Adaptive Learning, Monetary Policy and Carry Trades

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Abstract

This paper investigates how carry trades affect the economy of a host country with different monetary policy designs. Capital inflows are expansionary, leading the central bank to raise the interest rate, increasing carry trades' returns, and generating further capital inflows (carry trades' vicious circle). In this paper, monetary authorities want to mitigate or suppress this vicious circle. Through a forward looking model, we are able to introduce investors' expectations which are crucial concerning the monetary policy's impact on the evolution of the economy. Introducing adaptive learning, we investigate how the economy evolves when agents do not know the long run values of the targeted variables. To suppress the destabilizing impact of carry trades, the central bank has to implement a flexible inflation-capital targeting policy under discretion announcing the level of its long run capital inflows' target.

1 Introduction

Since the beginning of the 2000's unconventional monetary policies have emerged. In 2001, the Bank of Japan was the first central bank to undertake a quantitative easing

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(QE) program. After the 2008 crisis, the Federal Reserve Bank also resorted to such a policy. The European Central Bank is belatedly engaged in QE. Such a policy aims at injecting huge quantities of liquidity in order to boost growth in large economies. This policy aims at raising bank domestic credit but carry trades transfer such liquidity abroad. The point is that capital moves from large economies to small open economies such as New-Zealand, Australia and Brazil. Moreover, these economies' central banks target inflation, which means that their interest rates are high relative to the zero lower bounds reached by developed countries engaged in QE, leading to carry trades. An inflation targeting policy can destabilize a country subjected to carry trades through the following mechanism: when inflation increases, the central bank raises the interest rate which increases carry trades' returns. Given that capital inflows are expansionary, they enhance inflation, leading the central bank to raise again the interest rate. Thus, the more there are carry trades, the more they are attractive (we will call it the carry trades' vicious circle). The only tool to stabilize the financial sector in these small open economies are macroprudential policies but they are not able to act on the carry trades' vicious circle. In the case of New-Zealand, as presented in IMF Staff (2014), macroprudential policy only stabilizes the housing market. Consequently, the destabilizing effects have to be managed by the central bank. The aim of this paper is to investigate how the central bank of a small open economy can reduce or suppress the carry trades' vicious circle.

Carry trades are investments which involve borrowing a low-return currency in order to invest in a high-return one. Those strategies, widely investigated in macroeconomics, involve investments which seem less risky than usual financial operations. Burnside et al (2006), (2007) have shown that the Sharpe ratio associated to carry trades is higher than the Sharpe ratio of the US stock market, reflecting a better risk performance. Through this operation, investors, whose aim is to earn the interest differential, have to take into account exchange rate changes which directly impact the return of carry trades, see e.g

Burnside et al (2011). Changes in the exchange rate can either increase the gain, cancel it or even generate a loss. For example, an appreciation of the currency of the targeted country will raise the return of carry trades above the interest differential. Investors also have to care about the reversal of carry trades, as Plantin and Shin (2011) pointed out. After cumulative inflows generated by carry trades, investors sell the target country currency, leading to large outflows, reducing carry trades' returns. Such outflows also destabilize the host country in the sense that the expansionary effect of carry trades instantaneously disappears. This kind of investment is possible only if uncovered interest parity (UIP) does not hold. Fama (1984) has shown that UIP does not hold in the short run.

In a backward-looking model Plantin and Shin (2011) have shown that carry trades can be destabilizing when investors' strategies are complementary, pointing out the importance of investors' behavior. Carry trades' returns are directly linked to monetary policies which determine the interest differential. Many authors as Bullard and Mitra (2002), Evans and Honkapohja (2006, 2003a, 2002) as well as Orphanides and Williams (2005a,b) have shown, through adaptive learning, that agents beliefs are crucial concerning the monetary policy's effect on the economy. It is clear that agents' behavior plays a central role in the destabilizing character of carry trades. Hence it appears essential to consider non fully rational agents (thanks to adaptive learning) while studying the effect of monetary policies on carry trades.

In this paper, we merge the literatures about monetary policy, carry trades and adaptive learning in order to investigate which monetary policy can reduce or suppress the vicious circle generated by carry trades in small open economies. We begin with a strict inflation targeting policy (benchmark) which is, as mentioned before, favorable to carry trades' vicious circle. Thereafter, we investigate the case of a flexible inflation-output targeting policy in order to investigate whether adding an output objective in the central bank's loss function can reduce or suppress the carry trades' vicious circle. Taking into account the recent work of the IMF e.g. Ostry (2012), IMF Staff (2013), we consider monetary policies which manage capital inflows. The latter policies, by decreasing the interest rate after an increase in capital inflows, should suppress the carry trades' vicious circle. We introduce this central bank's behavior by including capital inflows in the loss function. Hence, thanks to our adaptive learning approach, we are able to investigate how the economy evolves when agents do not know the long run values of targeted variables.

Our results imply that two monetary policy designs perform best. On the one hand, when the central bank chooses a standard policy, as strict- or flexible inflation-output targeting, the carry trades' vicious circle is minimized by a discretionary flexible inflation-output targeting policy announcing the long run target of the output (this is the "second best" framework). On the other hand, the "first best" policy is flexible inflation-capital targeting under discretion announcing the long run capital inflows target.

The rest of the paper is laid out as follows. Section 2 presents the model. In section 3, we introduce a secret behavior of the central bank. Section 4 is devoted to the calibration of the model. Section 5 and 6 present the results with a transparent and a secret monetary policy respectively. Section 7 concludes.

2 The model

2.1 The exchange rate

Carry trades come from the action of borrowing an amount of a low-yield currency and investing it in a high-yield currency. Uncovered Interest Parity (UIP) states that the low/high return currency tends to appreciate/depreciate: $(1 + r_t) = (1 + r_t^*)\frac{E_t s_{t+1}}{s_t}$, with r_t and r_t^* the domestic and foreign interest rate respectively and s_t and $E_t s_{t+1}$ the current and expected exchange rates. Carry trades come from the failure of the UIP condition in the short run (investors bet against UIP). An increase in the host country interest rate increases the return of a carry trade which enhances capital inflows and appreciates the currency. Since Fama (1984), many authors have investigated whether UIP holds empirically by estimating the following equation $\Delta s_{t+K} = \alpha + \beta(r_t - r_t^*) + \epsilon_{t+k}$, where $\beta = 1$ if UIP holds. In the short run β is always negative which reflects the fact that an increase in the domestic interest rate appreciates the domestic currency. That is why we write a different equation from UIP which states that the high-return currency tends to appreciate: $(1 + r_t^*) = (1 + r_t)\frac{E_t s_{t+1}}{s_t}$ in the short run. When the economy reaches its long run equilibrium, UIP holds and carry trades stop, that is what Plantin and Shin (2011) call "the day of reckoning". Denoting F_t the forward rate and $E_t s_{t+1}$, the expected exchange rate, combining covered interest parity (CIP) and UIP, we have:

$$F_t = E_t s_{t+1}. \tag{1}$$

We now relax the CIP condition. Inserting the parameter δ (similarly to Chakraborty and Evans (2008)) in Equation (1), allows us to introduce exchange rate biasedness, i.e. the fact that the forward rate is not a perfect predictor of the future exchange rate (Fama (1984)). Equation (1) becomes:

$$F_t = \delta E_t s_{t+1} + \omega_t, \tag{2}$$

ω_t is an AR(1) shock which affects the exchange rate. Hence, we have: $\omega_t = \eta_3 \omega_{t-1} + \tilde{\omega_t}$. With $\tilde{\omega_t}$ an i.i.d random variable with zero mean and variance σ_ω^2. We rewrite our parity condition in log which gives:

$$s_t = F_t + r_t - r_t^*, \tag{3}$$

From Equations (2) and (3), we obtain the following exchange rate equation:

$$s_t = \delta E_t s_{t+1} + r_t + \omega_t. \tag{4}$$

Given that the foreign country is assumed to be engaged in quantitative easing, the foreign interest rate is set to its zero lower bound ($r_t^* = 0$). Equation (4) shows that an expected exchange rate appreciation will appreciate the current exchange rate. That is due to the fact that if agents expect an appreciation, they will buy the domestic currency, which will appreciate it at time t. By increasing the return of a carry trade, an increase in the interest rate appreciates the domestic currency.

