Adaptive Learning, Monetary Policy and Carry Trades

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February 2016

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. 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 (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

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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.

Carry trades are investments which involve borrowing a low-return currency in order to invest in a high-return one. Jonsson (2009) describes well the fact that in small open economies, increasing interest rates (particularly when the interest rate is above the one in other countries) during expansionary periods will attract capitals which will appreciate the exchange rate and lead to a false wealth effect. In other words, inflation targeting policies in small open economies can destabilize a country subject 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 given that there aim is not to act on the foreign exchange market, 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. Hence, we focus on the short run interest rate as the tool used by the central bank to stabilize the economy. Obviously, other policies could act on the above mentioned vicious circle as e.g. capital control, taxes on the foreign exchange market, exchange rate targeting among others but we leave such investigations for further research.

Carry trades' strategies are widely investigated in macroeconomics and involve investments which seem less risky than usual financial operations. Burnside et al (2006) 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. Indeed as reported in Jonsson (2009); Plantin and Shin (2016), 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 profitable only if uncovered interest parity (UIP) does not hold. Fama (1984) has shown that UIP does not hold in the short run.

One of the findings of Plantin and Shin (2016) is 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. Notice that we assume that the foreign country (a large economy) is at the zero lower bound by setting its interest exogenously and equals to zero. We begin with a strict inflation targeting policy (benchmark) which is, as mentioned before, favorable to the carry trades vicious circle. Thereafter, we study 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 considering monetary authorities which have both an inflation and a capital inflows target. More precisely, with such a policy, the central bank will minimize the spreads between inflation and capital inflows and their targets. 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 the targeted variables. In such a case, agents know which framework the central bank uses to implement its monetary policy but ignore the long run targets of the central bank.

Our results imply that two monetary policy designs better perform. 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 2.2 presents the model. In section 2.3, we introduce a secret behavior of the central bank. Section 2.4 is devoted to the calibration of the model. Section 2.5 and 2.6 present the results with a transparent and a secret monetary policy respectively. Section 2.7 investigates statistically how carry trades affect different inflation targeting countries. Section 2.8 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. Denoting F_t the forward rate and $E_t s_{t+1}$, the expected exchange rate, combining covered interest parity (CIP: $(1+r_t) = (1+r_t^*)\frac{F_t}{s_t}$) 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^2_ω. We rewrite our parity condition in log which gives:

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

Given that the foreign country is assumed to be engaged in quantitative easing, the foreign interest rate is set to its zero lower bound[1] ($r^*_t = 0$), then from Equations (2) and (3), we obtain the following exchange rate equation:

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

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

We introduce a friction in the financial markets by assuming that investors are not able to rebalance their portfolio at each period. Then, similarly to Plantin and Shin (2016)

[1] For simplicity, we include quantitative easing by assuming that the foreign interest rate is equal to zero. This assumption reflects well the zero lower bound reached by the foreign interest rate but do not account for the liquidity's injection. A model which includes the liquidity injection enhanced by QE would allow to analyze the impact of the increasing liquidity in the foreign country during QE. Our aim here is to focus on the inflation targeting country, thus our assumption is not too strong concerning the impact of carry trades on the domestic economy.

changes in capital inflows depend on the rate at which investors can rebalance their portfolio (λ). Notice that here $\lambda \in]0;1[$ is a constant, meaning that at each period there is a constant fraction of investors who are able to rebalance their portfolio. Expected changes in capital inflows also depend on 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. The assumption of a constant λ refers to the fact that investors are not able to rebalance their positions at each period. This assumption is realistic in the sense that carry trades can be done through forward contracts which fix a future date at which the investor will have to close its position (in the meantime, the investor would not be able to close it). 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 expected 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, we observe a negative effect of $\lambda\sigma(\tau E_t r_{t+1} + \mu E_t s_{t+1})$ which is linked to carry trades reversal. More precisely, the more investors take long positions on the domestic currency (the more $(\tau E_t r_{t+1} + \mu E_t s_{t+1})$is high), the less capital inflows will increase because investors expect future short positions on the domestic currency. 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 targeted inflation[2] ($\bar{\pi} = 0$). 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:

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

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

In Equation (9) expected capital inflows ($E_t n_{t+1}$) enhance growth. Such an assumption is line with Jonsson (2009) in the sense that capital inflows are expansionary by allowing to borrow cheap and lend more expensively. Such a relation is present when the expected exchange rate appreciates. Notice that g_t and u_t represent shocks which increase the output gap and inflation respectively, they both follow an AR(1) process. 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.

