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Monetary Policies and Destabilizing Carry Trades under Adaptive Learning [1]

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Abstract

This paper investigates how different monetary policy designs alter the effect of carry trades on a host small open economy. 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). This paper shows how monetary authorities can mitigate or suppress this vicious circle, when agents do not have full information about the central bank's objectives. The best way to deal with the destabilizing effect of carry trades is to target both inflation and capital inflows.

Index terms— Capital inflows, Carry trades, interest rate differential, Vicious circle, Inflation targeting
JEL classification: E44; E52; E58; F31; G15

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1 Introduction

Massive quantitative easing in large economies in the wake of the global financial crisis triggered a big wave of capital exports from these countries. Therefore, controlling the potential destabilizing effects of capital inflows driven by interest differentials (so called carry trades) has become a major policy issue in Small Open Economies (SOE) targeting inflation.

In this paper, we argue that the aforementioned potential destabilizing effect of carry trades could be managed by central banks. We then use a New Keynesian model to simulate shocks (demand and supply) with different monetary policies. Thereafter, the Impulse Response Functions (IRF) depict the way a carry receiver is affected by shocks according to its policy choice. We go further by considering that the changing behavior of monetary authorities could alter agents' expectations (adaptive learning) and the way shocks affect the whole economy. Overall, our analysis aims at displaying which monetary policy stabilizes a small open economy receiving carry trades.

It is worth noting that a consensus on either the stabilizing or destabilizing effect of carry trades has not been reached. On the one hand, part of the literature argues that such investments could stabilize an economy by helping Uncovered Interest Parity (UIP) to hold (see e.g. Kisgergely (2012) and Felcser and Vonnák (2014)). Burnside (2013) regresses future exchange rate changes on the current interest differential between New-Zealand and the United-States. He first uses a simple interest differential model and extends it with risk factors. He shows that the model with risk performs better at forecasting future exchange rates (NZD/USD and NZD/JPY) in-sample. In addition, he highlights that changes in the Reserve

Bank of New-Zealand's (RBNZ) Official Cash Rate are negatively correlated (from 1998 to 2007) with the expected rate of appreciation of the NZD, concluding that the RBNZ's response to capital inflows does not lead to further inflows. On the other hand, Jonsson (2009) emphasizes that in Iceland, speculative capital inflows destabilized the economy. According to Jonsson (2009), in SOEs, a central bank raising interest rate differentials during expansionary periods, in order to fight inflation, attracts foreign liquidity, leading to an exchange rate appreciation and an illusory wealth effect. The associated rise in carry trades' returns leads to further inflows, more inflation, and a further rise in domestic policy rates. Thus, the more there are carry trades, the more they are attractive (carry trades' vicious circle). In this paper, we focus on a way to mitigate such a vicious circle. In line with the destabilizing hypothesis, Agrippino and Rey (2013) show that a higher interest differential between Australia and the United-States leads to an appreciation in the Australian Dollar (deviation from UIP induced by carry trades). Brunnermeier et al. (2009) emphasize that carry trades' targeted currencies bear a crash risk since the exchange rate of a carry receiver appreciates gradually until there is a sudden depreciation (reversal of carry trades). This exchange rate behavior is known as going up by the stairs and down with the elevator.

Theoretically speaking, several authors reproduced and confirmed this exchange rate behavior induced by a risk of carry trades' reversal. By mean of a dynamic general equilibrium model, Bacchetta and Wincoop (2010) show that infrequent portfolio decisions lead to a delayed impact of interest rate shocks on exchange rates. Importantly, their results link the destabilizing effect of carry trades to infrequent portfolio decisions. Farhi and Gabaix (2016)'s microfounded exchange rate model reports that the higher the country risk, the higher the interest rate because high risk countries present a high risk of depreciation in the eventuality of a disaster. Accordingly, financial intermediaries holding those currencies need a higher return for bearing this risk. In the same vein, Gabaix and Maggiori (2015) propose a theoretical model in which the exchange rate is driven by financiers' (who intermediate trades on the Foreign Exchange market) risk bearing capacity. Their model, with three periods, illustrates well the exchange rate risk led by carry trades. The financier exploits the UIP failure by holding the high-interest-rate currency X and selling the low interest rate currency Y. In the first period, currency X is expected to appreciate because the financier is long (holds the risk). In the next period, given that the financier is short in currency Y, this same currency is expected to initially appreciate in order to depreciate later (the financier is short). Accordingly, the movements of the investment currency validate such expectations (Carry reversal). Hence, introducing financiers' risk bearing capacity allows these authors to reproduce the effect of a risk of reversal on the exchange rate. Plantin and Shin (2018)'s model highlights the self-fulfilling character of carry investments and reproduces well their destabilizing effects. The theoretical models mentioned here give crucial insights concerning the channels through which carry trades destabilize SOEs. While these papers identify correctly the disease they do not provide any cure, since they do not focus on a way to manage such destabilizing effects. Our model, which also reproduces the destabilizing effects of carry trades in SOEs targeting inflation, proposes a way to dampen them.