2.2 Capital inflows

Referring to Plantin and Shin (2011), changes in capital inflows depend on the rate at which investors can rebalance their portfolio (λ), the amount invested by investors who have had the opportunity to rebalance their portfolio (c_t) and the amount invested in domestic currency at time t, denoted n_t, which can be interpreted as current capital inflows.

$$E_t n_{t+1} - n_t = \lambda(c_t - n_t) + z_t, \tag{5}$$

z_t is a shock which affects capital inflows. Note that z_t is an AR(1) of the form: $z_t = \eta_4 z_{t-1} + \tilde{z}_t$, with $\tilde{z}_t$ an i.i.d random variable with zero mean and variance σ_z^2. Obviously, the amount invested by carry traders who have rebalanced their portfolio is linked to the return of a carry trade (that is why we set c_t as an endogenous variable) which depends positively on the host country's expected interest rate and the expected change in the exchange rate ($R_t = E_t r_{t+1} + E_t s_{t+1} - s_t$). Thus we have:

$$c_t = \tau E_t r_{t+1} + \mu(E_t s_{t+1} - s_t).$$

The parameters τ and μ introduce the fact that investors do not always grant the same importance to the changes in the exchange rate and the interest rate when they take their investment decision. More precisely, μ and τ are the elasticities of the amount invested by traders who have had the opportunity to rebalance their portfolio with respect to changes in the exchange and interest rates respectively. Hence, the expression of capital inflows is:

$$n_t = \sigma E_t n_{t+1} - \lambda\sigma\big\{\tau E_t r_{t+1} + \mu(E_t s_{t+1} - s_t)\big\} + z_t, \tag{6}$$

with $\sigma = \frac{1}{1-\lambda}$. Looking at Equation (6), we observe an opposite effect of the current and expected interest rates on capital inflows. On the one hand, an increase in the expected interest rate is perceived by investors as a future decrease in the output gap which makes them less confident about their investment, decreasing capital inflows (carry trades' reversal). On the other hand, a higher current interest rate appreciates the domestic currency which generates further capital inflows. λ reflects how important is the mass of investors on capital inflows. The more there are investors (λ is high), the more the impact of each variable on capital inflows is high. That means that through their decisions, when they are numerous, investors influence the macroeconomic variables by increasing capital inflows.

2.3 The monetary policies

We investigate several kind of monetary policies. We begin with the well-known strict inflation targeting policy which we use as a benchmark. From this benchmark we consider two different extensions of the monetary policy. On the one hand, monetary authorities can act in a standard way, adding an output gap target. On the other, they can have a capital inflows target. Depending on the monetary authorities' objectives the central bank will minimize either the first or the second loss function below:

$$min \frac{1}{2} E_t \left[\sum_{i=0}^{\infty} \beta^i [(\pi_{t+i} - \bar{\pi})^2 + \alpha_y (y_{t+i} - \bar{y})^2] \right], \tag{7}$$

$$min \frac{1}{2} E_t \left[\sum_{i=0}^{\infty} \beta^i [(\pi_{t+i} - \bar{\pi})^2 + \alpha_n (n_{t+i} - \bar{n})^2] \right]. \tag{8}$$

The central bank minimizes Equation (7) when it implements a flexible inflation-output targeting policy. Clarida, Gali and Gertler (2000) have modeled this kind of policy under discretion and commitment. Notice that $\alpha_y = 0$ reflects a strict inflation targeting policy. In Equation (8), the central bank implements a flexible inflation-capital targeting policy. $E_t\pi_{t+1}$ denotes expected inflation at time t for $t+1$, $E_t n_{t+1}$ expected capital inflows at time t for $t+1$, $\bar{\pi}$ and $\bar{n}$ are the targeted levels of inflation and capital inflows respectively. As suggested in the literature, the loss function implicitly takes 0 as the target inflation[1] ($\bar{\pi} = 0$). We use the same assumption concerning capital inflows' target ($\bar{n} = 0$). In Equation (7) $E_t y_{t+1}$ is the expected output gap at time t for $t+1$ and $\bar{y}$ the targeted level of the output gap. The output gap is constructed as follow, $y_t = x_t - o_t$ with x_t the current output and o_t potential output, both in log. Given that the loss function takes the potential output as the target, $\bar{y} = 0$. Notice that α_y is the weight that the central bank grants to the output gap and α_n the one devoted to capital inflows. The constraints for the minimization program are the output gap and inflation, which are expressed as follows:

$$y_t = E_t y_{t+1} + \upsilon E_t n_{t+1} - \varphi(r_t - E_t\pi_{t+1}) + g_t, \tag{9}$$

$$\pi_t = \kappa y_t - \phi s_t + \beta E_t\pi_{t+1} + u_t. \tag{10}$$

In Equation (9) representing the output gap (y_t), similarly to Plantin and Shin (2011), we add capital inflows. In our forward-looking model, expected capital inflows ($E_t n_{t+1}$) enhance growth. In Equation (10) an appreciation of the domestic currency reduces inflation. We are now able to minimize Equations (7) and (8) and investigate six different monetary policies.

In a first step, we investigate our benchmark which is a strict inflation targeting policy. Then, we consider that the central bank adds an output gap objective in its loss function

[1] Inflation is expressed as a percent deviation from trend.

analyzing a flexible inflation-output targeting policy both under discretion and commitment. Thereafter, we investigate whether adding a capital inflows target instead of an output gap one is more efficient regarding carry trades. Once again, we consider this framework both under discretion and commitment. To end up, we consider the exotic case of a strict capital inflows targeting policy. Obviously, this is not a realistic scenario and we expect this policy to be highly inflationary in presence of carry trades.

2.3.1 Strict inflation targeting

Similarly to Svensson (1997a), the first-order condition is the following $\pi_{t+i} = \bar{\pi}$. Inserting it into (10) and rearranging, we get the following reaction function:

$$r_t = \gamma_y E_t y_{t+1} + \gamma_\pi E_t \pi_{t+1} + \gamma_s E_t s_{t+1} + \gamma_n E_t n_{t+1} + \gamma_g g_t + \gamma_u u_t + \gamma_\omega \omega_t, \qquad (11)$$

with,

$$\begin{aligned} \gamma_\pi &= \psi(\beta + \kappa\varphi - 1); & \gamma_u &= \psi; \\ \gamma_n &= \varphi\kappa\upsilon; & \gamma_y = \gamma_g &= \psi\kappa; \\ \gamma_s &= \delta(1 - \psi\phi); & \gamma_\omega &= -\psi\phi; \\ \psi &= \frac{1}{\phi + \kappa\varphi}. \end{aligned}$$

Given that both the output gap and capital inflows are inflationary, after an increase in those two variables, the central bank raises the interest rate. Obviously, when expected inflation increases the central bank raises the interest rate in order to maintain inflation at the desired level. An expected domestic currency appreciation has two different impacts. On the one hand, it decreases inflation, leading the central bank to decrease the interest rate. On the other, it increases the expected return of carry trades, augmenting expected capital inflows, which are inflationary, bringing the central bank to raise the interest rate.

2.3.2 Flexible inflation-output targeting under discretion

The first order conditions, $y_t = -\frac{\kappa}{\alpha}\pi_t$ and $\pi_t = -\frac{\alpha}{\kappa}y_t$, are used to obtain the following reaction function:

$$r_t = \gamma_\pi E_t\pi_{t+1} + \gamma_y E_t y_{t+1} + \gamma_s E_t s_{t+1} + \gamma_n E_t n_{t+1} + \gamma_g g_t + \gamma_u u_t + \gamma_\omega \omega_t, \qquad (12)$$

with,

$$\begin{aligned}
\gamma_\pi &= (1-\zeta\iota)\left(1+\frac{\kappa\beta}{\varphi(\alpha+\kappa^2)}\right); & \gamma_u &= \frac{\kappa}{\varphi(\alpha+\kappa^2)}(1-\zeta\iota);\\
\gamma_n &= \frac{\upsilon}{\varphi}(1-\zeta\iota); & \gamma_y = \gamma_g &= \frac{1}{\varphi}(1-\zeta\iota);\\
\gamma_s &= -\zeta\iota\delta; & \gamma_\omega &= -\zeta\iota;\\
\iota &= \frac{\varphi(\kappa^2+\alpha)}{\varphi(\kappa^2+\alpha)+\phi\kappa}; & \zeta &= \frac{\phi\kappa}{\varphi(\alpha+\kappa^2)}.
\end{aligned}$$

In this framework, the central bank reacts in two ways following a higher expected inflation. On the one side, as usual, the central bank increases the interest rate in order to keep inflation around the targeted level. On the other, a higher inflation depreciates the domestic currency which reduces capital inflows, decreasing the output gap and bringing the central bank to cut the interest rate. An appreciation of the domestic currency diminishes inflation and the interest rate. The central bank reacts in two opposite ways after an increase in the output gap and capital inflows. On the one hand, since inflation rises, the central bank raises the interest rate. On the other hand, the domestic currency appreciates, reducing inflation, and the central bank decreases the interest rate. Notice that the final impact of an increase in both the expected output gap and capital inflows on the interest rate is positive.

2.3.3 Flexible inflation-output targeting under commitment

In this monetary policy setting, the first order conditions are $y_t = -\frac{\kappa}{\alpha}\pi_t + y_{t-1}$ and $\pi_t = -\frac{\alpha}{\kappa}(y_t - y_{t-1})$; thus the reaction function becomes:

$$r_t = \gamma_\pi E_t \pi_{t+1} + \gamma_y E_t y_{t+1} + \gamma_s E_t s_{t+1} + \gamma_n E_t n_{t+1} + \gamma_{ylag} y_{t-1} + \gamma_g g_t + \gamma_u u_t + \gamma_\omega \omega_t. \quad (13)$$

All the parameters in Equation (13) are the same as in Equation (12) except $\gamma_{ylag} = (\zeta\iota - 1)\frac{\iota\alpha}{\varphi(\alpha+\kappa^2)}$. Notice that, here, the central bank reacts both to the lagged and expected output gap. An increase in the lagged output gap announces a higher future interest rate, leading to a lower expected output gap. Under such circumstances, the central bank cuts the interest rate after an increase in the past output gap in order to honor its past promises.