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

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 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 $E_t \pi_{t+i} = \bar{\pi}$. 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,

$$\gamma_\pi = \psi(\beta + \kappa\varphi - 1); \qquad \gamma_u = \psi;$$

$$\gamma_n = \varphi\kappa\upsilon; \qquad \gamma_y = \gamma_g = \psi\kappa;$$

$$\gamma_s = \psi\phi\delta; \qquad \gamma_\omega = -\psi\phi;$$

$$\psi = \frac{1}{\phi + \kappa\varphi}.$$

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, $y_t = -\frac{\kappa}{\alpha_y}\pi_t$ and $\pi_t = -\frac{\alpha_y}{\kappa}y_t$, 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,

$$\gamma_\pi = (1-\zeta)\left(1 + \frac{\kappa\beta}{\varphi(\alpha+\kappa^2)}\right); \qquad \gamma_u = \frac{\kappa}{\varphi(\alpha+\kappa^2)}(1-\zeta);$$

$$\gamma_n = \frac{\upsilon}{\varphi}(1-\zeta); \qquad \gamma_y = \gamma_g = \frac{1}{\varphi}(1-\zeta);$$

$$\gamma_s = -\zeta\delta; \qquad \gamma_\omega = -\zeta;$$

$$\zeta = \frac{\phi\kappa}{\varphi(\alpha+\kappa^2)+\phi\kappa}.$$

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 framework the central bank announces its aim in terms of output gap. Thus if the monetary authorities want to be credible, they have to honor their past promises. That is why, we include the lagged output gap (y_{t-1}). 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:

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

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 both to 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 $\pi_t = \frac{\sigma}{\alpha}n_t$. Thereafter, we have to rewrite Equation (6) in order to introduce the variable n_t in Equation (10):

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

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:

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

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 $E_t n_{t+i} = \bar{n}$. Using the FOC and Equations (4) and (6), we obtain 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[3].

[3] 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.

3 Introducing a changing behavior of the central bank

Here we consider the case in which agents think that the central bank changes its behavior. We can think of the arrival of a new governor which leads agents to think that the long run objectives of the central bank will change. In such a case agents will ignore the long run targets of the central bank. More precisely agents will have to estimate the long run values of the output gap and 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 2.8.2, 2.8.3, 2.8.5 and 2.8.6. 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, A_t is a (5×1) vector containing the endogenous variables of the model ($A_t = (y_t, \pi_t, s_t, x_t, r_t)'$), M and Φ are (5×5) matrices of parameters and

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

With Ω_t a (5×1) vector of shocks which is defined as an AR(1) process. It clearly follows that Ω_{t-1} and ϵ_t are (5×1) vectors. F is a (5×5) matrix where $F = I\eta$ with I the identity matrix and $\eta \in]0;1[$. Then η represents the parameters in the diagonal of matrix F with all these parameters equal to 0.9. We could choose different values for these parameters but we assume that they are equal for simplicity. B is a (5×1) vector of constants, with $B = (I - M)\bar{A} - \Phi\bar{\Omega}$. The vector of constants 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):

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

The mapping from the PLM to the ALM is:

$$T(a, b) = (B + Ma,\ MFb + \Phi), \tag{27}$$

Thus, the E-stability is determined by the following differential equation:

$$\frac{da}{d\tau} = B + (M - I)a,$$
$$\frac{db}{d\tau} = \Phi + (MF - I)b.$$

Referring to Evans and Honkapohja (2001), $(\bar{a},\ \bar{b})$[4] is a globally stable equilibrium point if all the eigenvalues of M and MF are inside the unit circle. This is the case in the model, thus, whatever the initial values, $E(a_t,\ b_t) \rightarrow (\bar{a},\ \bar{b})$ as $t \rightarrow \infty$.

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, $B = (I - M - N)\bar{A} - \Phi\bar{\Omega}$ 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:

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

[4] Notice that here the rational expectation equilibrium is defined as follows: $\bar{a} = (I - M)^{-1}B$ and $\bar{b} = (I - MF)\Phi$.

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

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

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:

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

$$b = T(b) = (I - Mdb - MF)^{-1}\Phi,$$

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

The mapping from the PLM to the ALM is:

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

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:

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

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

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 quasi similar results with these three different specifications, the results reported in this paper are based on the CGG calibration. In Table 2, we 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.

$\alpha_y = 0.4$ which is a standard value in the literature. We also set $\alpha_n = 0.4$ 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% inflation shock on the economy with each monetary policy framework. We simulate such a shock because in a small open economy targeting inflation, the carry trades vicious circle appears after an increase in inflation. Considering the monetary policies targeting capital inflows, we also consider a 5% capital inflows shock, which reflects an increase in carry trades[5]. 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]We do not present the IRF because it does not reveal more evidence than before. However, the results are available upon request and a subsection is devoted to the economic explanation of such 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.