Besides these stability issues, carry-trade strategies are widely investigated in macroeconomics and involve investments which seem less risky than usual financial operations. Burnside et al. (2006) showed that in the US the Sharpe ratio associated with carry trades is higher than the Sharpe ratio of the US stock market, reflecting a better risk-adjusted performance. Such investments are profitable only if the UIP does not hold and their risk lies on exchange rate changes. An appreciation of the currency of the targeted country will raise the return of carry trades above the interest differential, playing against UIP. It is well known since Fama (1984) that UIP does not hold in the short run. Since then, several papers have also reported a β smaller than 1 in the Fama regression of current exchange rate returns on the interest differential, rejecting UIP (see among others Burnside et al. (2009)). Going further, Breedon et al. (2016) show that more than half of the forward bias is explained by order flow for the USD/EUR and USD/JPY. This finding clearly highlights that positions in the FX market (and carry trades) could explain part of the UIP failure.

The failure of UIP is linked to investors' behavior in the sense that if they are risk neutral UIP should hold. Thus, agents' behavior appears to be an important feature of carry investments. Besides, carry trades' returns are directly linked to monetary policies which determine the interest differential. Relaxing the rational expectation hypothesis and using the interest differential (thanks to a Taylor-type rule) Lansing and Ma (2017) are able to reproduce the forward premium anomaly. In addition, many authors as Bullard and Mitra (2002), Evans and Honkapohja (2006), Evans and Honkapohja (2003) as well as Orphanides and Williams (2005), have shown, in the presence of adaptive learning, that agents' beliefs condition the nature and magnitude of the effects of monetary policy on the economy. Therefore, such a channel implies that agents' beliefs could amplify the (de)stabilizing character of carry trades. Hence, it appears essential to consider how monetary policy affects the economy when agents do not know how the central bank implements its monetary policy.

Our results imply that two monetary policy designs are better able than strict inflation targeting to reduce the destabilizing effects of carry trades. On the one hand, the carry trades' vicious circle is hampered by a discretionary flexible inflation-output targeting policy in which the central bank announces the long run targets (this is the "second best" framework). On the other hand, the "first-best" policy is a flexible inflation-capital-inflows targeting policy under discretion, with a central bank announcement of its long run targets.

The contributions of this paper are threefold. First, in our knowledge we are the first to model the destabilizing effect of carry trades described in Jonsson (2009) in a pure forward looking model by relaxing the rational expectation hypothesis. Second, we consider that the central bank is able to control capital inflows by substituting the output target by a capital-flows target in a loss function à la Clarida et al. (1999). Lastly, we show (and model) how central banks can mitigate the destabilizing effects of carry trades.

The rest of the paper is laid out as follows. Section 2 presents the model. In section 3, we introduce adaptive learning. Section 4 is devoted to the calibration of the model. Section 5 and 6 present the results with rational and non rational agents respectively. Section 7 concludes.

2 The model

2.1 The exchange rate

Carry trades are associated with a strategy 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 rely on the failure of the UIP condition in the short run (investors bet against UIP). An increase in the host country's 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 negative most of the time reflecting 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 the so-called 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 (in log):

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

ω_t is an AR(1) process driven by a shock which affects the exchange rate, with $\omega_t = \eta_3 \omega_{t-1} + \tilde{\omega_t}$. $\tilde{\omega_t}$ is an i.i.d random variable with zero mean and variance σ^2_ω. We rewrite the 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] ($r^* = 0$). Making use of this assumption and Equations (2) and (3), one obtains 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 appreciates the current exchange rate. When 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.

[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 does not account for the injection of liquidity. 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 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.

2.2 Capital inflows

We introduce a friction in financial markets by assuming that investors are not able to rebalance their portfolio at each period. Then, similarly to Plantin and Shin (2018), changes in capital inflows depend on the rate (λ) at which investors can rebalance their portfolio. $\lambda \in]0;1[$ is a constant, such that at each period there is a fraction of investors who are able to rebalance their portfolio. This assumption is realistic in the sense that carry traders use forward contracts in which the date at which the investor has to close her position is set in the future (in the meantime, she would not be able to close it). Expected changes in capital inflows also depend on the amount invested by investors who have had the opportunity to change their positions (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 an AR(1) process of the form: $z_t = \eta_4 z_{t-1} + \tilde{z}_t$ affecting capital inflows. Where, $\tilde{z}_t$ is an i.i.d random variable with zero mean and variance σ_z^2. It is worth noting that the amount invested by carry traders who have rebalanced their portfolio is linked to the return of a carry trade and depends positively on the host country's expected interest rate and expected changes in the exchange rate ($R_t = E_t r_{t+1} + E_t s_{t+1} - s_t$). We then have:

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

If one considers any financial asset, investors do not grant the same weight to the risk and return of their investment. The parameters τ and μ introduce such a behavior in our model. Even more important, risk averse agents grant more weight to the risk than to the return of their investments. The risk of a carry trade lies in exchange rate changes. Then considering $\mu > \tau$ introduces risk averse agents in our model in the sense that they grant a larger weight to the risk (exchange rate changes) than to the return (interest rate) of a currency investment. Then, 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 $\sigma = \frac{1}{1-\lambda}$. The higher λ, the larger σ. Therefore, the more investors are able to rebalance their position, the higher the impact of the other variables on capital flows. In other words, a higher λ, by increasing the volume of positions, raises the impact of macroeconomic variables on capital inflows. Equation (6) depicts 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 the risk of a carry trade reversal. In other words, long positions on the domestic currency increase with $(\tau E_t r_{t+1} + \mu E_t s_{t+1})$. Given that agents are risk averse, the higher the amount of long positions, the higher the risk of a reversal (investors expect short positions), the lower capital inflows at time t. On the other hand, a higher current interest rate appreciates the domestic currency which generates further capital inflows.

