{(s_1 - s^{IP})[E_0(s_1) - s^{IP}]}{c + \theta V(\pi)} + \frac{1}{2}\lambda(s_1 - s^E)^2. \tag{19}$$

Again we use backward induction to find the Subgame Perfect Nash Equilibrium in this sequential game. We start with the second mover, the central bank. The central bank will choose s_1 to minimize the above loss function, taking capital flows $\frac{1}{c+\theta V(\pi)}[E_0(s_1) - s^{IP}]$ as given. The first-order condition yields

$$s_1^* = s^E - \frac{E_0(s_1) - s^{IP}}{\lambda(c + \theta V(\pi))}. \tag{20}$$

Speculators form their expected mean about s_1 based on the central bank's best response:

$$E_0(s_1) = E_0(s_1^*) = \frac{\lambda(c + \theta V(\pi))}{1 + \lambda(c + \theta V(\pi))}\bar{s} + \frac{1}{1 + \lambda(c + \theta V(\pi))}s^{IP}. \tag{21}$$

Note that Equation (20) implies that for speculators, $\pi = s_1 - s^{IP}$ follows a normal distribution with a variance $V(\pi) = V(s^E) = \bar{\sigma}^2$. To see this, note that if we guess $V(\pi)$ is a constant, we will find that for speculators, s_1 and consequently $\pi = s_1 - s^{IP}$ follow a normal distribution with indeed a constant variance of $V(\pi) = V(s_1) = V(s^E) = \bar{\sigma}^2$. Thus we verify that indeed $\pi = s_1 - s^{IP}$ follows a normal distribution with a variance $V(\pi) = V(s^E) = \bar{\sigma}^2$.

The equilibrium future exchange rate s_1 becomes

$$s_1 = s^E - \frac{E_0(s_1) - s^{IP}}{\lambda(c + \theta\bar{\sigma}^2)} = s^E - \frac{1}{1 + \lambda(c + \theta\bar{\sigma}^2)}(s^E - s^{IP}) - \frac{1}{1 + \lambda(c + \theta\bar{\sigma}^2)}(\bar{s} - s^E). \quad (22)$$

Comparing to the complete information case and ignoring the term $\theta\bar{\sigma}^2$ caused by risk aversion, now we have an additional term of $-\frac{1}{1+\lambda(c+\theta\bar{\sigma}^2)}(\bar{s} - s^E)$ caused by the predication error of speculators, $\bar{s} - s^E$.

3.2 Policy Implications

Now we can use this model with incomplete information to examine its policy implications. Our major results are as follows.

First, we find that the introduction of uncertainty will improve the central bank's welfare by discouraging capital outflows and therefore lowering the central bank's loss. To see this, note that the equilibrium loss of the central bank with the incomplete information is given by

$$L^{Incomplete} = \frac{(s_1 - s^{IP})[E_0(s_1) - s^{IP}]}{c + \theta\bar{\sigma}^2} + \frac{1}{2}\lambda(s_1 - s^E)^2 \quad (23)$$

Note that in equilibrium,

$$s_1 - s^{IP} = s^E - \frac{1}{1 + \lambda(c + \theta\bar{\sigma}^2)}\bar{s} - \frac{\lambda(c + \theta\bar{\sigma}^2)}{1 + \lambda(c + \theta\bar{\sigma}^2)}s^{IP} \quad (24)$$

$$E_0(s_1) - s^{IP} = \frac{\lambda(c + \theta\bar{\sigma}^2)}{1 + \lambda(c + \theta\bar{\sigma}^2)}(\bar{s} - s^{IP}) \quad (25)$$

$$s_1 - s^E = -\frac{E_0(s_1) - s^{IP}}{\lambda(c + \theta\bar{\sigma}^2)} = -\frac{1}{1 + \lambda(c + \theta\bar{\sigma}^2)}(\bar{s} - s^{IP}) \quad (26)$$

Assume that speculators have rational expectations such that $\bar{s} = s^E$. Then we find that

$$L^{Incomplete} = \{\frac{1}{c + \theta\bar{\sigma}^2}[\frac{\lambda(c + \theta\bar{\sigma}^2)}{1 + \lambda(c + \theta\bar{\sigma}^2)}]^2 + \frac{1}{2}\lambda[\frac{1}{1 + \lambda(c + \theta\bar{\sigma}^2)}]^2\}(s^E - s^{IP})^2. \quad (27)$$

