Optimal Foreign Exchange Intervention in an Inflation Targeting Regime: some cautionary tales*

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Abstract
Devaluations and fiscal retrenchments coming from developed countries are buffeting less developed countries. Many emerging market countries have adopted inflation targeting as “best practice,” but now they are being advised to enhance their inflation targeting regimes with foreign exchange intervention. Here we use a DSGE model to tell some cautionary tales about this advice. A Taylor rule guides interest rate setting, while foreign exchange interventions are used as a second tool of monetary policy. These interventions are effective in our model since domestic and key currency bonds are imperfect substitutes. We derive optimal (Ramsey) intervention policies in response to foreign deflations and fiscal retrenchments, and find that they are rather complex. So, we compare the optimal responses to policies that simply smooth real or nominal exchange rate movements. Our results suggest that discretion may be the better part of valor: pure inflation targeting may come closer to the optimal policy than exchange rate smoothing. A secondary result may also be of some interest: foreign exchange interventions have a stronger impact on inflation and output in an inflation targeting regime than do sterilized interventions; the Taylor rule augments the effects of a given intervention.

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1 Introduction

Monetary and fiscal policies in the developed countries have responded to the great recession, and to fiscal imbalances, and these policy shocks are being felt in less developed countries. The loose monetary policies of the Fed, the ECB, the Bank of England and the Bank of Japan have brought fresh accusations of currency wars,\(^1\) big fiscal retrenchments in the U.S. and Europe are on-again and off-again. How are emerging market countries responding to these shocks? Many central banks have eschewed their focus on exchange rate targeting and adopted inflation targeting as their nominal anchor; this is now viewed as best practise. And indeed, there seems to be a concern that public attention to movements in the exchange rate might be taken as a lack of commitment to the inflation target (although some central banks do continue to intervene in foreign exchange markets).\(^2\)

Advice now coming from IMF staff seems to be challenging this view: Blanchard\(^4\) explicitly advocates the use of foreign exchange intervention within an inflation targeting regime. Staff studies by Ostry and coauthors \(^{21},^{22}\) and Benes and coauthors \(^1\) assume that interest rates are guided by a Taylor rule while foreign exchange intervention seeks to smooth real or nominal exchange rates around some medium run target. These studies generally conclude that these leaning against the wind policies can be helpful in minimizing inflation and output fluctuations.

In this paper we use a DSGE model to tell cautionary tales about this enhanced

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\(^1\)For example, Brazilian Finance Minister Guido Mantega has made these charges repeatedly. See: "G20: Brazil Finance Minister: Currency Wars Have Become More Intense," WSJ, February 15, 2013.

These concerns are not restricted to developing countries. France, for example, has called for "medium-term" exchange rate targets, but the ECB has shown no inclination to respond.

\(^2\)See for example Blanchard\(^4\), Malloy\(^20\) or Villamizar-Villegas\(^25\).
inflation targeting regime. In our model, the central bank’s interest rate is guided by a Taylor rule while optimal (Ramsey) intervention policy seeks to maximize household welfare. An inflation targeting central bank will indeed want to intervene, but the optimal intervention policy proves to be rather complex; it would probably be difficult for a central bank to implement. So, we also consider intervention policies that have been observed in practice. An obvious alternative is to simply refrain from intervening; we will call this a pure inflation targeting regime. Other intervention policies involve leaning against the wind: they seek to limit changes in either real or nominal exchange rates.

Our cautionary tales suggest that discretion may be the better part of valor: pure inflation targeting may be preferable to leaning against the wind unless an appropriate intermediate exchange rate target can be identified. And, there is no one intermediate target that is appropriate for all shocks coming from abroad. Finding an appropriate intermediate target and implementing a successful leaning against the wind policy may be as difficult as implementing the optimal policy. A final result that may be of some interest is that foreign exchange interventions within an inflation targeting regime have much bigger effects on inflation and output than sterilized interventions of the same size; that is, the Taylor rule in an inflation targeting regime calls for interest rate settings that augment the effects of the original intervention. These two intervention policies should not be conflated.

Foreign interventions must have a different effect than open market operations if they are to have an independent effect in an inflation targeting regime, and this will be the case if home and foreign bonds are imperfect substitutes.\textsuperscript{3} The recent academic literature has shied away from these issues. One reason for this is that

\textsuperscript{3}The previously cited IMF staff papers discuss the empirical literature on the effectiveness of sterilized interventions. For a recent study, see Gagnon[11].
currently popular models almost invariably assume that bonds denominated in different currencies are indeed perfect substitutes. In our model, the home country uses home bonds and a key currency bond (in addition to money) to facilitate trade, and as we shall see this makes the two bonds imperfect substitutes.\textsuperscript{4} Our model has much in common with the earlier portfolio balance models of Kouri\textsuperscript{16}, Branson and Henderson\textsuperscript{5}, and more recently Blanchard Giavazzi, and Sa\textsuperscript{3}.