2.3 The monetary policies

The strict inflation targeting policy is used as a benchmark. Then, we introduce two extensions of our benchmark to flexible inflation targeting. On the one hand, monetary authorities can act in a standard way, adding an output gap target. On the other, they can have both an inflation and a capital inflows target. Depending on the monetary authorities' objectives, the central bank minimizes 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 et al. (1999) have modeled this kind of policy both 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 inflows 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 inflation target[2] ($\bar{\pi} = 0$). We also assume that the long run capital inflows' target is zero ($\bar{n} = 0$), which means that the central bank aims at stabilizing the financial system. In other words, monetary authorities' want to suppress capital flows' volatility in the long run. 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

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

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) expected capital inflows ($E_t n_{t+1}$) enhance growth. Such an assumption is in line with Jonsson (2009) in the sense that capital inflows are expansionary by allowing agents 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 how different monetary policies' setting alter the economy.

First, we investigate our benchmark which is a strict inflation targeting policy and the central bank only minimizes the deviation of inflation from its target ($\alpha_y = \alpha_n = 0$ in Equations (7) and (8)). Thereafter, we consider that the central bank also has an output objective. Hence, the central bank minimizes the deviation of both inflation and output from their target (the central bank minimizes Equation (7)). Finally, the central bank targets capital inflows' and minimizes Equation (8).

2.3.1 Strict inflation targeting

Inserting the first-order condition $E_t\pi_{t+i} = \bar{\pi}$ into Equation (10) gives the central bank reaction function:

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

with,

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

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. A higher expected inflation leads the central bank to raise the interest rate to bring inflation back to its target. An expected appreciation in the domestic currency has two effects even if it raises the interest rate in the end. First, it decreases inflation, leading the central bank to reduce the interest rate. Secondly, the expected appreciation increases carry trades' expected return, attracting expansionary capital and raising inflation, leading to a hike in the interest rate.

2.3.2 Flexible inflation-output targeting under discretion

The first order conditions are $y_t = -\frac{\kappa}{\alpha_y}\pi_t$ and $\pi_t = -\frac{\alpha_y}{\kappa}y_t$, and give the following reaction function:

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

with,

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

In this framework, the central bank reacts in two ways to higher expected inflation. The central bank increases the interest rate in order to keep inflation around its target. On the other hand, a higher inflation depreciates the domestic currency which reduces capital inflows, decreasing the output gap, and leading 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. Since inflation rises, the central bank raises the interest rate. However the appreciation reduces inflation leading the central bank to reduce the interest rate. In the end, the interest rate rises after an increase in the expected output gap and capital inflows.

2.3.3 Flexible inflation-output targeting under commitment

Under commitment, the central bank announces the output gap target, so has to honor its past promises in order to remain credible. Hence, the lagged output gap (y_{t-1}) is present in the reaction function. The first order conditions are $y_t = -\frac{\kappa}{\alpha_y}\pi_t + y_{t-1}$ and $\pi_t = -\frac{\alpha_y}{\kappa}(y_t - y_{t-1})$ leading to the following reaction function:

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

All the parameters in Equation (13) are the same as in Equation (12) except that the central bank also responds to the lagged output gap with the coefficient $\gamma_{ylag} = (\zeta\iota - 1)\frac{\iota\alpha_y}{\varphi(\alpha_y+\kappa^2)}$, where $\iota = \frac{\phi\kappa}{\varphi(\alpha_y+\kappa^2)}$. In such a context, to remain credible, the central bank responds to changes between the lagged and expected output gap. Therefore the higher the spread between expected and lagged output gap, the larger the increase in the interest rate after the shocks.

2.3.4 Flexible inflation-capital inflows targeting under discretion

Monetary authorities target both capital inflows and inflation to reduce the vicious circle generated by carry trades. Accordingly, the central bank minimizes Equation (8) under the constraints (9) and (10). The first order conditions resulting from this minimization program are $n_t = \frac{\alpha_x}{\sigma}\pi_t$ and $\pi_t = \frac{\sigma}{\alpha_x}n_t$. Thereafter, we have to rewrite Equation (6) in order to introduce the variable n_t in Equation (10):

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

Using the first order conditions, Equations (10) and (4), one obtains monetary authorities' 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

$$
\begin{aligned}
\gamma'_y &= \frac{\chi \alpha_x \kappa}{\sigma}; & \gamma'_\pi &= \chi\left(\frac{\alpha_x \kappa \varphi + \beta \alpha_x}{\sigma}\right); \\
\gamma'_s &= \chi\left(\lambda \sigma \mu - \frac{\alpha_x \phi \delta}{\sigma}\right); & \gamma'_n &= \chi\left(\frac{\alpha_x \kappa \upsilon}{\sigma} - \sigma\right); \\
\gamma'_r &= \chi \sigma \tau; & \gamma'_g &= \frac{\chi \alpha_x \kappa}{\sigma}; \\
\gamma'_u &= \frac{\chi \alpha_x}{\sigma}; & \gamma'_\omega &= \chi\left(\frac{\phi \alpha_x}{\sigma} + \lambda \sigma \mu\right),
\end{aligned}
$$

and $\chi = \frac{\sigma}{\lambda \sigma^2 \mu + \alpha_x \kappa \varphi + \alpha_x \phi}$. 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 to reduce inflation. The central bank reacts in two opposite ways after an increase in capital inflows and an appreciation of the domestic currency. Expansionary capital inflows generate a rise in inflation leading monetary authorities to increase the interest rate. On the other side, an increase in capital inflows makes carry trades more attractive, leading the central bank to reduce the interest rate in order to minimize capital inflows' volatility (notice that the whole impact is negative). The central bank increases the interest rate after an expected appreciation of the domestic currency because the latter reduces capital inflows. On the other hand, given that an appreciation of the domestic currency reduces inflation, the central bank lowers the interest rate not to deviate from the inflation target.