Recall that in the complete information case, the discretionary policy yields the equilibrium loss as follows

$$L^d = [\frac{1}{c}(\frac{\lambda c}{1+\lambda c})^2 + \frac{1}{2}\lambda(\frac{1}{1+\lambda c})^2](s^E - s^{IP})^2. \tag{28}$$

Compare the central bank loss with and without uncertainty, we find that with uncertainty, c is now replaced by $c + \theta\bar{\sigma}^2$. The additional term, $\theta\bar{\sigma}^2$, plays a role similar to an increase in c, which we prove in the complete information case will lower the central bank loss. Thus our model shows explicitly that maintaining an opacity policy about the central bank's exchange rate target will improve welfare. This result explains why the Chinese monetary authorities would prefer an opacity policy for the renminbi exchange rate.

Second, in this setup, we find that a central bank can never credibly reveal its exchange rate target, s^E to the market, as long as $s^E \neq s^{IP}$. Thus a central cannot use "cheap talk" to manipulate market expectations. The central bank's preferences present a typical time inconsistency issue studied by Barro and Gordon (1983). Given its preferences, the central bank would always lie to the market that its exchange rate target is s^{IP} at the beginning of the game. If speculators took the central bank's claim at the face value, they would expect that $E_0(s_1) = s^{IP}$. In this case, speculators will expect no profits from capital flows. As a result, capital flows will be zero. Then next period the central bank will set s_1 at $s^E > s^{IP}$ to achieve a minimum loss of zero. This is because with discretionary policy, a central bank will take $E_0(s_1)$ as given in the second period when it decides s_1, and its preferences always induce it to set s_1 at s^E given a zero capital flow.

Thus our model differs from that of Stein (1989). In the Stein (1989) model, the central bank also has an incentive to lie, but will not want to lie too much. As a result, in his model, it is possible for the central bank to credibly reveal a range of its target exchange rate to speculators. However, in our model, the central bank always wants to claim a target as close to s^{IP} as possible. Thus the "cheap talk" equilibrium in the Stein (1989) model cannot exist in our model. A key conclusion of our model is that when speculators have incomplete information about the central bank's exchange rate target, the central bank cannot influence speculators' beliefs about the exchange rate target through "cheap talk".

Third, we find that when speculators have incomplete information about the central bank's objective function, any signal that the central bank sends to the market about its objective function can greatly change speculators' beliefs, triggering large capital flows. This is particularly true in China's case when the central bank implements an opacity policy that intentionally leaves speculators in the dark about its preferences. To see this point, we can take the renminbi midpoint value determination mechanism reform as an example. When the Chinese monetary authorities announced this reform on August 11, 2015, it sent a strong signal to the market about its preferences. In our model, it could be interpreted as a pubic signal about s^E. More specifically, denote this signal by s_p, and we have

$$s_p = s^E + \varepsilon_p, \tag{29}$$

where $\varepsilon_p \sim N(0, \sigma_p^2)$. A lower σ_p means that the signal is more precise about s^E. Speculators will update their beliefs using Bayes' Rule after observing this public signal. Thus their updated belief will be as follows. First, the mean of s^E becomes the weighted average of s_p and $\bar{s}$, that is,

$$\bar{s}' = \frac{\alpha \bar{s} + \beta s_p}{\alpha + \beta}, \tag{30}$$

where $\alpha = \frac{1}{\bar{\sigma}^2}$ is the precision of speculators' prior belief, and $\beta = \frac{1}{\sigma_p^2}$ is the precision of the public signal. Second, the variance of s^E becomes

$$\bar{\sigma}'^2 = \frac{1}{\alpha + \beta}. \tag{31}$$

Thus we can tell that the public signal changes speculators' beliefs in two ways: First, it changes speculators' belief about the mean of the central bank' exchange rate target. Second, it reduces speculators' uncertainty about the central bank's exchange rate target. The variance of speculators about s^E is now lower. Since the Chinese monetary authorities have been implementing an opacity policy about its objective function, it implies that before the announcement, speculators had very noisy information about s^E, that is, $\bar{\sigma}$ is extremely high or α is extremely low. Thus the announcement serves as a public signal with a relatively much lower (higher) σ_p^2 (β). Equation (30) indicates that it means that speculators will put much higher weight on s_p when forming their expectation about the mean of s^E. On the other hand, the announcement on the renminbi midpoint value reform and the subsequent large devaluation on the same day after the announcement sent a strong signal to the market that the Chinese monetary authorities' exchange rate target is high (that is, the Chinese monetary authorities have a strong incentive to devalue its currency), which can be interpreted as a value of s_p much higher than $\bar{s}$. In such a case, we find that after the announcement, speculators' beliefs about s^E will change dramatically: First, they believe that the mean of s^E is much higher than $\bar{s}$ that they believed before the announcement. Second, their uncertainty about s^E is reduced greatly. These changes will lead to larger capital outflows. To see this, note that capital outflows are determined by