There is a very large literature pertaining to the general issues we discuss here. We are of course not the first to study the liquidity services of bonds. Early contributions to the literature include: Patinkin\textsuperscript{23}, who put both money and bonds in the household utility function; and Friedman\textsuperscript{10}, who discussed the optimum quantity of money and (private) bonds. More recent theoretical contributions include: Bansal and Coleman\textsuperscript{2}, who used the approach to study the equity premium puzzle and related issues; Holmstrom and Tirole\textsuperscript{15}, who argued that the private sector cannot satisfy its own liquidity needs when there is aggregate uncertainty; and Linnemann and Schabert\textsuperscript{19}, who used a model similar to ours to study macroeconomic policy.

Our basic assumption that government bonds provide liquidity should not be controversial. U.S. Treasuries facilitate transactions in a number of ways: they serve as collateral in many financial markets, and importers and exporters hold them as transaction balances. Empirical contributions to this literature include: Friedman and Kuttner\textsuperscript{9}, who studied the imperfect substitutability of commercial paper and U.S. Treasuries; Greenwood and Vayanos\textsuperscript{13}, who find that the supply of long-term relative to short-term bonds is positively related to – and predicts – the term spread; and Krishnamurthy and Vissing-Jorgensen\textsuperscript{17}, who find that the spread between

\textsuperscript{4}Canzoneri, Cumby and Diba\textsuperscript{8} used a similar structure to discuss empirical puzzles in the international finance literature, and Canzoneri and coauthors\textsuperscript{7} used a virtually identical structure to discuss the costs and benefits of being a key currency country.
liquid treasury securities and less liquid AAA debt moves systematically with the quantity of government debt.

The rest of the paper proceeds as follows: In Section 2, we outline a two country model suitable for studying foreign exchange intervention, and we illustrate the difference between interventions conducted within an inflation targeting regime and sterilized interventions. In Section 3, we derive the optimal interventions in response to monetary and fiscal policy shocks coming from abroad and compare them to intervention policies that lean against the wind; then we tell our cautionary tales. In Section 4, we conclude with a discussion of work for the future.

2 A Model of Foreign Exchange Intervention

Our model consists of a Home country (hereafter called “Home”) and a Key Currency country (hereafter called “KC”). Bonds are imperfect substitutes for money in each country,\(^5\) and this fact alone would make Home and KC bonds imperfect substitutes. But, there is more: all trade is priced in units of the key currency. So, Home households use KC bonds to facilitate trade, and the Home government holds KC bonds as official reserves for use in foreign exchange interventions. For simplicity, the two countries are symmetric apart for these two key currency assumptions. The fact that Home bonds are imperfect substitutes for KC bonds makes sterilized interventions effective in this model.

The rest of the model has standard NOEM features: Monopolistically competitive firms produce an aggregate consumption good in each country; household consump-

\(^5\)Canzoneri, Cumby, Diba and Lopez-Salido[6] present a closed economy model with banks, bank deposits and bank loans. Here, due to the complexity of the two country model, we take a less structural approach.
tion reflects habit formation and a bias for the domestically produced good; labor is the only factor of production (there being no land or investment); the labor market is competitive and wages are flexible, but prices are set in the staggered fashion of Calvo.

2.1 The Model

In this section, we describe the model’s basic structure. We also describe how we solve for the steady state and calibrate the model.

2.1.1 Households

We begin with the Home households. There is a continuum of Home households on the unit interval. The utility of household \( h \) is

\[
U_{\text{household}} = E \sum_{t=0}^{\infty} \beta^t \left[ \log(c_t(h) - \xi c_{t-1}) - (1 + \chi)n_t(h)^{1+\chi} \right]
\]

(1)

where \( c_t(h) \) is consumption of a composite final good (defined below), \( n_t(h) \) is hours of work, \( c_{t-1} \) is aggregate consumption last period, the parameter \( \xi \) is a measure of habit persistence, and the parameter \( \chi \) is the inverse of the Frisch elasticity of labor supply. Households are identical in equilibrium; so, we can dispense with household indices. The household’s budget constraint, in units of the Home consumption good, is

\[
m_t + b_t + b_{KC,t} q_t + (1 + \tau_t)c_t =
\]

(2)

\[6\] A note on notation: H and KC subscripts will be used to denote Home and KC assets and products when those bonds or products are used in both countries; Home money and bonds, for example, are not held by foreign entities, and therefore they need no subscript. Superscript *'s will denote KC household demands and supplies of assets and products; they will also denote KC interest rates, inflation rates, and velocity.
\[ w_t n_t + \left( m_{t-1} + R_{t-1}b_{t-1} + R_{t-1}^* b_{KC,t-1} q_t \right) / \Pi_t - x_t + (1 - s) \text{div}_{H,t} \]

Home households hold Home money, \( m_t \), Home bonds, \( b_t \), and KC bonds, \( b_{KC,t} \), to finance their purchases; \( \tau_t c_t \) is a transactions cost which will be described later; \( w_t \) is the competitive market wage; \( R_{t-1} \) is the gross nominal interest rate on Home bonds; \( \Pi_t = P_t / P_{t-1} \) is the gross rate of Home CPI inflation; \( x_t \) is a lump sum tax; \( \text{div}_{H,t} \) are dividends from Home firms and \( s \) is the share of Home equity held by KC households;\(^7\) and finally \( q_t \) is the real exchange rate (Home consumption goods per KC consumption good).