2.3.4 Flexible inflation-capital targeting under discretion

We now investigate the case of a central bank which reacts to both capital inflows and inflation. That means that the monetary authorities want to reduce the vicious circle generated by carry trades and target inflation. In this case the central bank has to minimize Equation (8) under the constraints (9) and (10). The first order conditions resulting from this minimization program are $n_t = \frac{\alpha}{\sigma}\pi_t$ and $\frac{\sigma}{\alpha}n_t$. Thereafter, we have to rewrite Equation (6) in order to introduce the variable n_t in Equation (10):

$$s_t = \frac{1}{\lambda\sigma}n_t - \frac{1}{\lambda}E_t n_{t+1} + \tau E_t r_{t+1} + \mu E_t s_{t+1} - \frac{1}{\lambda\sigma}z_t. \quad (14)$$

From the first order conditions, Equations (10) and (4), we get the following reaction function:

$$\begin{aligned} r_t = {} & \gamma_y E_t y_{t+1} + \gamma_\pi E_t \pi_{t+1} + \gamma_s E_t s_{t+1} + \gamma_n E_t n_{t+1} \\ & + \gamma_r E_t r_{t+1} + \gamma_g g_t + \gamma_u u_t - \gamma_\omega \omega_t - \chi z_t, \end{aligned} \tag{15}$$

with

$$\begin{aligned} \gamma_y &= \frac{\chi\alpha\kappa}{\sigma}; & \gamma_\pi &= \chi\left(\frac{\alpha\kappa\varphi + \beta\alpha}{\sigma}\right); \\ \gamma_s &= \chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right); & \gamma_n &= \chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \sigma\right); \\ \gamma_r &= \chi\sigma\tau; & \gamma_g &= \frac{\chi\alpha\kappa}{\sigma}; \\ \gamma_u &= \frac{\chi\alpha}{\sigma}; & \gamma_\omega &= \chi\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right), \end{aligned}$$

and $\chi = \frac{\sigma}{\lambda\sigma^2\mu + \alpha\kappa\varphi + \alpha\phi}$. In Equation (15) both γ_y and γ_π are positive, which means that after an increase in both the output gap and inflation, the central bank raises the interest rate, in order to reduce inflation. The central bank reacts in two opposite ways after an increase in capital inflows and an appreciation of the domestic currency. Given that capital inflows are expansionary, they increase inflation, that is why monetary authorities raise the interest rate. On the other side, an increase in capital inflows makes carry trades more attractive, which brings the central bank to reduce the interest rate in order to minimize capital inflows' volatility (notice that the whole impact is negative). On the one hand, the central bank increases the interest rate after an expected appreciation of the domestic currency because the latter reduces capital inflows. On the other, given that an appreciation of the domestic currency reduces inflation, the central bank lowers the interest rate not to deviate from its inflation target.

2.3.5 Flexible inflation-capital targeting under commitment

In this framework the central bank announces its aim in terms of capital inflows' volatility. Thus if the monetary authorities want to be credible, they have to honor their past promises. That is why, we include lagged capital inflows (n_{t-1}). Using the same methodology as in the previous section, we obtain the following first order conditions:

$$\begin{aligned} \pi_t &= \frac{\alpha}{\sigma}\pi_t + n_{t-1}, \\ n_t &= \frac{\sigma}{\alpha}(n_t - n_{t-1}). \end{aligned} \tag{16}$$

Using the first order conditions (16) and Equation (6), we get the optimal capital inflows:

$$\begin{aligned} n_t = \frac{\alpha\kappa}{\sigma}E_t y_{t+1} + \left(\frac{\alpha\kappa\varphi + \beta\alpha}{\sigma}\right)E_t\pi_{t+1} - \frac{\phi\delta\alpha}{\sigma}E_t s_{t+1} + \frac{\alpha\kappa\upsilon}{\sigma}E_t n_{t+1} - \\ \frac{\alpha\kappa\varphi + \phi\alpha}{\sigma}r_t + n_{t-1} + \frac{\kappa\alpha}{\sigma}g_t + \frac{\alpha}{\sigma}u_t - \frac{\phi\alpha}{\sigma}\omega_t. \end{aligned} \tag{17}$$

From Equations (6) and (17), we obtain the central bank's reaction function under commitment:

$$\begin{aligned} r_t = \gamma_y E_t y_{t+1} + \gamma_\pi E_t\pi_{t+1} + \gamma_s E_t s_{t+1} + \gamma_n E_t n_{t+1} + \\ \gamma_r E_t r_{t+1} + \chi n_{t-1} + \gamma_g g_t + \gamma_u u_t - \gamma_\omega \omega_t - \gamma_z z_t. \end{aligned} \tag{18}$$

The parameters in Equation (18) are the same as in Equation (15). The only innovation is the presence of lagged capital inflows. That means that the central bank reacts to all variables in the same way as under discretion, except that it increases the interest rate after a rise in past capital inflows. An increase in past capital inflows announces a lower future interest rate, decreasing expected capital inflows leading to a higher interest rate at time t.

2.3.6 Strict capital inflows targeting

Here we investigate the case of a central bank which only wants to minimize capital inflows' volatility in order to limit the vicious circle enhanced by carry trades. Our methodology is similar to the one developed in Svensson (1997a) but instead of controlling inflation, the central bank targets capital inflows. In this case, the loss function is of the following form $L = \frac{1}{2}E_t\left[\sum_{i=0}^{\infty}\beta^i(n_{t+i} - \bar{n})^2\right]$, and the first order condition is $E_t n_{t+i} = \bar{n}$, leading to the following reaction function:

$$r_t = \gamma_s E_t s_{t+1} + \gamma_n E_t n_{t+1} + \gamma_r E_t r_{t+1} - \omega_t - \gamma_z z_t, \tag{19}$$

with

$$\gamma_s = (1-\delta); \qquad \gamma_n = \frac{1-\sigma}{\lambda\sigma\mu};$$
$$\gamma_r = \frac{\tau}{\mu}; \qquad \gamma_z = \frac{1}{\lambda\sigma\mu}.$$

The first thing to note is that $\sigma > 1$; thus after an increase in capital inflows, the central bank decreases the interest rate. By reducing the interest rate, the central bank lowers carry trades' returns, allowing to maintain capital inflows around the target. As mentioned previously, this is not a realistic scenario and we expect it to be highly inflationary[2].

3 Introducing secret monetary policies

When the central bank acts secretly the authorities do not announce the long run targeted level of the economic variables, meaning that agents also have to estimate such levels. More precisely agents have to estimate the long run values of the output gap and

[2] We voluntary do not present the impulse response functions for this scenario. The results reveal that this monetary policy is inflationary after a 5% capital inflows shock (as expected) and the IRF are available upon request.

capital inflows as the case may be.

3.1 The formation of expectations under discretion

Concerning those monetary policies, we are in the case of purely forward looking models. The economy is formalized through the systems presented in Appendix A.2, A.3, A.5 and A.6. We rewrite these systems in the following way:

$$A_t = B + M\hat{E}_t A_{t+1} + \Phi\Omega_t. \tag{20}$$

$\hat{E}_t$ means that expectations are non rational, M and Φ are (5×5) matrices of parameters and

$$\Omega_t = F\Omega_{t-1} + \epsilon_t. \tag{21}$$

With Ω_t and Ω_{t-1} (5×1) vectors and ϵ_t an exogenous (5×1) vector of shocks. F is a (5×5) matrix where $F = I\eta$ with I the identity matrix and $\eta \in]0;1[$. B is a (5×1) vector of constants, with $B = (I - M)\bar{A} - \Phi\bar{\Omega}$. The vector of constant B is only present in the system when agents do not know the long run values of the targeted variables. Otherwise, $B = 0$ and agents do not have to estimate the vector of constants.

Agents will forecast $\hat{E}_t A_{t+1}$ using discounted least squares from the following econometric model: $A_t = a_{t-1} + b_{t-1}\Omega_t + \epsilon_t$, with a a (5×1) vector and b a (5×5) matrix. When agents know the targeted values, $a = 0$. Agents' perceived law of motion (PLM) is of the following form:

$$A_t = a + b\Omega_t. \tag{22}$$

At the beginning of period t, agents have estimated b_{t-1} using discounted least squares. Then the shocks Ω_t are realized and agents form their expectations from the PLM (22). Thereafter, A_t is generated according to system (20). In t+1, agents update their forecast with their past estimations of a and b, leading them to forecast according to:

$$\hat{E}_t A_{t+1} = a + Fb\Omega_t \tag{23}$$

Subsequently, agents estimate a and b according to the following algorithm:

$$\phi_t = \phi_{t-1} + \gamma R_{t-1}^{-1} z_{t-1}(A_t - \phi'_{t-1} z_{t-1}), \tag{24}$$

$$R_t = R_{t-1} + \gamma(z_t z'_t - R_{t-1}), \tag{25}$$

with γ a small positive constant representing the gain. R_t is an estimate of the second moment of Ω_t. $\phi_t = (a, b)'$ and $z_t = (1, \Omega_t)'$. Using Equations (23) and (20), we get the implied "Actual Law of Motion" (ALM):

$$A_t = (Mb_{t-1}F + \Phi)\Omega_t. \tag{26}$$

At the REE, the matrix b is constant, allowing us to get its equilibrium value $\bar{b}$. From Equations (20) and (23), we obtain the following value for $\bar{b}$:

$$\bar{b} = \Phi(I - MF)^{-1}. \tag{27}$$

In order to study the stability, we have to look at the following system of differential equations:

$$\frac{db}{d\tau} = R^{-1}\sigma_\Omega^2\big\{(MF - I)b + \Phi\big\},$$
$$\frac{dR}{d\tau} = \sigma_\Omega^2 - R.$$

Referring to Evans and Honkapohja (2001), $\bar{b}$ is a globally stable equilibrium point if all the eigenvalues of $(MF - I)$ are inside the unit circle. This is the case in the model, thus, whatever the initial values, $Eb_t \to \bar{b}$ as $t \to \infty$.