$$b = \frac{1}{c + \theta\bar{\sigma}^2}[E_0(s_1) - s^{IP}] = \frac{\lambda}{1 + \lambda(c + \theta\bar{\sigma}^2)}(\bar{s} - s^{IP}). \tag{32}$$

We can tell that after the announcement, $\bar{\sigma}$ will be replaced by a much lower value of $\bar{\sigma}'$, inducing a higher capital outflow. On the other hand, recall that

$$E_0(s_1) = \frac{\lambda(c + \theta\bar{\sigma}^2)}{1 + \lambda(c + \theta\bar{\sigma}^2)}\bar{s} + \frac{1}{1 + \lambda(c + \theta\bar{\sigma}^2)}s^{IP}. \tag{33}$$

After the announcement, we have

$$E_0'(s_1) = \frac{\lambda(c + \theta\bar{\sigma}'^2)}{1 + \lambda(c + \theta\bar{\sigma}'^2)}\bar{s}' + \frac{1}{1 + \lambda(c + \theta\bar{\sigma}'^2)}s^{IP}. \tag{34}$$

Thus the announcement has two effects on speculators' expectations about s_1, $E_0(s_1)$: First, s_1 is a weighted average of the central bank's target, s^E, and s^{IP}. After the announcement, speculators expect a much higher s^E, causing speculators to expect a higher s_1. Second, the weight that speculators assign to s^E and s^{IP} will shift. Because $\lambda(c + \theta\bar{\sigma}'^2)$ decreases due to the fact that $\bar{\sigma}' < \bar{\sigma}$, after the announcement speculators assign a lower weight to $E_0(s^E)$ but a higher weight to s^{IP}. The intuition behind this effect is that with a lower variance, speculators will increase capital outflows. As a central bank concerned for speculative profits, it will have a stronger incentive to set a exchange rate closer to s^{IP} to "punish" speculators. Thus we find that the announcement has a mixed effect on $E_0(s_1)$.

Combining all these effects, we find that after the announcement, capital outflows become

$$b' = \frac{1}{c + \theta\bar{\sigma}'^2}[E_0'(s_1) - s^{IP}] = \frac{\lambda}{1 + \lambda(c + \theta\bar{\sigma}'^2)}(\bar{s}' - s^{IP}). \tag{35}$$

Then we find that the effects inducing a higher capital outflow, b, dominate. A lower $\bar{\sigma}'$ and higher $\bar{s}'$ will lead to a higher capital outflow unambiguously.

The above model can be used to explain why the announcement about the renminbi midpoint value reform on August 11, 2015 suddenly triggered a large amount of capital outflows without any substantial changes in economic fundamentals. Since 2014, the renminbi exchange rate depreciation pressure against U.S. dollars has been gradually accumulated. This depreciation pressure was caused by various economic fundamental changes in China and the U.S., including the slow-down of the Chinese economy, a lower current account surplus in China, and a constantly appreciating U.S. dollars against other currencies due to the economic recovery in the U.S.. In contrast to a weaker fundamental value of the renminbi against the U.S. doallor, the actual renminbi exchange rate stood at a historically high level of 6.11 Chinese yuan per U.S. dollar until August, 2015. Actually, between the beginning of 2014 and August, 2015, the renminbi exchange rate was closely pegged to the U.S. dollars at this level without much deviation. Thus it is not surprising that a strong depreciation pressure was accumulated during this period. Thus the announcement was released in a particularly sensitive time when a renminbi depreciation pressure was huge. The sudden move of the Chinese monetary authorities was (correctly) interpreted by the market as a strong signal about the future depreciation of the renminbi. This is because when the announcement was made, the fundamental value of the renminbi that would have been determined by the market was much lower than its actual value. A more market-determined renminbi exchange rate implied a depreciation of the renminbi. Thus this announcement greatly reduced the uncertainty of speculators about the future renminbi exchange rate movement, which, as demonstrated by our model, triggered a huge amount of capital outflows.