Following Schmitt-Grohe and Uribe\cite{24}, we assume that transactions costs are proportional to consumption, and the factor of proportionality is an increasing function of velocity, \( \nu_t \):

\[
\tau_t = \frac{A(\nu_t - v)^2}{\nu_t} \quad \text{for} \quad \nu_t > v
\]

\[
\text{and} \quad \tau_t = 0 \quad \text{for} \quad \nu_t \leq v
\]

where \( v \) is the satiation level of velocity and \( A \) is a cost parameter. The new element here is in our definition of velocity:

\[
\nu_t = \frac{c_t}{\tilde{m}_t}
\]

where effective transactions balances – \( \tilde{m}_t \) – are a Cobb-Douglass aggregate of money and bonds:

\[
\tilde{m}_t = m_t^{\omega_1} b_t^{\omega_2} b_{KC,t}^{\omega_3}
\]

where \( 0 < \omega_1, 0 < \omega_2, 0 < \omega_3 \) and \( \omega_1 + \omega_2 + \omega_3 = 1 \); \( \omega_3 \) measures the importance of KC bonds in the Home household’s transactions.

\(^7\)We do not model the equities market. We simply assume that each household owns a proportionate share of the steady state Home country portfolio (of bonds and equity). The size and composition of this portfolio will be calibrated so that KC earnings on Home equity balance Home earnings on KC bonds in the steady state.
The Home household’s first order conditions include:

\[(c_t - \xi c_{t-1})^{-1} = \lambda_t[1 + 2A(\nu_t - v)]\]  \hspace{1cm} (6)

\[1 - A(\nu_t^2 - v^2)\omega_1(m_t/m_t) = \beta E_t[(\lambda_{t+1}/\lambda_t)/\Pi_t] \equiv 1/\tilde{R}_t\]  \hspace{1cm} (7)

\[1 - A(\nu_t^2 - v^2)\omega_2(m_t/b_t) = R_t\beta E_t[(\lambda_{t+1}/\lambda_t)/\Pi_t] \equiv R_t/\tilde{R}_t\]  \hspace{1cm} (8)

\[1 - A(\nu_t^2 - v^2)\omega_3(m_t/b_{KC,t}q_t) = R_t\beta E_t[(\lambda_{t+1}/\lambda_t)(q_{t+1}/q_t)(1/\Pi_t)]\]  \hspace{1cm} (9)

where \(\lambda_t\) is the marginal value of wealth. We can price a bond that does not provide liquidity services and call it the CCAPM bond; its gross return is \(\tilde{R}_t\). \(R_t/\tilde{R}_t\) is less than one, reflecting the non-pecuniary return on Home bonds. (6) defines the marginal value of wealth. When real resources are depleted in the purchase of consumption goods, the marginal value of wealth is less than the marginal utility of consumption. (7) and (8) are the first order conditions for money and Home bonds; (9) is the first order condition for KC bonds.

KC households are modeled symmetrically, but with one major exception: KC households do not use foreign bonds to finance their purchases. Their transactions costs are again proportional to consumption:

\[\tau_t^* = \frac{A^*(\nu_t^* - v^*)^2}{\nu_t} \text{ for } \nu_t^* > v^* \]  \hspace{1cm} (10)

and \(\tau_t^* = 0 \text{ for } \nu_t^* \leq v^*\)

and

\[\nu_t^* = \frac{c_t^*}{\bar{m}_t} \]  \hspace{1cm} (11)

But effective transactions balances \(-\bar{m}_t^*\) are a Cobb-Douglas aggregate of KC money and KC bonds:

\[\bar{m}_t = (m_t^*)^{\omega_1}(b_{KC,t}^*)^{\omega_2}\]  \hspace{1cm} (12)

where \(0 < \omega_1^*, 0 < \omega_2^*, \text{ and } \omega_1^* + \omega_2^* = 1.\)
2.1.2 Firms, Key Currency Pricing, Intermediate Goods, Final Goods

We model monopolistic competition in a standard way; so, our description of it can be brief, focusing on aspects that are specific to our model. In each country, a continuum of monopolistically competitive firms hire workers on a competitive labor market and produce a continuum of intermediate goods using a common linear technology. Intermediate goods firms in each country price their goods in the staggered manner of Calvo; the Calvo parameters are set so that average price duration is four quarters.

There is, however, an important asymmetry in the price setting. KC firms set their prices in terms of their own currency, both for goods sold at home and for goods that are exported; the law of one price holds for KC goods. Home firms set their prices in terms of their own currency for good sold domestically, but they set their prices in terms of the key currency for goods exported to KC.

The Home and KC national products, \( y_{H,t} \), and \( y^*_{{K,C,t}} \) are CES aggregates of the intermediate goods, with elasticity of substitution \( \zeta \). The final Home consumption good (appearing in the utility function (1)) is a CES aggregate of Home consumption of the Home product, \( c_{H,t} \), and Home consumption of the KC product, \( c_{{K,C,t}} \):

\[
c_t = \left[ \mu^{1/\eta} (c_{H,t})^{(\eta-1)/\eta} + (1 - \mu)^{1/\eta} (c_{{K,C,t}})^{(\eta-1)/\eta} \frac{1}{\eta/(\eta-1)} \right]
\]

where \( 1/2 < \mu < 1 \). The parameter \( \mu \) measures the degree of "home bias" in consumption. The final KC consumption good, \( c^*_t \), is defined in an analogous manner.