2.3.5 Flexible inflation-capital inflows targeting under commitment

Under commitment the central bank announces its aim in terms of capital inflows' volatility. Thus, in order to be credible, monetary authorities have to honor their past promises. Using the same methodology as in the previous section, we obtain the following first order conditions:

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

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

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

The reaction function under commitment is obtained with Equations (6) and (17) and is as follows:

$$\begin{aligned} r_t = \gamma_y' E_t y_{t+1} + \gamma_\pi' E_t\pi_{t+1} + \gamma_s' E_t s_{t+1} + \gamma_n' E_t n_{t+1} + \\ \gamma_r' E_t r_{t+1} + \chi n_{t-1} + \gamma_g' g_t + \gamma_u' u_t - \gamma_\omega' \omega_t - \gamma_z' z_t. \end{aligned} \tag{18}$$

The novelty in Equation (18) is the presence of lagged capital inflows. To remain credible the central bank responds to the deviation of expected from lagged capital inflows. The larger such a deviation, the more the central bank reduces the interest rate after the shocks.

3 Adaptive learning

It is well documented in the literature that errors in agents' expectations can alter the functioning of monetary policy. Importantly, agents could make mistakes about the evolution of the monetary policy. This could be due to a lack of credibility of monetary authorities, the arrival of a new governor, or a new inflation target. In all cases agents would observe what happens and correct their expectations. Imagine a central bank which announces a new inflation target. Even if agents give credit to monetary authorities, they would not think that the new target would be reached instantaneously. Therefore, they would observe new data and learn the new target over time. The adaptive learning approach perfectly mimics such behaviors.

3.1 Discretionary policy under adaptive learning

The economy is modeled by mean of five equations: the output gap, inflation, the exchange rate, capital inflows and the interest rate. We then rewrite the model in matrix form[3]:

$$A_t = B + M\hat{E}_t A_{t+1} + \Phi\Omega_t. \tag{19}$$

[3]Each vectors and matrices in the system (19) are detailed in a supplementary appendix available online.

$\hat{E}_t$ refers to non rational expectations, 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

$$\Omega_t = F\Omega_{t-1} + \epsilon_t. \tag{20}$$

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 $\eta \in]0;1[$[4]. B is a (5×1) vector of constants. Agents have wrong beliefs about B when they do not know the long run targets of the central bank.

Agents 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 central bank's targets, $a = \bar{a} = (0,0,0,0,0)'$. However, when agents have wrong beliefs about the central bank's targets $a \neq \bar{a}$, agents estimate the vector a and update their belief at each period until they converge to the real $\bar{a}$. Agents' perceived law of motion (PLM) is of the following form:

$$A_t = a_{t-1} + b_{t-1}\Omega_t. \tag{21}$$

At the beginning of period t, agents have estimated b_{t-1} using discounted least squares. Then the shocks Ω_t are realized, agents form their expectations from the PLM (21). Thereafter, A_t is generated according to system (19). In t+1, agents update their forecast with their past estimations of a and b, leading them

[4]For simplicity, we assume that all the parameters in the diagonal are equal to 0.9. We could assume that these parameters are not equal, but it would not change much the results.

to forecast according to:

$$\hat{E}_t A_{t+1} = a_t + F b_t \Omega_t \tag{22}$$

Subsequently, agents estimate a_t and b_t by mean of the following recursive least squares algorithm:

$$\phi_t = \phi_{t-1} + \gamma R_{t-1}^{-1} z_{t-1} (A_t - \phi'_{t-1} z_{t-1}), \tag{23}$$

$$R_t = R_{t-1} + \gamma (z_t z'_t - R_{t-1}), \tag{24}$$

Where γ is a small positive constant representing the gain. A constant γ means that agents weight more heavily recent than past data. R_t is an estimate of the second moment of Ω_t. Therefore, the higher the variance, the lower the weight agents grant to recent data. $\phi_t = (a, b)'$ and $z_t = (1, \Omega_t)'$. Using Equations (22) and (19), we get the implied "Actual Law of Motion" (ALM):

$$A_t = (M b_{t-1} F + \Phi) \Omega_t. \tag{25}$$

The mapping from the PLM to the ALM is:

$$T(a, b) = (B + Ma,\ MFb + \Phi), \tag{26}$$

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), $(\bar{a},\ \bar{b})$[5] is a globally stable equilibrium point if all the eigenvalues of M and MF are inside the unit circle. This is the case in this model, hence whatever the initial values $E(a_t,\ b_t) \to (\bar{a},\ \bar{b})$ as $t \to \infty$.