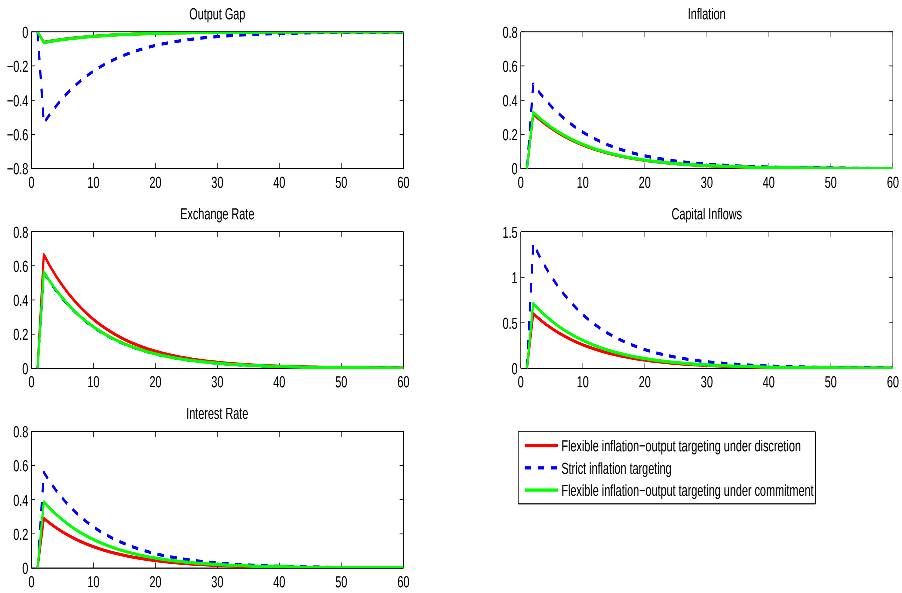

Figure 1 – Response to a 5% inflation shock

Figure (1) shows how the economy reacts after an inflation shock under three different monetary policies. 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 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. 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 the 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 both to 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 carry trades' vicious circle reacting to capital inflows. Thus, we consider a central bank which targets both inflation and capital inflows.

Figure (2) shows that with a flexible inflation-capital targeting policy, the carry trades vicious circle is suppressed both under discretion and commitment. After the 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. Through this mechanism monetary authorities are able to suppress the carry trades' vicious circle. Notice that under com-

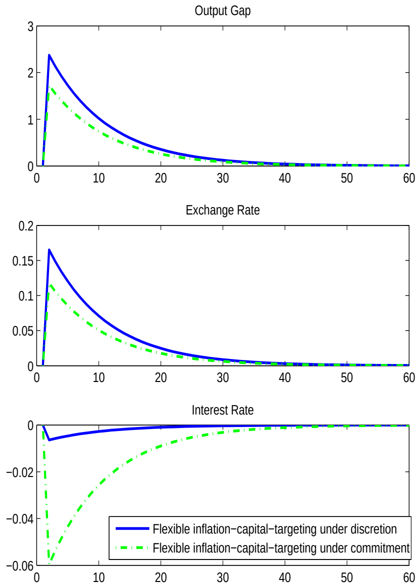

Figure 2 – Response to a 5% inflation shock

mitment, 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 following section we go further in the comparison of the monetary policies by plotting all the policies on the same graphic.

5.3 Further insights on monetary policies

Figure (3) allows to compare all the policies on the same graphic. Such an analysis helps to better understand how the shock impacts the economy according to the monetary policy framework. In order to see clearly the differences between monetary policies, we simulate an inflation shock on ten periods. Figure (3) clearly reveals a trade-off

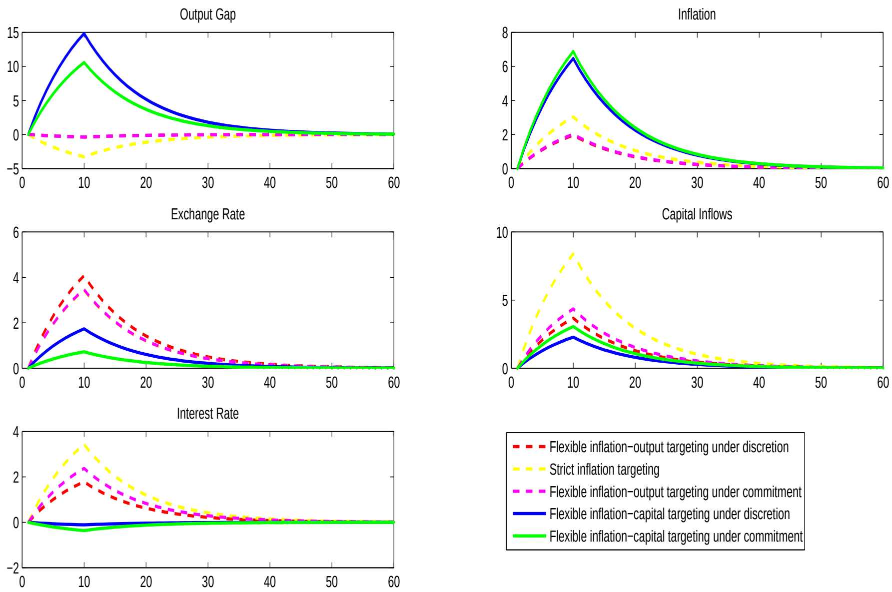

Figure 3 – Response to a 5% inflation shock

between inflation and capital inflows. A flexible inflation-output targeting policy leads to carry trades and further capital inflows. However, targeting inflation and capital inflows suppresses the carry trades vicious circle but is everytime more inflationary than a flexible inflation-output targeting policy. The aim of this paper is to find a monetary policy able to suppress the carry trades' vicious circle, thus we still consider the flexible inflation-capital targeting policy under discretion as the first-best. For the moment, we have shown which monetary policy is the most efficient regarding carry trades' vicious circle brought by an increase in inflation. We now consider an increase in capital inflows in the case of central banks targeting inflation.