2.1.3 Equilibrium Conditions

Most of the market equilibrium conditions are obvious. Here, we focus on those about which there may be some confusion. The equilibrium condition for KC bonds
is:

\[ d_t^* - b_{KC, t}^* = b_{KC, t} + b_{KC, t}^G \]  

(14)

where \( d_t \) is the total supply of KC bonds issued by the KC government and \( b_{KC, t}^G \) are the KC bonds held by the Home central bank. The KC bonds that are not held by KC households (the LHS of the equilibrium condition) must be held by Home households or the Home central bank (the RHS).

Government spending falls on the domestic good in each country, so the output equilibrium conditions are:

\[
y_{H,t} = (1 + \tau_t)c_{H,t} + g_t + (1 + \tau_t^*)c_{H,t}^*
\]

(15)

\[
y_{KC,t}^* = (1 + \tau_t^*)c_{KC,t}^* + g_t^* + (1 + \tau_t)c_{KC,t}
\]

2.1.4 The Steady State and Model Calibration –

The way we solve for the steady state equilibrium is dictated by our approach to the model’s calibration. We calibrate the KC economy to U.S. data, but we do not attempt to calibrate the Home economy to any particular country. Instead, apart from the key currency features, the Home calibration is reflective of the KC calibration. Table 1 reports the calibrated parameters.

Home and KC portfolios are not symmetric: KC residents hold equity claims on Home firms and Home residents hold KC bonds. KC residents earn the CCAPM rate on their Foreign equity claims, while Home residents earn the liquid bond rate on their KC bond holdings. Since liquid assets command a liquidity premium, KC earns a higher rate of return on its foreign assets than it pays on its foreign liabilities. KC is a net debtor, but the difference in the rates of return is sufficient in the steady state to balance the income receipts and payments. So, the current account is balanced in the steady state.
Canzoneri, Cumby and Diba[8] provides a discussion of data sources and estimation procedures for the parameters that we have estimated, including the shock processes described below. A number of other parameters reported in Table 1 have standard values taken from the literature. But our model has a number of parameters (those in our specifications of transactions costs and the transactions technology) that we cannot pin down in a standard way. We set \( \Pi^*, R^* \), and the ratios reported in the first panel of Table 1 using data, and we set transactions cost (\( \tau^* \)) to 0.8 percent of consumption. We then use the ratios in the steady state equations to back out the parameters reported in the second panel of Table 1, and calculate the relevant steady state values of some other variables along the way.

Specifically, we have \( \bar{R}^* = \Pi^*/\beta \); we set \( \bar{R} = \bar{R}^* \), \( \Pi = \Pi^* \), and \( q = 1 \), by symmetry. We then solve the Home household’s optimality conditions (7), (8) and (9) to eliminate the terms involving velocity and calculate the values of \( \omega_1, \omega_2 \) and \( \omega_3 \) that are consistent with the values of asset holding ratios found in Table 1. Similarly, we use the corresponding KC household’s optimality conditions to infer the values of \( \omega_1^* \) and \( \omega_2^* \). Next, we use the equations defining velocity and effective transactions balances to calculate the steady state values of velocity terms that are consistent with our asset holding ratios and the values of \( \omega_1, \omega_2, \omega_3, \omega_1^* \) and \( \omega_2^* \). We then solve (3) and (8), and their KC counterparts, for the satiation levels of velocity and the parameters \( A \) and \( A^* \) in our specification of transactions costs. Given these parameter values, the rest of our steady state calculations are standard – the real wage is pinned down by the firms’ optimality condition, we can calculate employment from the labor-leisure margin, and so on.
2.1.5 **Fiscal Policy** –

The Home government’s flow budget constraint is

\[ m_t + b_t - b_{KC,t}^G q_t + R_{t-1}^* b_{KC,t-1}^G q_t/\Pi_t^* = p_{H,t} g_t - x_t + (m_{t-1} + R_{t-1} b_{t-1})/\Pi_t \]  

(16)

Home government spending, \( g_t \), falls entirely on Home output; \( p_{H,t} \) is the price of Home goods relative to the price of the Home consumption good.

We assume Home government spending is held constant; that is, \( g_t = \bar{g} \), where bars indicate steady state values. Lump sum taxes, \( x_t \), assure fiscal solvency:

\[ x_t - \bar{x} = \varphi (b_t - \bar{b}) \]  

(17)

where \( \varphi \) is greater than the steady state real rate of interest on government bonds.

Fiscal policy is "Ricardian" in the sense of Woodford[26], or "passive" in the sense of Leeper[18]. However, the model is non-Ricardian in the traditional sense. Why? Government bonds provide liquidity services, so the government borrowing rate, \( R_t \), is less than the CCAPM rate, \( \bar{R}_t \), at which households discount their utility. Shocks to government spending or lump sum taxes – should we consider them – would have strong wealth effects on household consumption.