3.2 The formation of expectations under commitment

When the monetary policy is committed, there is a lagged vector in the system. Thus, in this framework, agents will observe one additional vector which will change the way they will forecast. Hence, the system becomes:

$$A_t = B + M\hat{E}_t A_{t+1} + NA_{t-1} + \Phi\Omega_t, \tag{28}$$

with N a (5×5) matrix and A_{t-1}, a (5×1) vector. Under commitment the vector of constants is of the following form, $B = (I - M)\bar{A} - \Phi\bar{\Omega}$ and agents' PLM becomes:

$$A_t = a + b\Omega_t + dA_{t-1}. \tag{29}$$

Using discounted least squares, agents will estimate the (5×5) matrices b and d and the (5×1) vector a. As previously, in $t + 1$, they update their forecast, but here with their past estimations of a, b and d. From Equation (29), we have:

$$\hat{E}_t A_{t+1} = (I + d)a + d^2 A_{t-1} + (bd + dF)\Omega_t. \tag{30}$$

Inserting Equation (30) in Equation (28), we obtain the following ALM:

$$A_t = B + M(I + d)a + (Md^2 + N)A_{t-1} + (Mbd + MbF + \Phi)\Omega_t. \tag{31}$$

Agents will estimate the matrices b and d and the vector a. Defining the parameters' matrix $\phi = (a, b, d)'$ and the state variable vector $z_t = (1, A_{t-1}, \Omega_t)'$, the estimation is based on the following recursive least squares algorithm:

$$\phi_t = \phi_{t-1} + \gamma R_{t-1}^{-1} z_{t-1}(A_t - \phi'_{t-1} z_{t-1}), \tag{32}$$

$$R_t = R_{t-1} + \gamma(z_t z'_t - R_{t-1}), \tag{33}$$

From Equations (29) and (30), the REE is defined as the fixed point of:

$$a = T(a) = (I - M - Md)^{-1} B,$$

$$b = T(b) = (I - Md - MdF)^{-1} \Phi,$$

$$d = T(d) = (I - Md)^{-1} N.$$

The mapping from the PLM to the ALM is:

$$T(a,b,d) = \{(I - M - Md)^{-1}B, (I - Md - MdF)^{-1}\Phi, (I - Md)^{-1}N\}.$$

In line with chapter 10 of Evans and Honkapohja (2001), E-stability depends on $DT_d(\bar{d})$ and $DT_d(\bar{b}, \bar{d})$. Proposition 10.1 of Evans and Honkapohja (2001) states that the solution is E-stable if all the eigenvalues of $DT_b(\bar{b})$ an $DT_d(\bar{b}, \bar{d})$ have real parts less than one. Here, we have:

$$DT_d(\bar{d}) = \{(I - M\bar{d})^{-1}N\}' \otimes \{(I - M\bar{d})^{-1}M\}, \tag{34}$$

$$DT_d(\bar{b}, \bar{d}) = F' \otimes \{(I - M\bar{d})^{-1}M\}. \tag{35}$$

Given that, in our framework, all the eigenvalues of (34) and (35) lie inside the unit circle, whatever the initial values, we have $Eb_t \to \bar{b}$ as $t \to \infty$ and $Ed_t \to \bar{d}$ as $t \to \infty$.

4 Calibrations

We are now able to study the dynamics of the system under learning. However, it is necessary to set the values of all parameters. We consider three different calibrations

Table 1: Parameters' value

Parameters	CGG	W	MN
κ	0.075	0.024	0.3
β	0.99	0.99	0.99
φ	4	$(0.157)^{-1}$	0.164

for the rules (11), (12), (13), (19), (15) and (18) which are taken from Clarida, Gali and Gertler (2000) (CGG), Woodford (1999) (W) and McCallum and Nelson (1999) (MN). Notice that we obtain the same results with these three different specifications. In Table 2, we set $\alpha_y = 0.4$ which is a standard value in the literature. We also set

Table 2: Other parameters' value

Parameters	Values
α_y	0.4
α_n	0.4
τ	0.1
μ	0.5
υ	0.03
λ	0.5
ϕ	0.1
δ	0.6
η	0.9

Recall that $F = I\eta$ with I a (5×5) identity matrix and $\Omega_t = F\Omega_{t-1} + \epsilon_t$ is a vector of exogenous shocks.

$\alpha_n = 0.4$ in order to have an harmonized framework. Concerning the parameters τ and μ, we assume that $\mu > \tau$ because the expected exchange rate is the only source of risk in carry trades. Thus investors grant more importance to exchange rate changes than interest rate changes because they are risk averse. Estimating the output gap and the reaction function of New Zealand from 1995 to 2008 with GMM, we find that capital inflows have a significant impact on the output gap (0.03). Thus, we set $\upsilon = 0.03$. The value of λ means that at each period, 50% of the investors can rebalance their portfolio. In line with most of the learning literature e.g. Branch and Evans (2005), Chakraborty and Evans (2008) and Orphanides and Williams (2005a), we set $\gamma = 0.04$. We study here the case of a "constant gain" least squares algorithm. We set $\delta = 0.6$ in line with Chakraborty and Evans (2008).

This calibrated model will be used to investigate the impact of a 5% supply shock on the economy. We also consider a 5% capital inflows shock but only for the exotic case. Notice that we choose T=150 which reflects a little less than 13 years using monthly data.

5 Which monetary policy performs the best?

In this section we investigate how the central bank can either reduce or suppress the vicious circle generated by carry trades. Agents know the true model of the economy, we will investigate later how mistakes in agents' beliefs will influence the economy after a shock.

5.1 Strict and flexible inflation-output targeting

In this framework, we investigate the cases of a central bank engaged either in inflation targeting or flexible inflation-output targeting both under discretion or commitment.

Figure (1) shows how the economy reacts after a supply shock under three different monetary policies. The first thing to note is that our results confirm the vicious circle enhanced by carry trades in a strict inflation-targeting country. An increase in inflation leads the central bank to raise the interest rate which increases the return of carry trades. Given that carry trades are expansionary, the increase in capital inflows brought

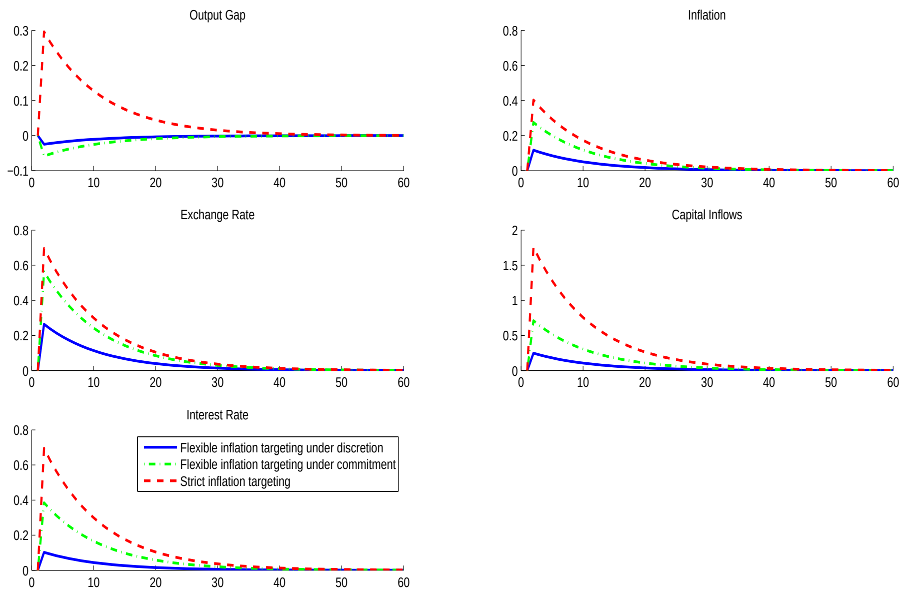

Figure 1: Response to a 5% supply shock

by the higher interest rate will increase inflation and the mechanism just mentioned will re-appear. Keeping in mind that the central bank wants to mitigate the latter vicious circle, the intuition is that reacting to both inflation and the output gap could diminish it.