3.2 Committed policy under adaptive learning

In such an environment, the central bank cares about the deviation of the expected from the lagged output gap or capital inflows. Indeed, by doing so, monetary authorities aim at remaining credible. Accordingly, a vector of lagged variables is now introduced in the model and the system can be written as follows:

$$A_t^c = B^c + M^c \hat{E}_t A_{t+1}^c + N A_{t-1} + \Phi^c \Omega_t, \tag{27}$$

with N a (5×5) matrix and A_{t-1}, a (5×1) vector. Under commitment, agents' PLM becomes:

$$A_t^c = a_{t-1}^c + b_{t-1}^c \Omega_t + d_{t-1} A_{t-1}. \tag{28}$$

Using discounted least squares, agents estimate the (5×5) matrices b^c and d and the (5×1) vector a^c. In $t+1$, agents update their forecast, with their past estimations of a^c, b^c and d. From Equation (28), we have:

$$\hat{E}_t A_{t+1}^c = (I + d_t) a_t^c + d_t^2 A_{t-1} + (b_t^c F + d_t b_t^c) \Omega_t. \tag{29}$$

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

Inserting Equation (29) in Equation (27), we obtain the following ALM:

$$A_t^c = B^c + M^c(I + d_{t-1})a_{t-1}^c + (M^c d_{t-1}^2 + N)A_{t-1} + (M^c b_{t-1}^c F + M^c d_{t-1} b_{t-1}^c + \Phi^c)\Omega_t. \tag{30}$$

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

$$\phi_t^c = \phi_{t-1}^c + \gamma R_{t-1}^{c-1} z_{t-1}^c (A_t^c - \phi_{t-1}^c z_{t-1}^c), \tag{31}$$

$$R_t^c = R_{t-1}^c + \gamma(z_t^c z_t^c - R_{t-1}^c), \tag{32}$$

From Equations (28) and (29), the REE is defined as the fixed point of:

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

The mapping from the PLM to the ALM is:

$$T(a^c, b^c, d) = \left\{(I - M^c - M^c d)^{-1} B^c, (I - M^c d b^c - M^c F)^{-1} \Phi^c, (I - M^c d)^{-1} N\right\}.$$

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

$$DT_d(\bar{d}) = \{(I - M^c\bar{d})^{-1}N\}' \otimes \{(I - M^c\bar{d})^{-1}M^c\}, \tag{33}$$

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

Given that, in our framework, all the eigenvalues of (33) and (34) lie inside the unit circle, whatever the initial values, we have $Ea_t^c \to \bar{a}^c$, $Eb_t^c \to \bar{b}^c$ as $t \to \infty$ and $Ed_t \to \bar{d}$ as $t \to \infty$.

4 Calibrated values

We follow Clarida et al. (2000) and set $\kappa = 0.075$, $\beta = 0.99$ and $\varphi = 4$. We set $\alpha_y = 0.4$ which is standard in the literature. We chose to set $\alpha_n = 0.4$ in order to present an harmonized framework. τ and μ are important parameters enabling us to introduce investors' risk aversion. The exchange rate being the only source of risk in carry investments, setting $\mu > \tau$ means that agents grant more importance to the risk than to the return, so that they are risk averse. $\lambda = 0.5$, therefore, 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 (2005), 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).

The parameter υ represents the effect of carry trades on growth. It is worth noting that the value of this parameter does not affect the results much[6] and a

[6]The results with different values of υ are available upon request.

larger υ only slightly increases the impact of the shock on the economy. Still, we estimate the New-Zealand output gap with GMM[7] in order to give an economic sense to the value we grant to this parameter. First, using monthly data from 2000 to 2015[8], we show that carry trades affect positively and significantly (validate the aforementioned expansionary effect) New-Zealand growth. Berge et al. (2010) report that carry trades strategies failed during the GFC; accordingly we run our estimations with two samples, one before and one after the GFC and with two source currencies (JPY and USD). This empirical investigation reports an υ between 0.2 and 1.1 for New-Zealand. We purposely set it to the lowest $\upsilon = 0.2$.

By mean of this calibrated model, we investigate how a 5% supply shock affects the economy. Finally, we set T=150 which reflects 12.5 years using monthly data.

5 Results under rational expectations

We investigate how the central bank can either reduce or suppress the vicious circle generated by carry trades. In this section, we consider rational expectations with agents having full knowledge of the model of the economy.

5.1 Standard monetary policies

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 directly increases the return of carry

[7] The instruments are lagged explained and financial variables according to the period studied. Estimation's results and the full set of instruments are available upon request.

[8] Data are taken from Datastream.

trades. Given that carry trades are expansionary, the increase in capital inflows (which increase indirectly carry returns through an appreciation of the currency) brought by the higher interest rate will increase inflation and the mechanism just mentioned will re-appear. Importantly, the shock increases the output gap, which reflects the overheating[9] of the economy, corroborating the destabilizing effect of carry trades described in (Jonsson (2009)). Indeed, carry trades, by generating capital inflows create an artificial growth, amplifying a currency crash effect in the event of a carry reversal. Interestingly, a policy targeting both inflation and the output gap responds less aggressively to inflation which could help mitigating the carry trades' vicious circle.

The aforementioned flexible policy, both under discretion and commitment downplays the carry trades' vicious circle. Figure (1) depicts 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. Interestingly, the interest rate being smaller after the shock, expansionary capital inflows are reduced and the overheating of the economy disappears with these two policies, reducing the potential effect of a reversal of carry trades. Under commitment, the lagged output gap is present in the model, leading to a higher inflation. Accordingly the central bank raises the interest rate to a larger extent under commitment, enlarging carry trades' returns.