KC fiscal policy is modeled in an analogous way, but with a few exceptions. The KC government does not hold Home government bonds. And, we model shocks to estimated KC spending and tax processes:

\[ \log(g_t^*) = (1 - 0.98) \log(\bar{g}^*) + 0.98 \log(g_{t-1}^*) - \varepsilon_{g^*} \]  

(18)

\[ \log(x_t^*) = 0.90 \log(x_{t-1}^*) + \varepsilon_{x^*} \]  

(19)

\( \varepsilon_{g^*} \) and \( \varepsilon_{x^*} \) represent fiscal retrenchments in the KC; the first is a spending cut, and the second is a tax increase. The KC has two lump sum taxes. One, \( x_t^* \), is used to

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8 See Appendix for the details.
assure fiscal solvency (via a policy analogous to equation (17); the other, $\tau'_t$, is used to define the tax shock.

2.2 Monetary Policy

We assume the Home central bank has adopted inflation targeting as it’s nominal anchor. The central bank uses a Taylor rule to guide it’s interest rate settings in this endeavour, and it uses open market operations (purchases or sales of Home government bonds) to achieve the interest rate settings prescribed by this rule. But since Home and Key currency bonds are imperfect substitutes, foreign exchange interventions (purchases or sales of foreign reserves) have different effects than open market operations. So, the Home central bank has a second monetary policy tool – foreign exchange interventions – that can enhance its basic inflation targeting regime. Here, we describe the general effects of a central bank sale of foreign reserves, and in the next section, we describe the optimal (Ramsey) intervention in response to various shocks emanating from the key currency country.

2.2.1 Inflation Targeting –

The Home central bank follows a Taylor rule (without a gap term) to implement it’s inflation targeting regime:

$$\log\left(\frac{R_t}{\bar{R}}\right) = 0.8 \log\left(\frac{R_{t-1}}{\bar{R}}\right) + (1 - 0.8)2.0 \log\left(\frac{\Pi_t}{\bar{\Pi}}\right)$$  (20)

where the steady state inflation rate, $\bar{\Pi}$, is the central bank’s inflation target. We assume that the policy rate is the Home government bond rate.
The KC central bank follows an analogous rule:\(^9\)

\[
\log\left(\frac{R_t^*}{\bar{R}^*}\right) = 0.8\log\left(\frac{R_{t-1}^*}{\bar{R}^*}\right) + (1 - 0.8)2.0\log\left(\frac{\Pi_t^*}{\bar{\Pi}^*}\right) - \varepsilon_{R^*}
\]

(21)

where \(\varepsilon_{R^*}\) is a cut in the KC policy rate. Since the Taylor rule is highly inertial, this shock produces a very persistent decrease in the KC policy rate, which would in turn create a persistent depreciation of the KC exchange rate.

2.2.2 A Home Foreign Exchange Intervention –

Here, we describe the short run effects of a very persistent sale of foreign reserves:\(^10\)

\[
\log(b_{KC,t}^G) = (1 - 0.95)\log(b_{KC}^G) + 0.95\log(b_{KC,t-1}^G) - \varepsilon_{b^*}
\]

(22)

Figure 1A illustrates the basic effects of this foreign exchange intervention. The sale of foreign reserves causes a real appreciation, which in turn lowers Home inflation and decreases Home output.

It is important to recognize that the effects of a foreign exchange intervention depend crucially upon what the Home central bank is doing with its open market operations and the interest rate. In Figure 1A, the central bank is using open market operations to make the policy rate consistent with its Taylor rule (20); that is, the intervention is conducted within an inflation targeting regime.

Alternatively, the central bank could use its open market operations to "sterilize" the foreign exchange intervention (that is, hold the Home money supply constant); in this case, interest rates will follow a very different path. The dashed lines in Figure

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\(^9\)The parameters in the interest rate rule are chosen to conform with standard estimates of the U.S. Taylor rule.

\(^{10}\)The parameters in this AR(1) process are actually taken from a regression of official holdings of U.S. treasury bonds.
IB show the effects of a sterilized intervention of the same size; here, both the Home and Foreign central banks are using open market operations to make their nominal money supplies grow at the steady state rate of inflation.

For better or worse, a given sale of foreign reserves has a greater impact on inflation and output in an inflation targeting regime. The intervention policies we discuss in the next section should not be confused with sterilized interventions; the distinction is important quantitatively. We turn next to optimal foreign exchange intervention within an inflation targeting regime.