An alternative way to understand the large amount of capital outflows after the announcement is as follows. This announcement indicates that the renminbi exchange rate is going through a regime change. Under the old regime before the announcement, the renminbi exchange rate was mainly determined by the Chinese monetary authorities who were highly concerned about the exchange rate stability, which could be interpreted as a relatively low value of λ. That is, the central bank does not care for the misalignment cost that much. However, when the Chinese monetary authorities announced that they would allow the midpoint value of the renminbi to be determined by the market, market participants rationally interpreted it as a dramatic change in the central bank's preferences. More specifically, speculators believed that now λ is much higher. This is because we usually interpret the central bank's long-run equilibrium exchange rate target as the exchange rate that induces external balance. In the long run, the market-determined exchange rate should always approach this level. Once speculators realize that the Chinese monetary authorities care much more about the misalignment cost, a huge capital outflow occurs.

4 Policy Discussion

With an increasingly growing Chinese economy, the renminbi exchange rate policy has become the center of many international policy debates. Different from most other countries in the world that allow their exchange rates to be determined mainly by the market to benefit from free capital flows and monetary autonomy, the Chinese monetary authorities have both a strong control over the renminbi exchange rate and monetary autonomy through tight capital controls. Additionally, a large amount of international reserves also enhance the Chinese monetary authorities' control over the reminbi exchange rate. In the past, the renminbi exchange rate was largely determined by the Chinese monetary authorities and closely pegged to the U.S. dollar. The announcement of the Chinese monetary authorities to reform the renminbi midpoint value determination mechanism on August 11, 2015 is one substantial step for China towards a more market-determined renminbi exchange rate regime.

Although the announcement caused the short-run fluctuations in the renminbi exchange market, it is no doubt that the Chnese monetary authorities' reform on the renminbi midpoint value determination mechanism is in the right direction. In the long run, a market-determined renminbi exchange rate can effectively reflect market demand and supply for the renminbi, leading to a renminbi exchange rate closer to its fundamental value. It is also a necessary condition for the Chinese monetary authorities to remove capital controls and allow free capital flows, which will be the ultimate goal of the renminbi exchange rate reform. However, we have to say that the timing and the manner in which the reform was executed are not ideal at all. When the announcement was made, the depreciation pressure perceived by the market was historically high. As a result, market participants interpreted this announcement as an accurate signal for an imminent large depreciation of the renminbi, which was exactly the Chinese monetary authorities intended to do. As a result, a huge amount of foreign capital flew out of China, causing financial market turbulence and capital losses for the Chinese monetary authorities.

One mechanism absent in our model is a self-fulfilling currency attack under a depreciation anticipation, which has been studied by a large body of literature.[6] In our model, the central bank can always control its exchange rate, s_1. This assumption holds only when the central bank has sufficient international reserves to defend its currency, that is, to use its international reserves to buy domestic currency. Once the central bank depletes its international reserves, it will lose control over the exchange rate, and the exchange rate will be determined by market forces, which could be interpreted as s^E in our model. Thus a currency depreciation could be self-fulfilling: If speculator believe that other speculators will launch an attack, they will launch an attack too. As a result, the central bank depletes its international reserves to defend its currency, and is forced to let the currency depreciate indeed. On the other hand, if speculators believe that other speculators will not launch an attack, they will not launch an attack either. As a result, the central bank will not deplete its international reserves and allow its currency to depreciate. Coordination among speculators is critical in such a self-fulfilling currency attack, because an individual speculator's payoff from a strategy depends on strategies adopted by other speculators. Although the Chinese monetary authorities did not lose their control over the renminbi exchange rate due to their tight capital controls and large international reserves, the self-

[6] The related works include Flood and Garber (1984) and Morris and Shin (1998) among many others.

fulfilling mechanism accounted at least partly for the huge capital outflows in the recent episode. The announcement on the renminbi midpoint value determination mechanism reform, to some degree, served as a coordination tool for speculators. Once being aware that other speculators will sell the renminbi, an individual speculator will have a stronger incentive to sell the renminbi as well, because it is more possible that the renminbi will depreciate. Although in China's case, the Chinese monetary authorities are not at the risk of exhausting international reserves and losing control over the exchange rate, the large coordinated selling pressure from speculators still causes a substantial depreciation of the renminbi. Thus the Chinese monetary authorities should be particularly cautious when implementing any exchange rate policy under depreciation pressure to avoid this coordinating effect.