Our results depict that a flexible inflation-output targeting policy allows the authorities to mitigate the carry trades' vicious circle. However, even if the destabilizing effect is mitigated it is still present. Accordingly, we investigate whether a

[9]Given that the interest rate increases, the output gap should decrease, however carry trades enhance growth, that is why we refer to an overheating of the economy.

policy targeting capital inflows is able to perform better.

5.2 Flexible inflation-capital inflows targeting

By mean of a flexible inflation-capital inflows targeting policy, monetary authorities aim at suppressing the destabilizing loop enhanced by carry trades by reducing the interest rate after incoming flows. Therefore, we consider a central bank which targets both inflation and capital inflows.

Figure (2) shows that with a flexible inflation-capital targeting policy under commitment, the carry trades vicious circle is suppressed. Indeed, after the supply shock, inflation increases, leading agents to expect an increase in the interest rate and more capital inflows. Then, the central bank cuts the interest rate in order to reduce carry trades' returns and reach its capital-inflows target. Through this mechanism the monetary authorities are able to suppress the carry trades' vicious circle. However, by reducing sharply the interest rate, such a policy is hugely inflationary. In addition, the output gap rises sharply due to a falling interest rate and larger capital inflows.

The flexible inflation-capital inflows targeting policy under discretion also performs well at mitigating the carry trades' vicious circle. After the shock, the interest rate rises to a tiny extent, affecting carry trades' returns and capital inflows. Consequently, this policy is able to mitigate the aforementioned destabilizing loop. In addition, this policy performs well in terms of inflation stability (inflation almost sticks to the target after the shock).

The central banks' main objective remains inflation stabilization. Therefore, a flexible inflation-capital inflows targeting policy performs better than standard monetary policies both in terms of inflation and carry trades' destabilizing effect. Figures (1) and (2) depict that a flexible inflation-capital inflows targeting policy under discretion mitigates the destabilizing effect of carry trades and performs well in terms of price stabilization (first-best). In addition, a standard flexible inflation-output policy (second-best) under discretion is also able to downplay the carry trade' vicious circle but to a smaller extent than the aforementioned first-best policy.

6 Results under adaptive learning

Agents do not have full information about the central bank's objectives. For example, such a lack of information could happen after a change in the monetary policy objectives, the arrival of a new governor or a lack of credibility in monetary authorities. As a matter of fact, whatever the reason of agents' misperception, agents have to observe data and learn from it.

Table (2) presents the true values of the targets and what agents believe the targets are. 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 growth objective. Thus, with such a belief, agents also think that the central bank has a higher inflation target and responds less aggressively to inflation.

Concerning a flexible inflation-capital targeting policy, agents also think that the authorities have a long run growth objective and target a positive level of capital inflows[10].

[10]Such a policy could be relevant in small open economies suffering from a lack of domestic

6.1 Standard flexible policy under discretion

Figure (3) shows that when agents do not know the long run targets of the central bank, the carry trades' vicious circle is amplified, destabilizing the economy more than under a RE framework. Such an overestimation of the inflation shock can be explained in two steps. Agents overestimate both the inflation and output-gap targets. Accordingly, they think that the central bank will respond to inflation to a smaller extent. Then, according to agents' beliefs, inflation itself increases more right after the shock. Given that agents overestimate the impact of the shock on inflation, they also overestimate the increase in the interest rate and in capital inflows. Such a mechanism leads to a bigger destabilizing loop enhanced by agents' beliefs. Overall, in such a context, the destabilizing effects of carry trades are worsened and more persistent.

Monetary authorities should clearly communicate about their inflation and output-gap objectives in order to mitigate carry trades' destabilizing effects. A flexible inflation-capital inflows targeting policy under discretion is prone to mitigate carry trades' vicious circle.

6.2 Inflation-capital inflows targeting under discretion

We consider a central bank targeting both inflation and capital inflows under discretion (which was our first-best policy under RE). Agents overvalue the long run capital inflows target. The results are reported in Figure (4). After the shock, all the variables respond in the same way as in Figure (2), and the explanations presented in section 5.2 are valid.

saving.

Still, figure (4) also depicts that in the presence of adaptive learning the destabilizing effect of carry trades worsens and is more persistent. Given that agents overestimate the long run target of capital-inflows, they also overestimate the increase in the interest rate after the inflation shock, leading to more capital inflows. Given that the flexible inflation-capital inflows targeting policy under commitment is able to suppress the carry trades' vicious circle, we also investigated how misspecifications in agents' beliefs affect the impact of this policy. The results can be found in the online appendix.

7 Conclusion

We study the impact of carry trades on the targeted economy. Recall that carry trades destabilize an inflation targeting small open economy in the sense that capital inflows lead its 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 at work and investigate other monetary policies which could mitigate or suppress this vicious circle.

Through a forward-looking model, we examine two monetary strategies with strict inflation targeting or 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. Interestingly a flexible inflation-capital inflows targeting policy under discretion appears to be the best strategy to stabilize an economy subject to carry trades. Considering non-fully rational agents, we investigate how misperception of the long run targets of the central bank affects the effects of monetary policy. It is worth noting that regardless of the policy implemented, when agents do not have full information about the central bank's objective, the carry trades' destabilizing effect is amplified.