Hence, we investigate the case of a central bank implementing a flexible inflation-output targeting policy and whether discretion is more efficient than commitment. The first important point is the fact that in all cases the vicious circle generated by carry trades is downplayed when the central bank includes an output gap objective in its loss function. Figure (1) reveals that the vicious circle is minimized when monetary policy is discretionary. Indeed, the interest rate increases less after an increase in inflation, which raises carry trades' returns to a lesser extent. The most important vicious circle appears under commitment, due to the fact that the lagged output gap was higher than the current one. Given that the central bank takes into account this variable under commitment, it means that inflation will be impacted positively by this lagged variable. Thus inflation increases more than under discretion, leading the central bank to raise the interest rate to a larger extent, which makes carry trades more attractive.

We have seen that in the case of strict and flexible inflation-output targeting, a central bank which wants to downplay the vicious circle generated by carry trades has to react to both inflation and the output gap under discretion. However, even if this framework allows the central bank to mitigate the vicious circle, the latter is still present. This has motivated us to investigate the case of a central bank which directly reacts to capital inflows by decreasing the interest rate.

5.2 Flexible inflation-capital targeting

Here, the central bank wants to suppress the vicious circle generated by carry trades by reacting to capital inflows. Thus, we consider a central bank which targets both inflation and capital inflows.

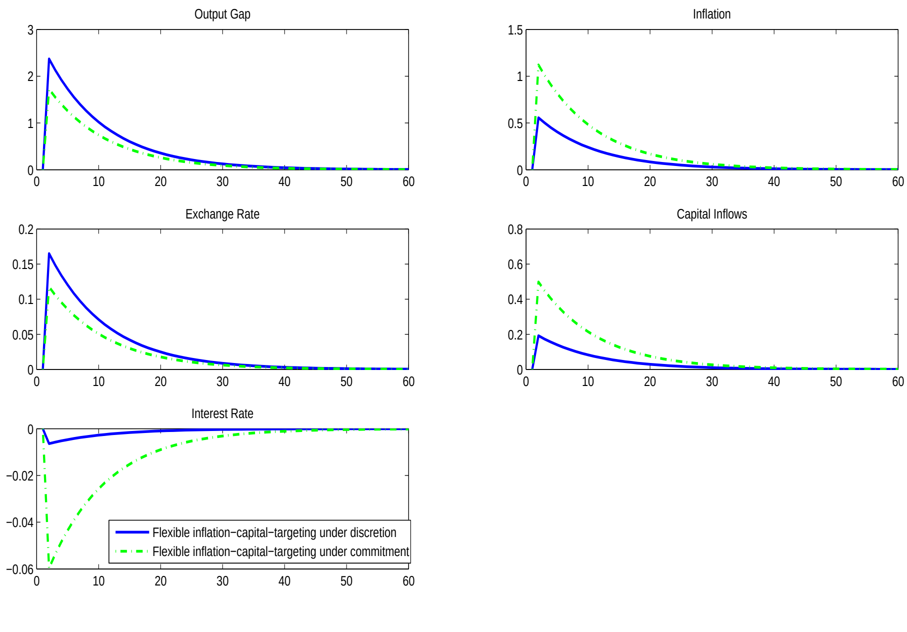

Figure 2: Response to a 5% supply shock

Figure (2) shows that with a flexible inflation-capital targeting policy, the carry trades vicious circle is suppressed both under discretion and commitment. The thing is that after the supply shock, inflation increases, leading agents to expect an increase in the interest rate and capital inflows. At this point, the central bank cuts the interest rate in order to reduce carry trades returns and respect its capital inflows target. That is through this mechanism that monetary authorities are able to suppress the carry trades vicious circle. Notice that under commitment, through the expected increase in capital inflows, capital inflows deviate from the central bank commitment, leading to cut the interest rate to a larger extent.

We can discriminate one of the two policies studied in this section. Given that the inflation objective is crucial for central banks, we consider here that the flexible inflation-capital targeting policy under discretion performs better than the one under commitment. Indeed, thanks to this policy, monetary authorities are able to suppress the carry trades' vicious circle without enlarging inflation too much.

Thanks to Figures (1), and (2), we have identified the most efficient monetary policies either in a standard strict and flexible inflation-output targeting framework or reacting both to inflation and capital inflows. The best way to design monetary policy is a flexible inflation-capital targeting policy under discretion (first-best). However if the central bank wants to keep a standard flexible inflation-output targeting framework it should target both inflation and the output gap under discretion (let us call it "the second best"). In the light of our results, we want to investigate how our "first" and "second best" monetary policies are impacted when agents do not know the long run targets of the economic variables.

6 Central Banks acting secretly

In this section we assume that the central bank does not announce its long run targets. More precisely, it means that agents will forecast the values contained in the vector $(\bar{y}, \bar{\pi}, \bar{s}, \bar{n}, \bar{r})'$. It is well established that central banks announce their inflation targets. However, concerning a flexible inflation-output targeting policy, it is not straightforward to announce the output target. Hence we will investigate how the economy reacts when agents do not know the output target. Thereafter, with a flexible inflation-capital targeting policy, both under discretion (first-best) and commitment, we investigate whether the central bank should announce its long run capital inflows target or not. The following table shows the true values of the long run targets and agents' beliefs.

Table 3: Targeted values

Flexible inflation targeting under discretion	Capital inflows targeting
$\bar{y}_{RE} = 0$	$\bar{n}_{RE} = 0$
$\bar{y}_L = 0.05$	$\bar{n}_L = 0.01$

Table (3) introduces misspecifications in agents beliefs. Under flexible inflation-output targeting agents think that the output gap target is positive instead of being equal to zero. In this case agents think that monetary authorities target a long run positive output gap reflecting a long run objective in growth. Concerning a flexible inflation-capital targeting policy, agents think that the authorities have the same objective in the long run by targeting a positive long run level of capital inflows.

6.1 The "second-best" framework

Figure (3) shows that a secret behavior of the central bank destabilizes the economy in the sense that the vicious circle generated by carry trades is worsened compared to the RE framework. Given that agents believe that there is a positive long run output

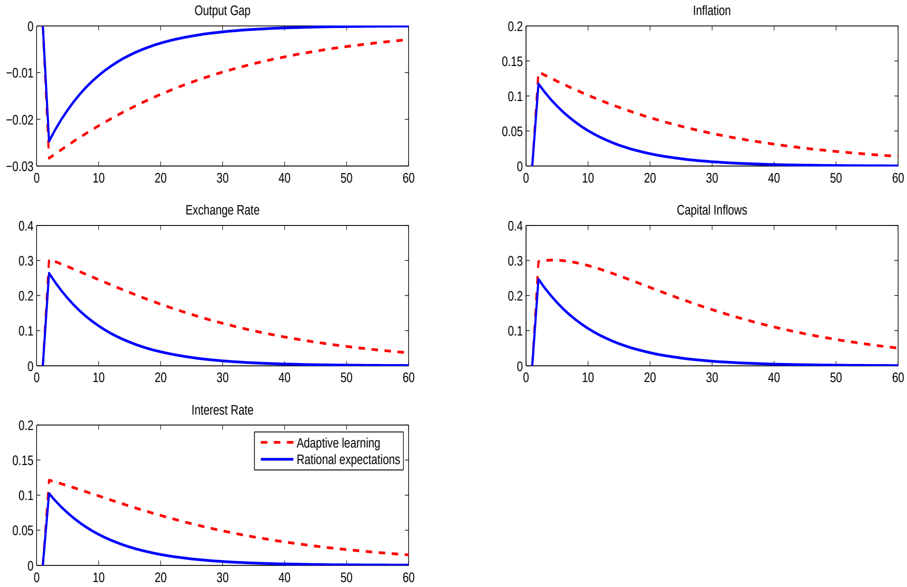

Figure 3: The "second best": secret monetary policy
Response to a 5% supply shock

gap target, they expect a higher inflation, leading to a more aggressive monetary policy, increasing carry trades' returns. Thus, with such a framework, the destabilizing effect of carry trades is worsened and more persistent.

Monetary authorities have to announce their long run output gap target in order to mitigate carry trades' destabilizing effect. We have seen that flexible inflation-capital targeting policies are prone to suppress carry trades vicious circle, we now investigate those policies with misspecifications.

6.2 The "first-best" framework

We consider a flexible inflation-capital targeting policy under discretion with agents overestimating the long run capital inflows target.

Given that agents think that the capital inflows target is positive, they expect an increase in the interest rate. As shown in Figure (4) the way agents behave seriously

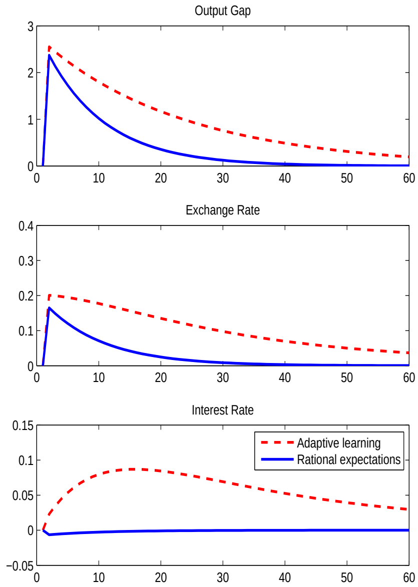

Figure 4: The "first best": secret monetary policy
Response to a 5% supply shock

impacts the economy and the effect of the monetary policy. The increase in the interest rate enlarges carry trades returns leading to capital inflows. With such agents' beliefs, the carry trades' vicious circle usually present with standard monetary policies also appears with a central bank having objectives in terms of capital inflows. Thus, in such a framework, agents' beliefs cancel the positive effect of the monetary policy.