5 Conclusions

This paper is motivated by the sudden large capital outflows in China triggered by the announcement of the Chinese monetary authorities about the reform on the renminbi midpoint value determination on August 11, 2015. We establish formal models to explore optimal exchange rate policy when a currency is anticipated to depreciate. In our models, speculators form rational expectations about the central bank's future exchange rate policy and make their decisions about the size of capital outflows to maximize their expected profits. On the other hand, the central bank chooses the future exchange rate to minimize both its capital loss due to speculative activities and the misalignment cost caused by the deviation of the actual exchange rate from its long-run equilibrium target. The major policy implications produced by our models are as follows: First, when speculators have perfect information about the central bank's exchange rate target, it will be optimal for the central bank to pre-commit to a specific exchange rate level, rather than deciding it discretionarily. Second, when speculators have incomplete information about the central bank's exchange rate target, the central bank will not be able to credibly reveal its target to speculators through "cheap talk". Third, in the incomplete information case, foreign exchange rate policy will serve as a public signal, which may affect speculators' expectations substantially and trigger a large amount of capital outflows.

Appendix

A The proof of $L^d - L^c > 0$

Given Equations (10) and (12), we have

$$L^d - L^c = [\frac{1}{c}(\frac{\lambda c}{1+\lambda c})^2 + \frac{1}{2}\lambda(\frac{1}{1+\lambda c})^2](s^E - s^{IP})^2 - [\frac{1}{c}(\frac{\lambda c}{2+\lambda c})^2 + \frac{1}{2}\lambda(\frac{2}{2+\lambda c})^2](s^E - s^{IP})^2$$

Note that

$$\begin{aligned} \frac{1}{c}(\frac{\lambda c}{1+\lambda c})^2 - \frac{1}{c}(\frac{\lambda c}{2+\lambda c})^2 &= \frac{\lambda^2 c^2}{c}(\frac{1}{(1+\lambda c)^2} - \frac{1}{(2+\lambda c)^2}) \\ &= c\lambda^2 \frac{3+2\lambda c}{(1+\lambda c)^2(2+\lambda c)^2} \\ &= \frac{3\lambda^2 c + 2\lambda^3 c^2}{(1+\lambda c)^2(2+\lambda c)^2}. \end{aligned} \quad (36)$$

Additionally,

$$\begin{aligned} \frac{1}{2}\lambda(\frac{1}{1+\lambda c})^2 - \frac{1}{2}\lambda(\frac{2}{2+\lambda c})^2 &= \frac{1}{2}\lambda\frac{(2+\lambda c)^2 - 4(1+\lambda c)^2}{(1+\lambda c)^2(2+\lambda c)^2} \\ &= \frac{-2\lambda^2 c - \frac{3}{2}\lambda^3 c^2}{(1+\lambda c)^2(2+\lambda c)^2}. \end{aligned} \quad (37)$$

Thus we find

$$\begin{aligned} L^d - L^c &= [\frac{3\lambda^2 c + 2\lambda^3 c^2}{(1+\lambda c)^2(2+\lambda c)^2} + \frac{-2\lambda^2 c - \frac{3}{2}\lambda^3 c^2}{(1+\lambda c)^2(2+\lambda c)^2}](s^E - s^{IP})^2 \\ &= \frac{\lambda^2 c + \frac{1}{2}\lambda^3 c^2}{(1+\lambda c)^2(2+\lambda c)^2}(s^E - s^{IP})^2, \end{aligned} \quad (38)$$

which is positive. ■

B The proof of the reduced form utility function in the incomplete information case

Note that the utility will follow a log-normal distribution provided that π is normally distributed. As a result, the expected utility is given by

$$\begin{aligned} EU &= -E\left\{exp[-\theta(b\pi - \frac{1}{2}cb^2)]\right\} = -\{-\theta[bE(\pi) - \frac{1}{2}cb^2] + \frac{\theta^2}{2}b^2V(\pi)\} \qquad (39) \\ &= \theta bE(\pi) - \frac{1}{2}\theta cb^2 - \frac{1}{2}\theta^2 b^2 V(\pi) \\ &= \theta[bE(\pi) - \frac{1}{2}cb^2 - \frac{1}{2}\theta b^2 V(\pi)]. \end{aligned}$$

Because θ is a positive constant, we can reduce the above expected utility as follows:

$$W = bE_0(\pi) - \frac{1}{2}cb^2 - \frac{\theta}{2}b^2V(\pi). \qquad (40)$$

■

References

Angeletos, George-Marios, Christian Hellwig, and Alessandro Pavan, 2006, "Signaling in a Global Game: Coordination and Policy Traps," *Journal of Political Economy*, 114, 452-84.