Overall, our results suggest that two monetary strategies are able to mitigate the carry trades' destabilizing effect in SOEs. On the one hand, a standard flexible inflation-output targeting monetary policy under discretion performs better than a strict inflation targeting policy. Indeed, with the flexible policy (second-best) the hike in the interest rate after the shock is smaller, attenuating the carry trades' destabilizing effect. Still, when the central bank targets both inflation and capital inflows under discretion (first-best), the carry trades' vicious circle is mitigated and the price level is stabilized.

This paper is motivated by the following statements: large scale monetary expansion (through QE) in large countries leads them to export capital to small open economies which target inflation, raising the issue of destabilizing carry trades. 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 results suggest that SOEs' receiving carry trades could be stabilized by targeting both inflation and capital inflows under discretion.

In this paper, we purposely focus on capital inflows' management as a tool to stabilize SOEs receiving carry trades. Indeed several papers show that under some economic conditions the use of capital controls is justified and viable (see among others Ostry et al. (2010) and Montecino and Cordero (2010)). Still, other policies as exchange rate targeting, macroprudential policies or taxes could be used to break the destabilizing effect of carry trades. Thus, further research investigating how the aforementioned policies alter carry trades' destabilizing loop would be useful.

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Table 1 – Parameters' value

Parameters	Values	Parameters	Values
α_y	0.4	λ	0.5
α_n	0.4	ϕ	0.1
τ	0.1	δ	0.6
μ	0.5	η	0.9
υ	0.1	κ	0.075
β	0.99	φ	4

Table 2 – Agents' perception of the central bank's targets

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

8 Tables and figures

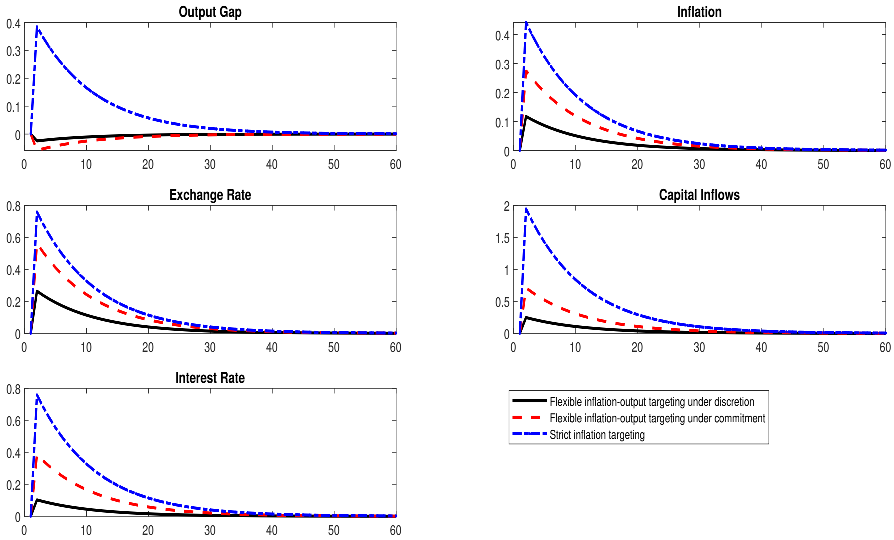

Figure 1 – Standard monetary policies under RE
Response to a 5% supply shock

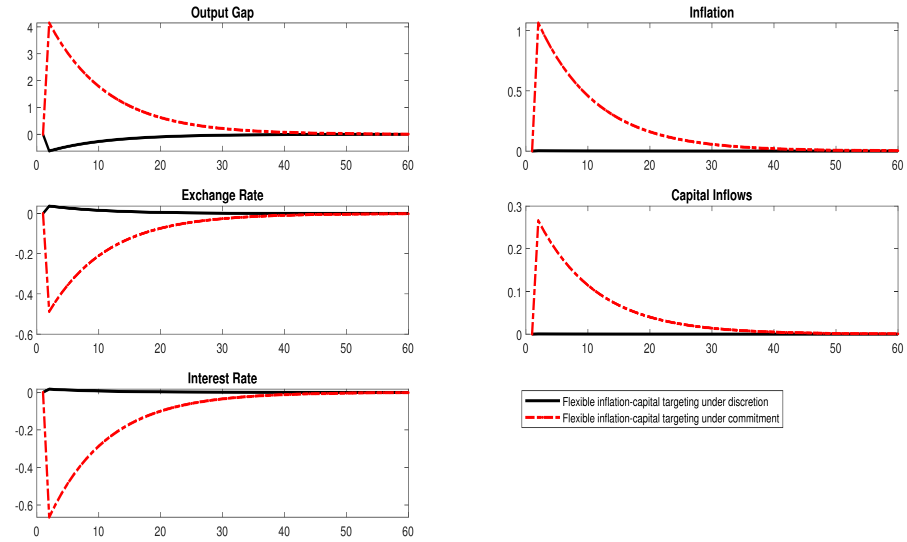

Figure 2 – Flexible inflation-capital targeting under RE
Response to a 5% supply shock

