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Monetary-Exchange Rate Policy and Current Account Dynamics

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A dynamic stochastic general equilibrium monetary model with incomplete and imperfect asset markets, monopolistic competition and staggered nominal price rigidities is developed to shed light on the role of exchange rate and its relation with current account dynamics in the formulation of monetary-exchange rate policies. The paper shows that the dynamic relationship between real exchange rate and net foreign assets affect the behavior of domestic inflation and aggregate output as a result of incomplete risk sharing due to incomplete asset markets,. This, in turn, implies that the optimal monetary policy should entail a response to net foreign asset position or the real exchange rate gap defined as the difference between actual real exchange rate and the value that would prevail with flexible prices and complete asset markets. In comparing the performance of alternative monetary-exchange rate policy rules, an interesting and fairly robust result that stands out is that 'dirty floating' outperforms flexible exchange rate regime with domestic inflation targeting.

1. Introduction

Traditionally, the effects of monetary policy on aggregate economic activity in an open economy setting have been largely studied within the framework developed by Mundell (1963), Fleming (1962), and Dornbusch (1976). Although the Mundell-Fleming-Dornbusch (MFD) framework has played a dominant role in shaping the literature on open economy macroeconomics (largely due to its empirical success and popularity among policy makers), it has certain important methodological drawbacks. These include lack of microfoundations for the aggregate macroeconomic relationships, inability to provide well-defined welfare criteria by which to evaluate the effectiveness of alternative macroeconomic policies, disregard of the role of the intertemporal budget constraints, which is central in the analysis of the current account and exchange rate dynamics, and failure to provide an explicit account of how monetary policy affects firm's production and price-setting decisions.

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Beginning with the seminal contribution by Obstfeld and Rogoff (1995a, 1996), considerable amount of research (labelled as 'New Open Economy Macroeconomics' (NOEM)[1]) has been done to overcome these drawbacks. The highlighting features of a typical NOEM model are dynamic general equilibrium framework as the workhorse of analysis, staggered price-setting structure, and the use of nominal interest rate as an instrument of monetary policy. Examples of this literature include Clarida, Gali and Gertler (2001), Gali and Monacelli (2002), Monacelli (2000), McCallum and Nelson (2000), Walsh (1999), and many others. Some of the important and widely accepted results of optimal monetary policy in an open economy setting are provided by Clarida, Gali and Gertler (2001) and Gali and Monacelli (2002). For instance, they claim that under certain standard conditions domestic inflation targeting is the optimal monetary policy and that the central bank should not respond to exchange rate movements, that is, it should allow the exchange rate to float freely. Moreover, there is no role for current account dynamics and the welfare criterion or the objective function of the central bank just includes targeting domestic inflation and output around the 'flexible-price' optimal value.

The contribution of this paper is that it provides new insights to the questions pertaining to the conduct of monetary policy in an open economy by clarifying the role of exchange rate and its relation with current accounts in a dynamic general equilibrium model with incomplete and imperfect asset markets, monopolistic competition, and staggered nominal price rigidities. In particular, the paper explicitly captures the interaction of current account dynamics with key macroeconomic variables, analyzes their implications for the monetary-exchange rate policy, and demonstrates that the welfare-enhancing monetary policy implies a dirty float under domestic inflation targeting.

The debate over the role of exchange rate in the formulation of monetary policy is far from being settled. Numerous issues have been considered in the NOEM literature in this regard. For instance, it depends on the currency in which firms set their prices. If firms set their prices in the seller's currency, known as producer currency pricing (PCP), then a number of researchers such as Obstfeld and Rogoff (1995a), Gali and Monacelli (2002), Clarida, Gali and Gertler (2001), Engle (2002), Corsetti and Pesenti (2001a, 2001b) and Sutherland (2000, 2002) have shown that the monetary authority should only target domestic prices and let the exchange rate float. On the other hand, if firms are assumed to set their prices in the buyer's currency, known as local currency pricing (LCP), then the domestic