3 Intervention Policies

In this section, we derive the Ramsey response to policy shocks coming from developed economies, or in our simple two country framework, the KC.\textsuperscript{11} The first shock is a sustained decrease in the KC policy rate; this creates a sustained depreciation of the KC currency (unless of course the Home central bank does something to thwart it). The second shock is a sustained decease in KC government spending, and the third is a sustained increase in KC taxes. The final shock is combination of all three shocks: a one standard deviation cut in the policy rate, a one standard deviation cut in government spending, and a one standard deviation increase in taxes.\textsuperscript{12}

As we shall see, the Ramsey responses are rather complex; implementing a Ramsey policy may be beyond the capability of central banks in practise. So, for each shock coming from the KC, we will consider three alternative policies that have actually been used in practise. The first is to simply do nothing; that is, the Home central

\textsuperscript{11}The calibration of these shocks is discussed Canzoneri, Cumby and Diba.[8]

\textsuperscript{12}The standard deviations come from estimates of stochastic processes for U.S. government spending, taxes, and the U.S. Taylor rule. See Canzoneri and coauthors[8]
bank sticks to pure inflation targeting, as defined by its Taylor rule. The second and third alternatives are leaning against the wind policies. One is to smooth nominal exchange rate movements; more specifically, foreign exchange interventions limit the standard deviation of changes in the nominal exchange rate to half of what it would be with pure inflation targeting. The other is to smooth real exchange rate movements; the standard deviation of changes in the real exchange rate is limited to half of it would be with be with pure inflation targeting. In each case, the exchange rate is smoothed around its long run equilibrium value. A vast empirical literature is devoted to estimating these equilibrium values; so, we will assume that these intervention policies would indeed be implementable.

First however, we must discuss how we select the steady state level of foreign reserves. On the one hand, the Home government would like to sell all of its KC bonds – or even go negative in them if that were allowed – because they pay less than the CCAPM bond (which has no liquidity value); on the other hand, the Home central bank needs foreign reserves to conduct its intervention policy. It is beyond the scope of the present paper to calculate the optimal steady state level of reserves. Instead, we assume that the Ramsey planner maximizes

$$ U_{Ramsey} = U_{household} + \kappa E \sum_{t=0}^{\infty} \beta^t \log(l_{KC,t}^{C}) $$

where $U_{household}$ was defined in equation (1). We set $\kappa$ at a very small number (0.001); so, the Ramsey planner is basically maximizing household utility.

In describing the various intervention policies, we will focus our attention on two of the factors that the planner generally has to trade off: getting the right balance between labor and leisure, and minimizing fluctuations in the aggregate price level.\textsuperscript{13}

\textsuperscript{13}With staggered price setting, fluctuations in the aggregate price level cause a dispersion of intermediate goods’ prices that distorts household consumption decisions; see Woodford\textsuperscript{27}. 
Since firms’ production is linear in labor, output is synonymous with work effort in the impulse response functions analyzed in the next section. \(^{14}\) Our focus on inflation and output volatility is similar to that in many official studies of intervention policy, and monetary policy more generally. \(^{15}\) Note however, that our Ramsey planner is concerned with the household’s labor - leisure balance, and is not trying minimize output fluctuations per se. This fact drives many of our results.

Our purpose here is to derive the Ramsey response to the foreign shocks described above and to compare its medium run effects with those of the alternative intervention policies; we take the medium run to be four years (or sixteen quarterly periods).

### 3.1 Responses to a Foreign Depreciation

The solid lines in Figure 2A show the optimal response to a sustained cut in the KC policy rate. The dashed lines show what would happen if the Home central bank stuck to pure inflation targeting. We begin with the latter.

With no intervention, the real exchange rate appreciates, as would be expected, but Home output rises. This may sound contradictory, and indeed in a symmetric version of our model, Home output falls (at least initially). \(^ {16}\) Several factors limit the output decrease in either version of our model: First, KC income rises and this creates demand for the Home good, partially offsetting the relative price effect. And second, the real appreciation lowers the price of KC goods, and this is deflationary

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\(^{14}\) Staggered price setting creates a distortion between aggregate output and the aggregate work effort. However, the distortion is second order; so, it does not show up in impulse functions derived from the linearized model.

\(^{15}\) See for example the recent intervention studies of Ostry, Ghosh and Chamon[21] and Benes, Berg, Portillo and Vavra[1]

\(^{16}\) In the symmetric version, Home households do not use KC bonds for transactions purposes or price their exports in terms of the key currency.
in the initial period; that is, the Taylor rule implies that Home nominal (and real) interest rates fall. In the present version of our model, there is also a third factor. The appreciation increases the real value of Home households’ stock of KC bonds; this creates a strong non-Ricardian wealth effect on Home consumption, and adding this last factor eliminates the decrease in output altogether.

The optimal foreign exchange intervention is for the Home central bank to actually buy KC bonds. As explained in Section 2, this has an expansionary effect on inflation and output. In other words, pure inflation targeting results in too little work and not enough consumption; the optimal intervention seeks to correct this imbalance. So, both the Taylor rule and the optimal intervention are expansionary, and to an extent that they actually destabilize output. This intervention policy also smooths fluctuations in the inflation rate, reducing the relative price distortion created by staggered price setting.

It would appear, however, that the outcomes for inflation and output under these two policies are not too dissimilar, at least over the first six or eight quarters. The Ramsey policy is of course the best policy, but it may be impractical to implement. Can a leaning against the wind policy do better than pure inflation targeting?

Figure 2B compares the optimal intervention policy with the two policies of leaning against the wind. Reducing the volatilities of nominal or real exchange rate changes by half requires large purchases of KC bonds; these interventions are much larger than is optimal. And the paths of the real exchange rate are far from optimal, especially for real exchange rate smoothing.