5.4 Increasing carry trades

Concerning flexible inflation-capital targeting policies, we also investigate what happens after a 5% capital inflows shock, revealing a direct increase in carry trades. This investigation clearly reveals that the discretionary flexible inflation-capital policy also suppresses the carry trades vicious circle after such a shock[6]. After an increase in carry trades, with the first-best policy, the central bank is still able to avoid the carry trades' vicious circle.

As mentioned previously, we also consider the exotic case of a strict capital inflows targeting policy. This kind of policy could exist in a small open economy hit by a financial crisis. Such a policy suppresses the carry trades' vicious circle but is hugely inflationary. We now consider an economy in which agents do not know the level of the variables that the central bank targets. Introducing such a misspecification allows to investigate how agents beliefs affect the efficiency of the monetary policies.

5.5 Changing behavior of central banks

In this section we assume that agents think that the central bank has changed its long run targets. More precisely, it means that agents will forecast the values contained in the vector $(\bar{y}, \bar{\pi}, \bar{s}, \bar{n}, \bar{r})'$. Several central banks clearly announce their inflation targets, but in some cases the target is between a range of values or not clearly announced. Moreover, concerning a flexible inflation-output targeting policy, it is not straightforward to announce the output target. It is also possible that agents do not know the long run

[6]The IRF are not presented here but available upon request.

targets of the central bank when a new governor arrives or when agents do not trust monetary authorities. 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
$\bar{\pi}_{RE} = 0$	$\bar{y}_{RE} = 0$	$\bar{n}_{RE} = 0$
$\bar{\pi}_{L} = 0.05$	$\bar{y}_{L} = 0.05$	$\bar{n}_{L} = 0.01$

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. Thus, with such a belief agents also think that the central bank has a higher inflation target. Indeed, thinking that the central bank has a higher objective in growth, agents obviously expect the central bank to react less strongly to inflation in order to let growth increase. 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[7].

5.5.1 The "second-best" framework

Figure (4) shows that when agents do not know the long run targets of the central bank it destabilizes the economy in the sense that the vicious circle generated by carry trades is worsened compared to the RE framework. Such an overestimation of the

[7] Such a policy could be considered by agents in small open economies which suffer from a lack of domestic saving.

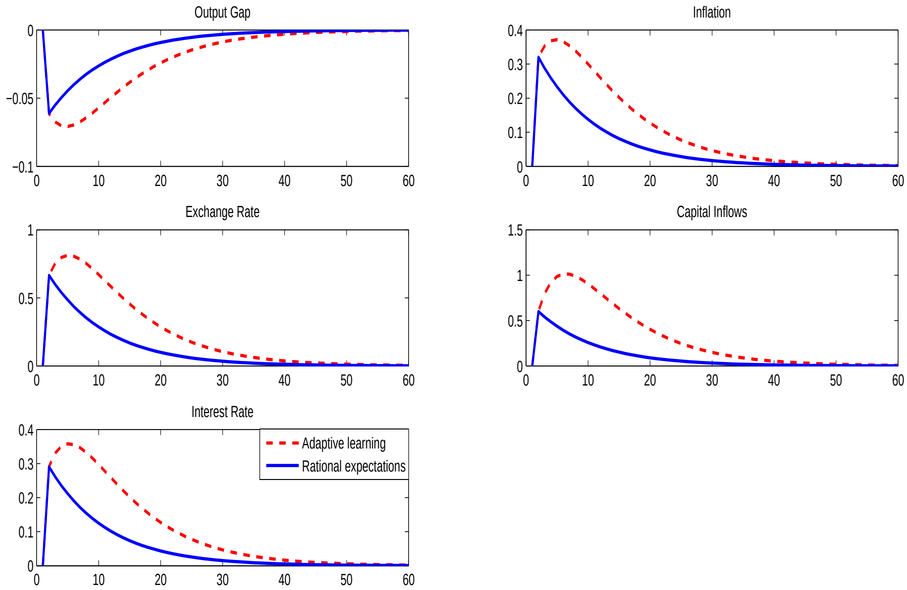

Figure 4 – Response to a 5% supply shock
Agents have wrong beliefs about inflation and the output gap

inflation shock can be explained in two steps. Given that agents think that both the inflation and output gap targets are higher, they believe that the central bank will react less strongly to inflation which lead them to overestimate the impact of the inflation shock on inflation itself. Hence, inflation increases more after the shock. Then, agents observe that inflation raised less than what they expected, leading them to overestimate the answer of the central bank to the shock in order to converge to the true model of the economy. 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.