Given that the flexible inflation-capital targeting policy under commitment also suppresses the carry trades' vicious circle, we investigate how misspecifications in agents' beliefs affect the economy in such a framework.

6.3 Flexible inflation-capital targeting under commitment

In this framework agents do not know the long run capital inflows target which lead them to overestimate the impact of the shock on each variable. As presented in Figure (5), the central bank cuts strongly the interest rate in order to suppress carry trades

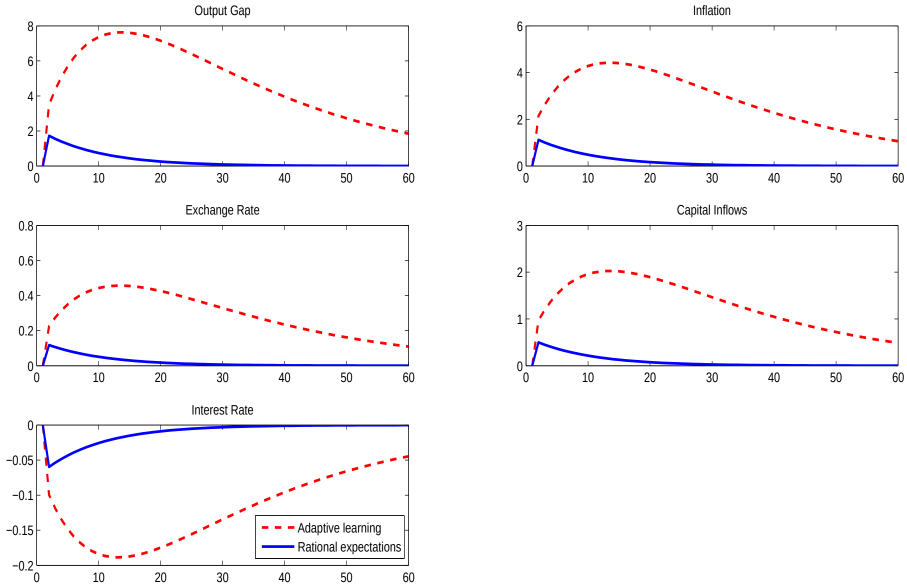

Figure 5: Flexible inflation-capital targeting under commitment: secret monetary policy
Response to a 5% supply shock

vicious circle. Given that agents learn from their past errors, each variable converges to its REE. In such a framework, carry trades vicious circle is also suppressed but the policy becomes highly inflationary which is not desirable. From Figure (5), we can tell that monetary authorities should be transparent concerning their long run target in order to avoid an higher impact of the shock on each economic variable.

This section shows how it is important to keep in mind that agents are not fully rational. The fact that they are econometricians makes the economy to evolve differently, even more when they do not know the steady states.

7 Conclusion

We study the impact of carry trades on the targeted economy. Recall that carry trades destabilize an inflation targeting economy in the sense that capital inflows lead the central bank to raise the interest rate, which increases carry trades' returns and generates further capital inflows. In this paper, we show this to be the case and investigate other monetary policies which could mitigate or suppress this vicious circle.

Through a forward-looking model, we investigate strict inflation targeting and flexible inflation-output targeting under discretion and commitment. We find that flexible inflation-output targeting under discretion is able to mitigate the carry trades' vicious circle. Given that the destabilizing impact of those investments persists, we investigate the case of a central bank which wants to stabilize the economy by targeting both inflation and capital inflows. Our results imply that the best framework to stabilize an economy subject to carry trades is a flexible inflation-capital targeting policy under discretion. Considering non fully rational agents, we then investigate the case of a secret monetary policy in which agents do not know the long run targets. Figures (3), (4) and (5) show that under secrecy, whatever the policy implemented, the economy is destabilized.

The main result obtained is that for an economy subject to carry trades, there are two solutions for the central bank. On the one hand if monetary authorities want to keep a standard framework as strict inflation targeting or flexible inflation-output targeting, they should use a discretionary flexible inflation-output targeting policy, choosing the "second-best" framework. On the other, a flexible inflation-capital targeting policy under discretion totally suppresses the vicious circle, that is the "first-best" monetary policy according to our study.

Large scale monetary expansion (through QE) in large countries leads them to export capital to small open economies which target inflation. To avoid the destabilizing effect of these capital inflows, the small open economies' central banks should seriously take this problem into account while setting their monetary policy. Our recommendation is a flexible inflation-capital targeting policy under discretion announcing the long run capital inflows target.

In this paper we deliberately focus on capital inflows management to suppress the carry trades' vicious circle. Nevertheless the vicious circle could be suppressed by other policies. Thus, further research could investigate how macroprudential policies, exchange rate targeting or taxes could mitigate or suppress the vicious circle presented in our paper.

A Appendix

A.1 The model in level

In such a framework, the model is not in deviation, thus the model is of the form: $A_t - \bar{A} = M(E_t A_{t+1} - \bar{A}) + \Phi(\Omega_t - \bar{\Omega})$, leading to $A_t = B + ME_t A_{t+1} + \Phi\Omega_t$ with $B = (I - M)\bar{A} - \Phi\bar{\Omega}$. In order to calculate the steady states, we have to consider separately Equations (4), (6), (9), (10) and the reaction function corresponding to the studied case. Thus, according to the monetary policy we consider Equations (11), (12), (13), (19), (15) and (18). For example, under a flexible inflation-targeting policy, we rewrite Equations (4), (6), (9), (10) and (12) in level, which allows to obtain:

$$0 = \gamma_g \bar{g} + \gamma_u \bar{u} + \gamma_\omega \bar{\omega}, \tag{36}$$

$$\bar{r} = (\frac{1}{\varphi} - \gamma_g)\bar{g} - \gamma_u \bar{u} - \gamma_\omega \bar{\omega}, \tag{37}$$

$$\bar{r} = -\gamma_g \bar{g} - \gamma_u \bar{u} - (1 + \gamma_\omega)\bar{\omega}, \tag{38}$$

$$\frac{\bar{r}}{a} - \kappa\bar{y} + \phi\bar{s} = -(\kappa\varphi\gamma_g - \kappa + \phi\gamma_g)\bar{g} - (\kappa\varphi\gamma_u + \phi\gamma_u)\bar{u} - (\kappa\varphi\gamma_\omega + \phi\gamma_\omega + \phi)\bar{\omega}, \tag{39}$$

$$\bar{r} + \bar{s} = -\gamma_g \bar{g} - \gamma_u \bar{u} - (1 + \gamma_\omega)\bar{\omega} - \frac{1}{\lambda\sigma\mu}\bar{z}, \tag{40}$$

with $a = \frac{1}{\kappa\varphi + \phi}$. From Equations (37) and (38), $\bar{\omega} = -\frac{1}{\varphi}\bar{g}$. Given that UIP holds in the long run $\bar{\omega} = 0$, leading to $\bar{g} = 0$, and using Equations (36) to $\bar{u} = 0$. Thus, retaking Equations (37) and (38), we get that $\bar{r} = 0$. From the model, we know that in the case of flexible inflation targeting, $\bar{y} = \bar{\pi} = 0$. In addition, with Equations (39) and (40), we can conclude that $\bar{s} = \bar{z} = 0$. Thus we have,

$$\begin{pmatrix} \bar{y} \\ \bar{\pi} \\ \bar{s} \\ \bar{n} \\ \bar{r} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

We use the same methodology for each type monetary policy. The constant terms are zero in all cases because UIP holds in the long run.