Maintaining "competitiveness" is the usual concern in a currency war, but policies of smoothing relative prices around their long run values would not seem to be appropriate in this regard. When competitiveness is evaluated with the labor - leisure decision in mind, it is not synonymous with relative price smoothing.
Nominal exchange rate smoothing results in an output path that is relatively close to optimal; moreover, inflation fluctuations are almost eliminated. Real exchange rate smoothing appears to do rather poorly – there is not nearly enough work effort after the second period and too much leisure. In addition, inflation fluctuates widely, which increases relative price dispersion and lowers welfare. Pure inflation targeting certainly seems preferable to real exchange rate smoothing in response to a low interest rate policy coming from abroad.

3.2 Responses to Foreign Fiscal Retrenchments

Fiscal retrenchments can come in the form spending cuts or tax hikes, or some combination of the two. We have assumed that taxes are non-distortionary, but even a lump sum tax increase will lower aggregate demand in our model since it is non-Ricardian. As explained earlier, household wealth effects play a large role in our model, and fiscal retrenchments – at home or abroad – can have a strong impact on consumption and output.

3.2.1 A Foreign Government Spending Cut

The solid lines in Figure 3A show the optimal response to a sustained decrease KC government spending, and the dashed lines show what would happen if the Home central bank stuck to pure inflation targeting. As before, we begin with this case.

With no intervention, the KC spending cut decreases the demand for KC goods, causing the Home real exchange rate to appreciate. This in turn decreases Home inflation and output. But once again, the initial effect on the real exchange rate is attenuated by several factors: The first is nominal price rigidity, which slows relative price adjustments. And the second is the Home central bank’s inflation targeting;
its Taylor rule calls for a decrease in interest rates, which limits the nominal and real appreciations.

The KC spending cut is a relative demand shock, and efficiency requires a relative price adjustment. Price rigidities and inflation targeting get in the way of this. Output and the work effort do not fall enough. Once again the labor - leisure margin is out of balance; households are off their labor supply curve because of price rigidity.

The optimal foreign exchange intervention is to sell KC bonds, causing the real exchange rate to appreciate more, and bringing the labor - leisure margin more into balance. The optimal policy is not to stabilize output, but to push it further down. Both inflation and output fall more, and Taylor rule calls for an even bigger decrease in interest rates. It is interesting to note that inflation targeting and foreign exchange intervention are taking opposite stances in this case. The Taylor rule calls for inflationary interest rate setting, while the optimal intervention policy calls for deflationary foreign bond sales. Inflation credibility (the inflation targeting) and optimal stabilization (the optimal intervention policy) are at odds with one another.

Figure 3B compares the optimal intervention policy with the two policies of leaning against the wind. Reducing the volatilities of nominal and real exchange rate changes by half requires large purchases of KC bonds. These interventions go in the opposite direction of the optimal interventions. Leaning against the wind does tend to stabilize output, but once again, that is not the best thing to do. In addition, inflation fluctuations are large compared to their optimal path.

The basic message here is that efficient adjustment to real shock requires a change in relative prices. Stabilizing exchange rates around their long run equilibrium values appears to be counterproductive. Comparing figures 3A and 3B, pure inflation targeting would seem preferable to the leaning against the wind policies.
3.2.2 A Foreign Tax Increase

Figures 4A and 4B show the various policy responses to a sustained increase in KC taxes, and they tell much the same story as the spending cut. The KC consumer has a home bias for the KC good, so the tax hike decreases the relative demand for KC goods. The efficient adjustment to this shock requires a change in relative prices. For the reasons given above, the real appreciation under pure inflation targeting is insufficient. And the optimal intervention is to sell reserves, amplifying the real appreciation. Once again, intervention policy works to undo the damage done by interest rates under inflation targeting.

Intervention policies that lean against the wind are counter productive: they go the wrong way. Comparing the two figures, pure inflation targeting seems preferable to leaning against the wind.

3.3 Responses to a Depreciation and a Fiscal Retrenchment

Figures 5A and 5B show the policy responses to a combination of shocks coming from abroad: the KC interest rate is lowered by one standard deviation, KC government spending is cut by a standard deviation, and KC taxes are increased by a standard deviation. The solid lines in Figure 5A show the optimal response, and the dashed lines show the response to pure inflation targeting. The results are of course a kind of averaging of the three previous exercises.

With this combination of shocks, the shape of the paths for inflation and output look like those in Figure 2A for a KC interest rate cut. However, the policy prescription for foreign exchange intervention looks more like those in Figures 3A and 4A for fiscal retrenchments. The central bank sells reserves to increase the real exchange rate appreciation, and decrease the work effort. And once again, inflation targeting
and foreign interventions work in opposite directions: since inflation and output fall initially, the Taylor rule calls for an inflationary policy, while the optimal intervention policy is deflationary.

Figure 5B shows that the optimal intervention is relatively modest, while the leaning against the wind policies require massive interventions and in the wrong direction. Pure inflation targeting seems preferable to leaning against the wind for this combination of shocks.