5.6 The "first-best" framework

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

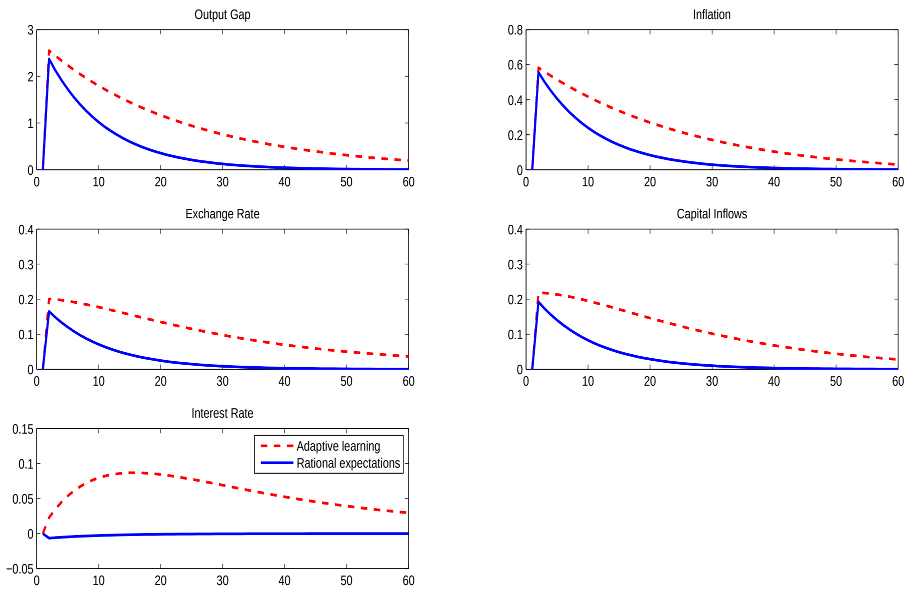

Figure 5 – The "first best": secret monetary policy
Response to a 5% inflation shock

Given that agents think that the capital inflows target is positive, they expect an increase in the interest rate. As shown in Figure (5) the way agents behave seriously 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.

5.7 Flexible inflation-capital targeting under commitment

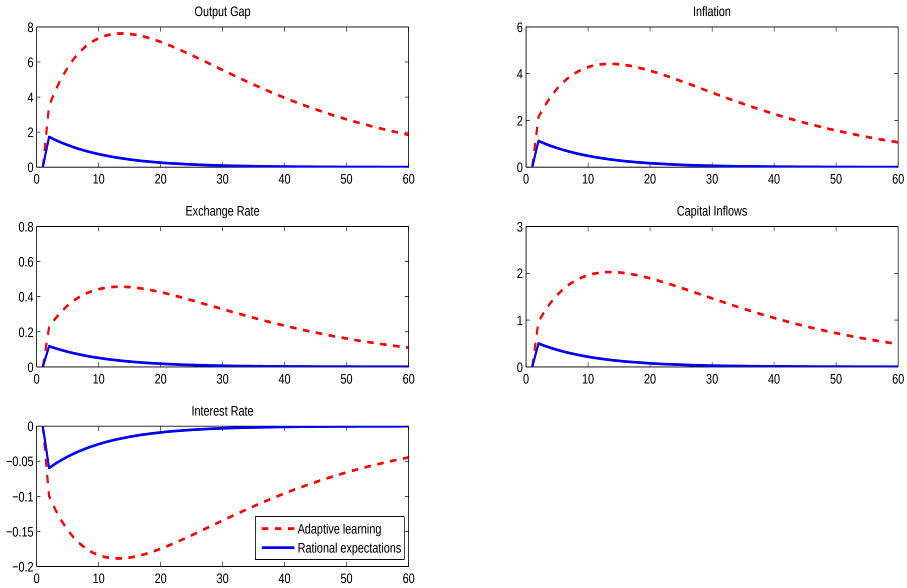

Figure 6 – Flexible inflation-capital targeting under commitment: secret monetary policy
Response to a 5% inflation shock

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 (6), the central bank cuts strongly the interest rate in order to suppress carry trades 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 (6), 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.

5.8 Further insights in monetary policies with adaptive learning

We have already seen that when agents have wrong beliefs concerning the long run targets of the central bank, the carry trades vicious circle is every time increased. We now take a look at the differences between the different monetary policies under adaptive learning.