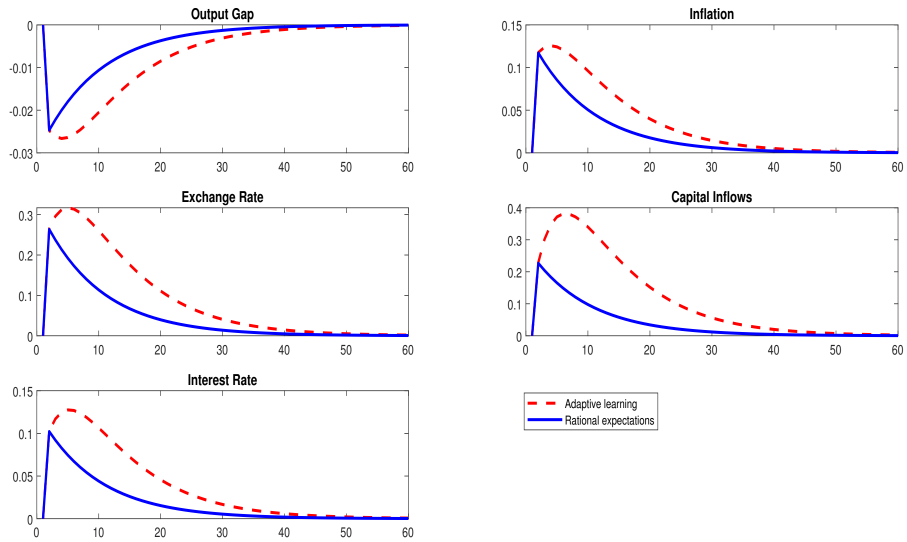

Figure 3 – The "second-best" policy under AL
Response to a 5% supply shock

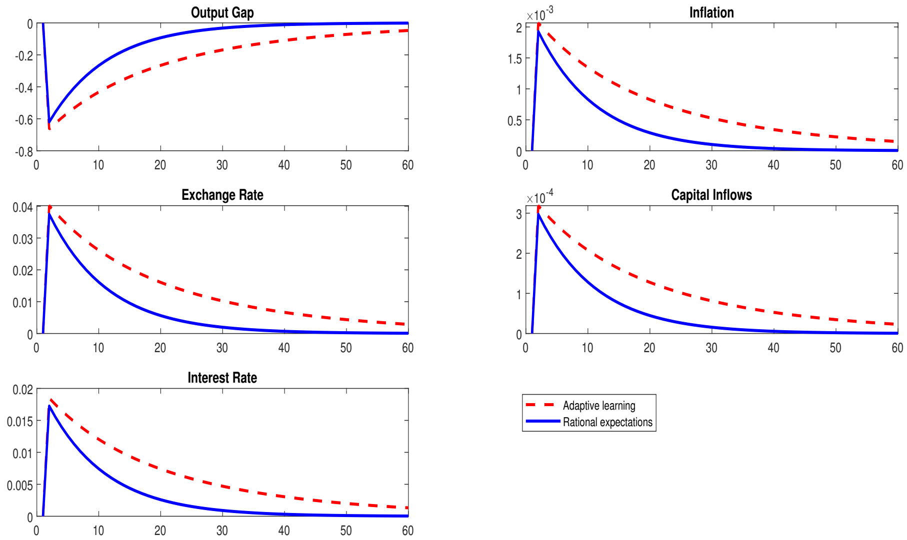

Figure 4 – The "first-best" policy under AL
Response to a 5% supply shock

9 Appendix

9.1 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 $A_t = B + ME_t A_{t+1} + \Phi\Omega_t$. We compute the steady states with the different monetary policies by making use of Equations (4), (6), (9), (10), (11), (12), (13), (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:

$$0 = \gamma_g \bar{g} + \gamma_u \bar{u} + \gamma_\omega \bar{\omega}, \tag{35}$$

$$\bar{r} = (\frac{1}{\varphi} - \gamma_g)\bar{g} - \gamma_u \bar{u} - \gamma_\omega \bar{\omega}, \tag{36}$$

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

$$\frac{\bar{r}}{a} - \kappa\bar{y} + \phi\bar{s} = -(\kappa\varphi\gamma_g - \kappa + \phi\gamma_g)\bar{g} - (\kappa\varphi\gamma_u + \phi\gamma_u)\bar{u} - (\kappa\varphi\gamma_\omega + \phi\gamma_\omega + \phi)\bar{\omega}, \tag{38}$$

$$\bar{r} + \bar{s} = -\gamma_g \bar{g} - \gamma_u \bar{u} - (1 + \gamma_\omega)\bar{\omega} - \frac{1}{\lambda\sigma\mu}\bar{z}, \tag{39}$$

with $a = \frac{1}{\kappa\varphi + \phi}$. From Equations (36) and (37), $\bar{\omega} = -\frac{1}{\varphi}\bar{g}$. Given that UIP holds in the long run $\bar{\omega} = 0$, leading to $\bar{g} = 0$. Thereafter, using Equations (35) gives $\bar{u} = 0$. Thus, retaking Equations (36) and (37) give $\bar{r} = 0$. In the case of flexible inflation targeting, the central bank's targets are $\bar{y} = \bar{\pi} = 0$. At last, making use of Equations (38) and (39) $\bar{s} = \bar{z} = 0$. Accordingly the steady states' values are captured by the following vector

$$(\bar{y}, \bar{\pi}, \bar{s}, \bar{n}, \bar{r})' = (0, 0, 0, 0, 0)'.$$

Using the same methodology with the alternative policies lead to the same vector for the steady states' values.