4 Leaning Against the Wind: cautionary tales

The last section offered some cautionary tales about intervention policies that lean against the wind when external events cause exchange rates to fluctuates. Smoothing real exchange rate movements seems to be particularly problematic. In many cases, pure inflation targeting – or refraining from intervening – seemed the better part of valor.

The advantage of the leaning against the wind policies is that they are implementable. In practise. All they require is an estimate of the long run equilibrium value of the real (or nominal) exchange rate, and there has been considerable effort put into obtaining such estimates. By contrast, the Ramsey policies described here are quite complex and are probably not implementable.

The problem is that efficient adjustment to real shocks requires movements in relative prices, at least in the short to medium run; the real exchange rate can accommodate some of the real consequences of changes in relative supplies and demands if it is allowed to move. Moreover, with price rigidities, the same is true for

\footnote{If the shocks are not stationary, the long run real exchange rate will also be affected. The shocks we considered were all stationary.}
monetary shocks, such as the foreign depreciation considered above.

To be fair, most of those who advocate leaning against the wind policies would probably not characterize them as we have here. They advocate smoothing real or nominal exchange rate movements around "intermediate" targets, not a long run value. We have not tried to derive operational intermediate targets because it is not clear how one would do so. For one thing, there is no single intermediate target for either the nominal or the real exchange rate. The appropriate intermediate target depends upon the shock, or combination of shocks, that is causing the exchange rate to move. These leaning against the wind policies might be as complex as the Ramsey policy.

Of course, pure inflation targeting requires none of this; it is operational. The real question for central banks is if they think they have enough information to intervene successfully. Once again, discretion may be the better part of valor.

5 In Conclusion

We have already summarized our main conclusions in the last subsection. In concluding, we will discuss two topics that might be worth pursuing in future work. Our cautionary tales suggest that smoothing exchange rate movements around previously estimated long run equilibrium values may not be a good idea. Smoothing around a state (or shock) dependent intermediate target may be an effective policy. The problem of course is in identifying the appropriate target. This project seems well worth pursuing, especially at central banks that want to implement the enhanced inflation targeting regime advocated recently by IMF staff.

Another issue is whether or not foreign exchange interventions have a different ef-
fect than open market operations, and if they do, why.\textsuperscript{18} As mentioned earlier, there is an empirical literature suggesting that they do, but the answer is still controversial. We have made home and foreign bonds imperfect substitutes in our model by assuming that they both facilitate trade. If however they are imperfect substitutes for some other reason – say risk premia, or capital market imperfections – then foreign exchange interventions could have very different effects than what we obtain in our model. All of this suggests that model uncertainty should be taken into account if a central bank is serious about trying to implement the enhanced inflation targeting regime.

There is literature on robust control that incorporates model uncertainty into policy evaluation.\textsuperscript{19} In particular, this literature tries to develop policy rules that are robust to model misspecification. In our case, bonds may not even be imperfect substitutes, or they may be imperfect substitutes in a different way, or to a different degree, than was modeled. Applying these techniques to the issues discussed here would seem most appropriate.

\textsuperscript{18}As explained earlier, home and foreign bonds must be imperfect substitutes if foreign exchange intervention is to be an additional policy tool in an inflation targeting regime.

\textsuperscript{19}See Hansen and Sargent\cite{HansenSargent2012} and Giordani and Soderlind\cite{GiordaniSoderlind2009}
References


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Figure 1A: Foreign reserve sale (within the context of inflation targeting)
Figure 1B: foreign reserve sale

inflation

output

real exchange rate

foreign reserves

inflation targeting = solid; sterilized intervention = dashed
Figure 2A: foreign interest rate decrease

- Inflation
- Output
- Nominal government bond rate
- Real government bond rate
- Real exchange rate
- Foreign reserves

Ramsey policy = solid; no intervention = dashed
Figure 2B: foreign interest rate decrease

Ramsey policy = solid; smoothed nominal exchange rate = dashed; smoothed real exchange rate = dotted
Figure 3A: foreign government spending decrease

- Inflation
- Output
- Nominal government bond rate
- Real government bond rate
- Real exchange rate
- Foreign reserves

Ramsey policy = solid; no intervention = dashed
Figure 3B: foreign government spending decrease

Ramsey policy = solid; smoothed nominal exchange rate = dashed; smoothed real exchange rate = dotted
Figure 4A: foreign tax increase

- Inflation
- Output
- Nominal bond rate
- Real government bond rate
- Real exchange rate
- Foreign reserves

Ramsey policy = solid; no intervention = dashed
Figure 4B: foreign tax increase

inflation

output

realexchange rate

foreign reserves

Ramsey policy = solid; smoothed nominal exchange rate = dashed; smoothed real exchange rate = dotted
Figure 5A: Foreign depreciation and fiscal retrenchment

- Inflation
- Output
- Nominal government bond rate
- Real government bond rate
- Real exchange rate
- Foreign reserves

Fadley policy = solid; no intervention = dashed
Figure 5B: foreign depreciation and fiscal retrenchment

Ramsey policy = solid; smoothed nominal exchange rate = dashed; smoothed real exchange rate = dotted