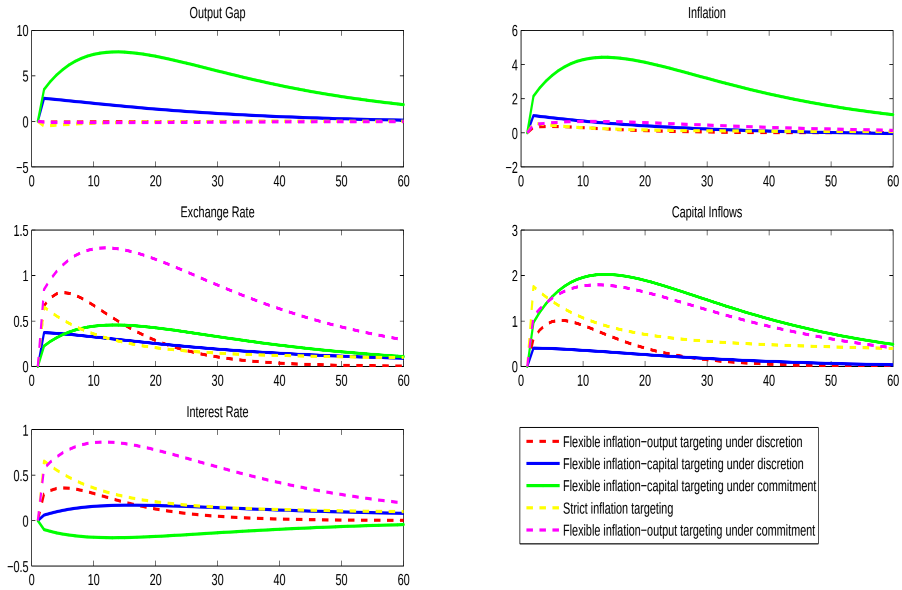

Figure 7 – Response to a 5% supply shock
Policies with wrong beliefs

Figure 7 shows that when agents have wrong beliefs about the long run targets of the central bank, there is still an arbitrage between inflation and capital inflows between the second and first best monetary policies. However in such a case, what we can conclude is that the central bank has to make agents aware of the long run targets not to destabilize more the economy. Concerning the flexible inflation-capital targeting policy under commitment with agents' wrong beliefs, the results reveal that with this policy the interest rate decreases after the shock which is a good point concerning carry trades destabilizing effect. However such a policy is hugely inflationary which is clearly not wanted by monetary authorities. The strict inflation targeting policy and the flexible inflation-output targeting policy under commitment still enhance the carry trades' vicious circle. Notice that the destabilizing effect is even bigger when agents do not know the long run targets of the central bank.

6 A Statistical analysis

In the theoretical part, we have shown that a strict inflation targeting policy was the more destabilizing policy in countries subject to carry trades. In this section we investigate whether real data conclude the same. Such an investigation is done through a simple statistical analysis. We consider seven inflation targeting countries (targeted currencies), Australia, Canada, Czech-Republic, Iceland, New-Zealand, Poland and Sweden and two source countries, Japan and the United-States. For the Nominal exchange rates, we use monthly data from datastream. We also use the 3-month interbank interest rates from the Fred (Federal Reserve Economic data) database. Then, in line with Brunnermeier and Pederson (2008), we construct the return from investing in the foreign currency by borrowing in the domestic currency as follows:

$$z_{t+1} = (i_t^* - i_t) - \Delta s_{t+1}, \tag{36}$$

with $s_t = log\ (nominal\ exchange\ rate)$ and Δs_{t+1} the depreciation of the foreign currency. i_t and i_t^* denote the log of the domestic and foreign interest rates respectively. Notice that the foreign interest rate i_t^* is the inflation targeting country in which the investment is done. Accordingly, we investigate the case of an investment in each currency. Concerning the domestic interest rate, we use alternatively the US interest rate and the Japanese interest rate in order to consider the two countries as the source of the investment.

Table 4 reports a positive correlation between the average interest differential and

Table 4 – Summary Statistics

	AUD	CAD	CZK	JPY	ISK	NZD	PLN	SEK
Δs_t	-0.002	-0.001	-0.002	0.0001	0.003	-0.003	-0.001	-0.001
z_{USt}	0.018	0.008	0.008	-0.017	0.019	0.019	0.017	0.005
$i^*_{t-1} - i_{USt-1}$	0.016	0.007	0.006	-0.017	0.022	0.016	0.016	0.004
Skewness CT_{US}	-1.414	-1.154	-0.287	-0.143	-1.836	-0.657	-1.071	-0.191
z_{jpt}	0.035	0.025	0.025	–	0.036	0.036	0.035	0.022
$i^*_{t-1} - i_{jpt-1}$	0.033	0.024	0.023	–	0.039	0.033	0.034	0.022
Skewness CT_{jp}	-1.535	-0.663	-0.364	–	-1.711	-0.849	-1.198	-0.268

Notes: We use monthly data from January 2001 to March 2015. Δs_t represents the monthly change in the foreign exchange rate (Units of foreign currency per US Dollars).

the average return of a carry trade which sheds light on the violation of the UIP for the period studied. The four first lines of table 4 focus on US-sourced carry trades. Importantly, the return of the JPY is negative in the sense that this currency is also a sourced currency. Moreover, the interest differential between Japan and the US is negative which clearly sheds light on the importance of the interest differential for carry trades. The three last lines of table 4 present statistics for Japan-sourced carry trades. Given that changes in the exchange rate JPY/USD are close to zero (0.0001), we use the exchange rate between inflation targeting countries and the USD to construct portfolios with JPY as the funded currency[8].