A.2 Strict inflation targeting

$$\begin{pmatrix} y_t \\ \pi_t \\ s_t \\ n_t \\ r_t \end{pmatrix} = \begin{pmatrix} 1-\varphi\psi\kappa & \varphi(1-\psi\varphi(\beta+\kappa\varphi-1)) & \varphi\psi\delta\phi & \upsilon-\varphi\psi\kappa\upsilon & 0 \\ \kappa(1-\varphi\psi\kappa-\phi\varphi) & \beta+\kappa\varphi(1-\psi(\beta+\kappa\varphi-1) & \phi\delta(\kappa\varphi\psi-1-\psi\phi) & \kappa\upsilon(1-\varphi\psi\kappa-\phi\psi) & 0 \\ \psi\kappa & \psi(\beta+\kappa\varphi-1) & \delta(1-\psi\phi) & \phi\kappa\upsilon & 0 \\ \lambda\sigma\mu\psi\kappa & \lambda\sigma\mu\psi(\beta+\kappa\varphi-1) & \lambda\sigma\mu(\delta-\delta\psi\phi-1) & \sigma(1+\lambda\mu\kappa\upsilon) & -\lambda\sigma\tau \\ \psi\kappa & \psi(\beta+\kappa\varphi-1) & \delta(1-\psi\phi) & \psi\kappa\upsilon & 0 \end{pmatrix} \begin{pmatrix} E_t y_{t+1} \\ E_t \pi_{t+1} \\ E_t s_{t+1} \\ E_t n_{t+1} \\ E_t r_{t+1} \end{pmatrix}$$

$$+ \begin{pmatrix} 1-\varphi\psi\kappa & -\varphi\psi & \varphi\psi\phi & 0 & 0 \\ \kappa(1-\kappa\varphi\psi)-\phi\psi & 1 & \phi(\kappa\varphi\psi-1+\psi\phi) & 0 & 0 \\ \kappa\psi & \psi & 1-\psi\phi & 0 & 0 \\ \kappa\lambda\sigma\mu\psi & \lambda\sigma\mu\psi & \lambda\sigma\mu(1-\psi\phi) & 1 & 0 \\ \kappa\psi & \psi & -\psi\phi & 0 & 0 \end{pmatrix} \begin{pmatrix} g_t \\ u_t \\ \omega_t \\ z_t \\ q_t \end{pmatrix}$$

A.3 Flexible inflation targeting under discretion

$$
\begin{pmatrix} y_t \\ \pi_t \\ s_t \\ n_t \\ r_t \end{pmatrix}
=
\begin{pmatrix}
\zeta\iota & -\frac{\beta\kappa}{\varphi(\alpha+\kappa^2)}\big(1-\zeta\iota\big) & \varphi\zeta\delta\iota & \upsilon\zeta\iota & 0 \\
\kappa\zeta\iota - \frac{\phi\iota}{\varphi} & \beta - (1-\zeta\iota)\frac{\beta\kappa^2}{\alpha+\kappa^2} - \phi\iota\big(1+\frac{\beta\kappa}{\alpha+\kappa^2}\big) & \iota\delta(\kappa\varphi\zeta - \phi) & \upsilon\iota\big(\kappa\zeta - \frac{\phi}{\varphi}\big) & 0 \\
\frac{\iota}{\varphi} & \iota\big(1+\frac{\beta\kappa}{\varphi(\alpha+\kappa^2)}\big) & \iota\delta & \frac{\iota\upsilon}{\varphi} & 0 \\
\frac{\lambda\sigma\mu\iota}{\varphi} & \lambda\sigma\mu\iota\big(1+\frac{\beta\kappa}{\varphi(\alpha+\kappa^2)}\big) & \lambda\sigma\mu(\delta\iota - 1) & \sigma\big(1+\frac{\lambda\mu\iota\upsilon}{\varphi}\big) & -\lambda\sigma\mu\tau \\
\frac{1}{\varphi}(1-\iota\zeta) & 1+\frac{\kappa\beta}{\varphi(\alpha+\kappa^2)}(1-\iota\zeta) & -\iota\zeta\delta & \frac{\upsilon}{\varphi}(1-\iota\zeta) & 0
\end{pmatrix}
\begin{pmatrix} E_t y_{t+1} \\ E_t \pi_{t+1} \\ E_t s_{t+1} \\ E_t n_{t+1} \\ E_t r_{t+1} \end{pmatrix}
$$

$$
+
\begin{pmatrix}
\iota\zeta & (\iota\zeta - 1)\frac{\kappa}{\alpha+\kappa^2} & \varphi\iota\zeta & 0 & 0 \\
\kappa\zeta\iota - \frac{\phi\iota}{\varphi} & 1 - \kappa(1-\zeta\iota) - \frac{\phi\iota\kappa}{\varphi(\alpha+\kappa^2)} & \iota(\kappa\varphi\zeta - \phi) & 0 & 0 \\
\frac{\iota}{\varphi} & \frac{\iota\kappa}{\varphi(\alpha+\kappa^2)} & \iota & 0 & 0 \\
\frac{\iota\lambda\sigma\mu}{\varphi} & \frac{\iota\lambda\sigma\mu\kappa}{\varphi(\alpha+\kappa^2)} & \lambda\sigma\mu\iota & 1 & 0 \\
\frac{1}{\varphi}(1-\iota\zeta) & \frac{\kappa}{\varphi(\alpha+\kappa^2)}(1-\iota\zeta) & -\iota\zeta & 0 & 0
\end{pmatrix}
\begin{pmatrix} g_t \\ u_t \\ \omega_t \\ z_t \\ q_t \end{pmatrix}
$$

A.4 Flexible inflation targeting under commitment

We just add one lagged vector and one matrix of parameters to the optimal monetary policy under discretion.

$$\begin{pmatrix} \frac{(\zeta\iota-1)\kappa}{\alpha+\kappa^2} & 0 & 0 & 0 & 0 \\ \frac{\phi\iota\alpha}{\varphi(\alpha+\kappa^2)} - \frac{\kappa^2(1-\zeta\iota)}{\alpha+\kappa^2} & 0 & 0 & 0 & 0 \\ -\frac{\iota\alpha}{\varphi(\alpha+\kappa^2)} & 0 & 0 & 0 & 0 \\ -\frac{\zeta\lambda\sigma\mu\alpha}{\varphi(\alpha+\kappa^2)} & 0 & 0 & 0 & 0 \\ (\iota\zeta-1)\frac{\iota\alpha}{\varphi(\alpha+\kappa^2)} & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} y_{t-1} \\ \pi_{t-1} \\ s_{t-1} \\ n_{t-1} \\ r_{t-1} \end{pmatrix}$$

A.5 Strict capital inflows targeting

$$\begin{pmatrix} y_t \\ \pi_t \\ s_t \\ n_t \\ r_t \end{pmatrix} = \begin{pmatrix} 1 & \varphi & \varphi(\delta-1) & -\frac{\varphi(\alpha-\sigma)}{\lambda\sigma\mu} & -\frac{\varphi\tau}{\mu} \\ \kappa & \kappa\varphi+\beta & \kappa\varphi(1-\delta)+\phi & -\frac{\phi-(\alpha-\sigma)(1+\kappa\varphi)}{\lambda\sigma\mu} & -\frac{\kappa\varphi\tau+\phi\tau}{\mu} \\ 0 & 0 & 1 & \frac{\alpha-\sigma}{\lambda\sigma\mu} & \frac{\tau}{\mu} \\ 0 & 0 & 0 & \frac{\alpha-\sigma}{\lambda\sigma\mu}+\sigma & \frac{\tau}{\mu} \\ 0 & 0 & 1-\delta & \frac{\alpha-\sigma}{\lambda\sigma\mu} & \frac{\tau}{\mu} \end{pmatrix} \begin{pmatrix} E_t y_{t+1} \\ E_t \pi_{t+1} \\ E_t s_{t+1} \\ E_t n_{t+1} \\ E_t r_{t+1} \end{pmatrix}$$

$$+ \begin{pmatrix} 1 & 0 & \varphi & \frac{\varphi}{\lambda\sigma\mu} & 0 \\ \kappa & 1 & \kappa\varphi & \frac{\kappa\varphi+\phi}{\lambda\sigma\mu} & 0 \\ 0 & 0 & 1 & -\frac{1}{\lambda\sigma\mu} & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & -1 & -\frac{1}{\lambda\sigma\mu} & 0 \end{pmatrix} \begin{pmatrix} g_t \\ u_t \\ \omega_t \\ z_t \\ q_t \end{pmatrix}$$

A.6 Flexible capital inflows targeting under discretion

Recall:

$$A_t = ME_tA_{t+1} + \Phi\Omega_t$$

With M, the 5×5 matrix:

$$\begin{pmatrix}
1 - \frac{\varphi\chi\alpha\kappa}{\sigma} & \varphi\left(1 - \chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right)\right) & -\varphi\chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right) & \upsilon - \varphi\chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \sigma\right) & -\varphi\chi\sigma\tau \\
\kappa - \frac{\chi\alpha\kappa}{\sigma}(\kappa\varphi + \phi) & \beta + \kappa\left(\varphi - \varphi\chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right)\right) - \phi\chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right) & \left(\frac{\alpha\phi\delta}{\sigma} - \lambda\sigma\mu\right)(\kappa\varphi\chi + \phi\chi) - \phi\delta & \kappa\upsilon + \left(\sigma - \frac{\alpha\kappa\upsilon}{\sigma}\right)(\kappa\varphi\chi + \phi\chi) & -\kappa\varphi\chi\sigma\tau - \phi\chi\sigma\tau \\
\frac{\chi\alpha\kappa}{\sigma} & \chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right) & \delta + \chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right) & \chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \sigma\right) & \chi\sigma\tau \\
\lambda\alpha\chi\kappa & \lambda\chi(\alpha\kappa\varphi + \alpha\beta) & \lambda\sigma\delta + \lambda\sigma\chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right) - \lambda\sigma\mu & \sigma + \lambda\sigma\chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \sigma\right) & \lambda\sigma^2\chi\tau - \lambda\sigma\tau \\
\frac{\chi\alpha\kappa}{\sigma} & \chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right) & \chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right) & \chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \upsilon\right) & \lambda\sigma\tau
\end{pmatrix}$$