Angeletos, George-Marios, Christian Hellwig, and Alessandro Pavan, 2007, "Dynamic Global Games of Regime Change: Learning, Multiplicity and Timing of Attacks," *Econometrica*, 75(3), 711-756.

Barro, Robert, and David Gordon, 1983, "Rules, Discretion and Reputation in a Model of Monetary Policy," *Journal of Monetary Economcis*, 12, 101-21.

Carlson, John A., Carol L. Osler, 2000, "Rational Speculators and Exchange Rate Volatility," *European Economic Review*, 44(2), 231-53.

Chutasripanich, Nuttathum, and James Yetman, 2015, "Foreign Exchange Intervention: Strategies and Effectiveness," BIS Working Papers No 499.

Corsetti, G., Dasgupta, A., Morris, S., Shin, H.S., 2004, "Does One Soros Make a Difference? A Theory of Currency Crises with Large and Small Traders, "*Review of Economic Studies*, 71, 87-113.

De Grauwe, Paul, and Marianna Grimaldi, 2006, "Exchange Rate Puzzles: A Tale of Switching Attractors," *European Economic Review*, 50(1), 1-33.

Dominguez, Kathryn M., and Jeffrey A. Frankel, 1993, "Does Foreign Exchange Intervention Matter? The Portfolio Effect," *American Economic Review*, 83(5), 1356-69.

Flood, Robert, and Peter Garber, 1984, "Collapsing Exchange-Rate Regimes: Some Linear Examples," *Journal of International Economics*, 17, 1-13.

King, Michael R., 2003, "Effective Foreign Exchange Intervention: Matching Strategies with Objectives," *International Finance*, 6(2), 249-71.

Krugman, Paul, 1979, "A model of balance-of-payments crises," *Journal of Money, Credit and Banking*, 11(3), 311-325.

Li, Mei and Junfeng Qiu, 2011, "Endogenous Inflows of Speculative Capital and the Optimal Currency Appreciation Path", *Canadian Journal of Economics*, 44(1), 364-379.

Li, Mei, and Junfeng Qiu, 2013, "Speculative Capital Inflows, Adaptive Expectations, and the Optimal Renminbi Appreciation Policy", *China Economic Review*, 25, 117-138.

Li, Mei, and Frank Milne, 2014, "The Role of a Large Trader in a Dynamic Currency Attack Model", *Journal of Financial Intermediation*, 23(4), 590-620.

Morris, Stephen, and Hyun Song Shin, 1998, "Unique Equilibrium in a Model of Self-fulfilling Currency Attacks," *American Economic Review*, 88, 587-97.

Morris, Stephen, and Hyun Song Shin, 2004, "Coordination Risk and the Price of Debt,"*European Economic Review*, 48(1), 133-153.

Mussa, Michael, 1981, "The Role of Official Intervention,"New York: Group of Thirty.

Obstfeld, Maurice, 1986, “Rational and Self-Fulfilling Balance-of-Payments Crises,” *American Economic Review*, 76(1), 72-81.

Sarno, Lucio and Mark P. Taylor, 2001, “Official Intervention in the Foreign Exchange Market: is It Effective and, If So, How does It Work?” *Journal of Economic Literature*, Vol. XXXIX, 839-68.

Spronk, Richard, Willem Verschoorm, and Remco Zwinkels, 2013 “Carry Trade and Foreign Exchange Rate Puzzles,” *European Economic Review*, 60, 17-31.

Stein, Jeremy, 1989, “Cheap Talk and the Fed: A Theory of Imprecise Policy Announcements,” *American Economic Review*, 79, 32-42.

Vitale, Paolo, 2003, “Foreign Exchange Intervention: How to Signal Policy Objectives and Stablise the Economy,” *Journal of Monetary Economics*, 50, 841-70.

Vives, Xavier, 2005, “Complementarities and Games: New Developments,” *Journal of Economic Literature*, XLIII, 437-479.