First, table 4 sheds light on the fact that currencies with the higher yield are the same with the two sourced currencies, revealing again how important is the interest differential concerning carry trades. This analysis also reveals that in the two cases, ISK is the currency which presents the higher yield and also the most negative skewness[9]. For example, an investor taking a position in ISK financed in USD would earn the average interest differential (0.022), minus the negative excess return of the ISK relative to USD

[8]It means that when the foreign currency appreciates relative to the USD it also appreciates relative to the JPY. Thus, constructing the return from Japan-sourced carry trades with the exchange rate relative to the USD is a good way to approximate the return of Japan-sourced carry trades.

[9]The NZD and AUD have also a high yield compared to the other currencies as reported in table (4), we will analyze such currencies later on.

(0.03) and would be subject to the negative skewness of -1.836. Notice that ISK is a special currency in our sample in the sense that this is the only one which presents a negative excess FX return. Such a characteristic is linked to the financial crisis in this country and clearly reveals that carry trades reversal did happen in Iceland.

A relevant feature pointed out by table 4 is the similar return offered by investing in NZD and AUD with the two sourced currencies (quite equals for an investment sourced in USD). More importantly, the results reveal that investing in NZD offer the same return as investing in AUD; but while investing in NZD, the negative skewness is far smaller. Such a finding reveals that the two currencies offer a similar return with a different risk. Such an acknowledgment sheds light on the attractiveness of the NZD as a targeted currency for carry trades.

Overall, our statistical results reveal that carry trades indeed destabilize inflation targeting countries. Such a conclusion lies on the fact that we find negative skewness for all the inflation targeting countries studied in this section. Thus our panel of countries present carry trades reversal risks.

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 (4), (5) and (6) show that when agents do not know the long run targets of the central bank, 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.

8 Appendix

8.1 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:

$$0 = \gamma_g \bar{g} + \gamma_u \bar{u} + \gamma_\omega \bar{\omega}, \tag{37}$$

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

$$\bar{r} = -\gamma_g \bar{g} - \gamma_u \bar{u} - (1 + \gamma_\omega)\bar{\omega}, \tag{39}$$

$$\frac{\bar{r}}{a} - \kappa\bar{y} + \phi\bar{s} = -(\kappa\varphi\gamma_g - \kappa + \phi\gamma_g)\bar{g} - (\kappa\varphi\gamma_u + \phi\gamma_u)\bar{u} - (\kappa\varphi\gamma_\omega + \phi\gamma_\omega + \phi)\bar{\omega}, \tag{40}$$

$$\bar{r} + \bar{s} = -\gamma_g \bar{g} - \gamma_u \bar{u} - (1 + \gamma_\omega)\bar{\omega} - \frac{1}{\lambda\sigma\mu}\bar{z}, \tag{41}$$

with $a = \frac{1}{\kappa\varphi + \phi}$. From Equations (38) and (39), $\bar{\omega} = -\frac{1}{\varphi}\bar{g}$. Given that UIP holds in the long run $\bar{\omega} = 0$, leading to $\bar{g} = 0$, and using Equations (37) to $\bar{u} = 0$. Thus, retaking Equations (38) and (39), 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 (40) and (41), 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 monetary policy. The constant terms are zero in all cases because UIP holds in the long run.

8.2 Strict inflation targeting

We have

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

With M the (5×5) following matrix:

$$\begin{pmatrix} 1-\varphi\psi\kappa & \varphi(1-\psi\varphi(\beta+\kappa\varphi-1)) & -\varphi\psi\delta\phi & \upsilon-\varphi\psi\kappa\upsilon & 0 \\ \kappa(1-\varphi\psi\kappa-\phi\varphi) & \beta+\kappa\varphi(1-\psi(\beta+\kappa\varphi-1) & -\phi\delta(\kappa\varphi\psi+1+\psi\phi\delta) & \kappa\upsilon(1-\varphi\psi\kappa-\phi\psi) & 0 \\ \psi\kappa & \psi(\beta+\kappa\varphi-1) & \delta(1+\psi\phi\delta) & \phi\kappa\upsilon & 0 \\ \lambda\sigma\mu\psi\kappa & \lambda\sigma\mu\psi(\beta+\kappa\varphi-1) & \lambda\sigma\mu(\delta+\delta\psi\phi-1) & \sigma(1+\lambda\mu\kappa\upsilon) & -\lambda\sigma\tau \\ \psi\kappa & \psi(\beta+\kappa\varphi-1) & \psi\phi\delta & \psi\kappa\upsilon & 0 \end{pmatrix},$$