And Φ the 5×5 matrix:

$$\begin{pmatrix}
1 - \frac{\varphi\chi\alpha\kappa}{\sigma} & -\frac{\varphi\chi\alpha}{\sigma} & \varphi\chi\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right) & \varphi\chi & 0 \\
\kappa\left(1 - \frac{\kappa\varphi\chi\alpha+\phi\alpha\chi\kappa}{\sigma}\right) & 1 - \frac{\kappa\varphi\chi\alpha+\phi\chi\alpha}{\sigma} & (\phi\chi + \kappa\varphi\chi)\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right) & 0 & 0 \\
\frac{\chi\alpha\kappa}{\sigma} & \frac{\chi\alpha}{\sigma} & 1 - \chi\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right) & -\chi & 0 \\
\lambda\chi\alpha\kappa & \lambda\chi\alpha & \lambda\sigma\left(1 - \chi(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu)\right) & 1 - \lambda\sigma\chi & 0 \\
\frac{\chi\alpha\kappa}{\sigma} & \frac{\chi\alpha}{\sigma} & -\chi\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right) & -\chi & 0
\end{pmatrix}$$

A.7 Flexible capital inflows targeting under commitment

Recall:

$$A_t = ME_tA_{t+1} + NA_{t-1} + \Phi\Omega_t$$

With M, the 5×5 matrix:

$$\begin{pmatrix} 1 - \frac{\varphi\chi\alpha\kappa}{\sigma} & \varphi\left(1 - \chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right)\right) & -\varphi\chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right) & \upsilon - \varphi\chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \sigma\right) & -\varphi\chi\sigma\tau \\ \kappa - \frac{\chi\alpha\kappa}{\sigma}(\kappa\varphi + \phi) & \beta + \kappa\left(\varphi - \varphi\chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right)\right) - \phi\chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right) & \left(\frac{\alpha\phi\delta}{\sigma} - \lambda\sigma\mu\right)(\kappa\varphi\chi + \phi\chi) - \phi\delta & \kappa\upsilon + \left(\sigma - \frac{\alpha\kappa\upsilon}{\sigma}\right)(\kappa\varphi\chi + \phi\chi) & -\kappa\varphi\chi\sigma\tau - \phi\chi\sigma\tau \\ \frac{\chi\alpha\kappa}{\sigma} & \chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right) & \delta + \chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right) & \chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \sigma\right) & \chi\sigma\tau \\ \lambda\alpha\chi\kappa & \lambda\chi(\alpha\kappa\varphi + \alpha\beta) & \lambda\sigma\delta + \lambda\sigma\chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right) - \lambda\sigma\mu & \sigma + \lambda\sigma\chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \sigma\right) & \lambda\sigma^2\chi\tau - \lambda\sigma\tau \\ \frac{\chi\alpha\kappa}{\sigma} & \chi\left(\frac{\alpha\kappa\varphi+\alpha\beta}{\sigma}\right) & \chi\left(\lambda\sigma\mu - \frac{\alpha\phi\delta}{\sigma}\right) & \chi\left(\frac{\alpha\kappa\upsilon}{\sigma} - \upsilon\right) & \lambda\sigma\tau \end{pmatrix}$$

Φ the 5×5 matrix:

$$\begin{pmatrix} 1 - \frac{\varphi\chi\alpha\kappa}{\sigma} & -\frac{\varphi\chi\alpha}{\sigma} & \varphi\chi\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right) & \varphi\chi & 0 \\ \kappa\left(1 - \frac{\kappa\varphi\chi\alpha+\phi\alpha\chi\kappa}{\sigma}\right) & 1 - \frac{\kappa\varphi\chi\alpha+\phi\chi\alpha}{\sigma} & (\phi\chi + \kappa\varphi\chi)\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right) & 0 & 0 \\ \frac{\chi\alpha\kappa}{\sigma} & \frac{\chi\alpha}{\sigma} & 1 - \chi\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right) & -\chi & 0 \\ \lambda\chi\alpha\kappa & \lambda\chi\alpha & \lambda\sigma\left(1 - \chi(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu)\right) & 1 - \lambda\sigma\chi & 0 \\ \frac{\chi\alpha\kappa}{\sigma} & \frac{\chi\alpha}{\sigma} & -\chi\left(\frac{\phi\alpha}{\sigma} + \lambda\sigma\mu\right) & -\chi & 0 \end{pmatrix}$$

And N the 5×5 matrix:

$$\begin{pmatrix} 0 & 0 & 0 & -\varphi\chi & 0 \\ 0 & 0 & 0 & -\kappa\varphi\chi - \phi\chi & 0 \\ 0 & 0 & 0 & \chi & 0 \\ 0 & 0 & 0 & \lambda\sigma\mu\chi & 0 \\ 0 & 0 & 0 & \chi & 0 \end{pmatrix}$$

References

Blake, A.P. 2012, “Determining optimal monetary speed limits,” *Economics Letters* 116. 269-271.

Branch, W.A. and Evans, G.W. 2005, “A Simple Recursive Forecasting Model,” *Economic Letter* 91. 158-166.

Bullard, J. and Kaushik, M. 2002, “Learning about Monetary Policy Rules,” *Journal of Monetary Economics* 49. 1105-1129.

Burnside, G., Eichenbaum, M. and Rebelo, S. 2011, “Carry Trade and Momentum in Currency Markets,” *The Annual Review of Financial Economics* 3. 511-535.

Burnside, G., Eichenbaum, M., Kleshchelski, I. and Rebelo, S. 2006, “The Returns to Currency Speculation,” *NBER Working Paper* 12489.

Burnside, G., Eichenbaum, M. and Rebelo, S. 2007, “The Returns to Currency Speculation in Emerging Markets,” *The American Economic Review* 97. 2. 333-338

Chakraborty, A. and Evans, G.W. 2008, “Can Perpetual Learning Explain the Forward-Premium Puzzle?,” *Journal of Monetary Economics* 55. 477-490.

Clarida, R., Gali, J. and Gertler, M. 2002, “A Simple Framework for Monetary Policy Analysis,” *Journal of Monetary Economics* 49. 879-904

Clarida, R., Gali, J. and Gertler, M. 2000, “Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory,” *Quarterly Journal of Economics* 115. 147-180

Clarida, R., Gali, J. and Gertler, M. 1999, “The Science of Monetary Policy: A New Keynesian Perspective,” *Journal of Economic Literature* 37. 1661-1707

Evans, G.W. and Honkapohja, S. 2006, “Monetary Policy, Expectations and Commitment,” *The Scandinavian Journal of Economics* 108. 1. 15-38

Evans, G.W. and Honkapohja, S. 2003a, “Adaptive learning and monetary policy design,” *Journal of Money, Credit and Banking* 35. 1045-1072.

Evans, G.W. and Honkapohja, S. 2002, “Monetary Expectations and Commitment,” *ECB Working Paper* 124.

Evans, G.W. and Honkapohja, S. 2001, “Learning and Expectations in Macroeconomics,” *Princeton University Press.*

Fama, E.F. 1984, “Forward and spot exchange rates,” *Journal of Monetary Economics* 14. 319-338.

IMF Staff, prepared by the Strategy, Policy and Review Department. 2013, “Guidance Note for the Liberalization and Management of Capital Inflows,” *International Monetary Fund*, April.

IMF Staff. 2014, “New Zealand,” *IMF Country Report*, 14/158.

McCallum, B.T. and Nelson, E. 1999, “Performance of Operational Policy Rules in an Estimated Semi-Classical Model,” *NBER Chapters in: Monetary Policy Rules* 15-56 National Bureau of Economic Research, Inc.

Orphanides, A. and Williams, J.C. 2005a, “The Decline of Activist Stabilization Policy: Natural Rate of Misperceptions, Learning and Expectations” *Journal of Economic Dynamics and Control*, 29. 11. 1927-1950.

Orphanides, A. and Williams, J.C. 2005b, “Monetary Policy with Imperfect Knowledge,” *Finance and Economics Discussion Series*, 51.

Ostry J.D. 2012, “Managing Capital Inflows: What Tools to Use,” *Asian Development Review*, 29. 1. 82-88.

Plantin, G. and Shin, H.C. 2011, “Carry Trades, Monetary Policy and Speculative Dynamics,” *CEPR Discussion Papers*, 8224.

Svensson, L.E.O. 1997a,“Inflation Forecast Targeting: Implementing and Monitoring Inflation Targets,” *European Economic Review*, 41. 1111-1146

Walsh, C.E. 2003, “The Output Gap and Optimal Monetary Policy” *The American Economic Review* 93. 1. 265-278.

Woodford, M. 2013, “Macroeconomic Analysis Without the Rational Expectations Hypothesis,” *Annual Review of Economics*, 5. 303-346.

Woodford, M. 2003, “Interest and Prices: Foundations of a Theory of Monetary Policy,” *Princeton University Press.*

Woodford, M. 1999, “Optimal Monetary Policy Inertia,” *The Manchester School, Supplement*, 67. 1-35