Φ the following (5×5) matrix:

$$\begin{pmatrix} 1-\varphi\psi\kappa & -\varphi\psi & \varphi\psi\phi & 0 & 0 \\ \kappa(1-\kappa\varphi\psi)-\phi\psi & 1 & \phi(\kappa\varphi\psi-1+\psi\phi) & 0 & 0 \\ \kappa\psi & \psi & 1-\psi\phi & 0 & 0 \\ \kappa\lambda\sigma\mu\psi & \lambda\sigma\mu\psi & \lambda\sigma\mu(1-\psi\phi) & 1 & 0 \\ \kappa\psi & \psi & -\psi\phi & 0 & 0 \end{pmatrix},$$

and $B = (I - M)\bar{A} - \Phi\bar{\Omega}$.

8.3 Flexible inflation targeting under discretion

We have

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

With M the (5×5) following matrix:

$$\begin{pmatrix} \zeta\iota & -\frac{\beta\kappa}{\varphi(\alpha+\kappa^2)}\big(1-\zeta\iota\big) & \varphi\zeta\delta\iota & \upsilon\zeta\iota & 0 \\ \kappa\zeta\iota - \frac{\phi\iota}{\varphi} & \beta - (1-\zeta\iota)\frac{\beta\kappa^2}{\alpha+\kappa^2} - \phi\iota\big(1+\frac{\beta\kappa}{\alpha+\kappa^2}\big) & \iota\delta(\kappa\varphi\zeta-\phi) & \upsilon\iota\big(\kappa\zeta-\frac{\phi}{\varphi}\big) & 0 \\ \frac{\iota}{\varphi} & \iota\big(1+\frac{\beta\kappa}{\varphi(\alpha+\kappa^2)}\big) & \iota\delta & \frac{\iota\upsilon}{\varphi} & 0 \\ \frac{\lambda\sigma\mu\iota}{\varphi} & \lambda\sigma\mu\iota\big(1+\frac{\beta\kappa}{\varphi(\alpha+\kappa^2)}\big) & \lambda\sigma\mu(\delta\iota-1) & \sigma\big(1+\frac{\lambda\mu\iota\upsilon}{\varphi}\big) & -\lambda\sigma\mu\tau \\ \frac{1}{\varphi}(1-\iota\zeta) & 1+\frac{\kappa\beta}{\varphi(\alpha+\kappa^2)}(1-\iota\zeta) & -\iota\zeta\delta & \frac{\upsilon}{\varphi}(1-\iota\zeta) & 0 \end{pmatrix},$$

Φ the following (5×5) matrix:

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

and $B = (I - M)\bar{A} - \Phi\bar{\Omega}$.

8.4 Flexible inflation targeting under commitment

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

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

Notice than under commitment, $B = (I - M - N)\bar{A} - \Phi\bar{\Omega}$.

8.5 Strict capital inflows targeting

Once again, the system is the following: $A_t = B + ME_tA_{t+1} + \Phi\Omega_t$, with M the (5×5) following matrix:

$$\begin{pmatrix} 1 & \varphi & \varphi(\delta-1) & -\frac{\varphi(\alpha-\sigma)}{\lambda\sigma\mu} & -\frac{\varphi\tau}{\mu} \\ \kappa & \kappa\varphi+\beta & \kappa\varphi(1-\delta)+\phi & -\frac{\phi-(\alpha-\sigma)(1+\kappa\varphi)}{\lambda\sigma\mu} & -\frac{\kappa\varphi\tau+\phi\tau}{\mu} \\ 0 & 0 & 1 & \frac{\alpha-\sigma}{\lambda\sigma\mu} & \frac{\tau}{\mu} \\ 0 & 0 & 0 & \frac{\alpha-\sigma}{\lambda\sigma\mu}+\sigma & \frac{\tau}{\mu} \\ 0 & 0 & 1-\delta & \frac{\alpha-\sigma}{\lambda\sigma\mu} & \frac{\tau}{\mu} \end{pmatrix},$$

and Φ:

$$\begin{pmatrix} 1 & 0 & \varphi & \frac{\varphi}{\lambda\sigma\mu} & 0 \\ \kappa & 1 & \kappa\varphi & \frac{\kappa\varphi+\phi}{\lambda\sigma\mu} & 0 \\ 0 & 0 & 1 & -\frac{1}{\lambda\sigma\mu} & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & -1 & -\frac{1}{\lambda\sigma\mu} & 0 \end{pmatrix}.$$

Notice that with such a policy, $B = (I - M)\bar{A} - \Phi\bar{\Omega}$.

8.6 Flexible capital inflows targeting under discretion

Recall:

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

Notice that $B = (I - M)\bar{A} - \Phi\bar{\Omega}$.
M is 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:

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

8.7 Flexible capital inflows targeting under commitment

Recall:

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

Notice that $B = (I - M - N)\bar{A} - \Phi\bar{\Omega}$.
M is 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:

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

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