[1] A number of articles provide detailed and critical survey of this literature. For example, Sarno (2001), Lane (2001), Bowman and Doyle (2003) and Van Hoose (2004).

price level remains completely unaffected by exchange rate movements and therefore to ensure complete risk sharing the monetary authority should keep the exchange rate fixed [Betts and Devereux (2000), Devereux and Engel (2000, 2002)]. Other variations in this debate include traded versus non-traded goods [Obstfeld and Rogoff (2000, 2002)], complete versus incomplete exchange rate pass-through [Corsetti and Pesenti (2001b), Sutherland (2002), Smets and Wouters (2002)], and domestic versus CPI inflation targeting [Svensson (2000)]. It is important to note, however, that most of this literature ignores the dynamics of current account or net foreign assets.

It seems that the key motivation to shut down the current account channel as a dynamic shock-propagation mechanism is to keep the analysis simple. This is accomplished by either incorporating the complete asset markets assumption[2] [e.g. Clarida, Gali and Gertler (2001), Gali and Monacelli (2002), Chari, Kehoe and McGrattan (1998) and Devereux and Engel (2000)] or by imposing a unitary elasticity of substitution between domestic and foreign goods[3] [e.g., Corsetti and Pesenti (2001a, 2001b), Tille (2001)]. However, as pointed out by Obstfeld and Rogoff (1995b), the assumption of complete asset markets is not realistic in a model with imperfections and rigidities in goods market because with nominal rigidities monetary policy will affect real variables including the current account. Thus, with incomplete asset markets the dynamics of current account does matter for monetary policy because then, besides dealing with the distortions created by monopolistic competition, the central bank needs to address the inefficiencies caused by incomplete asset markets. Moreover, in an empirical paper, Lane and Milesi-Ferretti (2002) link net foreign asset positions to long-run values of real exchange rates and suggest that optimal monetary policy responses may depend on the movements in the current account.

Based on these observations, I have incorporated incomplete asset markets by assuming that domestic economic agents have access to a one-period risk-less (non-contingent) domestic bond and a foreign bond.[4] Thus, all country specific

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[2] Complete asset markets mean that economic agents are able to trade as many state-contingent assets as there are future states of nature thus insuring themselves against any type of risk or shock that may hit the economy. Thus, complete risk pooling takes place among countries and there will be no gains from intertemporal trade. That is, current account remains unaffected.

[3] A unit elasticity of substitution implies that expenditures on domestic and foreign goods incurred by the economic agents are constant leading to constant export revenues. This implies that if the current account begins in balance, it remains in balance. The advantage of this approach is that we can solve the model without resorting to log-linearization.

[4] An alternative method of introducing incomplete asset markets is to assume that the economic agents have access to state-contingent assets that have nominal rather than real pay-offs. Markets are

shocks/risks cannot be fully insured against, so there is a possibility that current account imbalances may occur. It is important to note, however, that in all future periods after a shock the consumption differential between countries follows a random walk meaning that there is no well-defined endogenously determined unique steady state. Since there is a possibility of an infinite number of steady-state equilibria, log-linearization of the model is also problematic and can be very inaccurate [Kim and Kose (2001)] because one would be approximating the dynamics of the model around a moving steady state. In order to explore the implications of current account dynamics for other macroeconomic variables and monetary policy, while maintaining a unique steady state, an endogenous risk premium that depends on the domestic country's net foreign asset position is incorporated. Examples of this approach include Benigno (2001) and Selaive and Tuesta (2003).[5]

The main result of the paper is that managed exchange rate regime (dirty floating) is superior to flexible exchange rate regime under domestic inflation targeting. The central bank faces no trade-off between stabilizing the real exchange rate and domestic inflation and output gap. Volatility in both output and domestic inflation goes down and so does the volatility in real exchange rate thus improving social welfare. However, it is important to note that as the central bank tries to stabilize the real exchange rate 'too much', that is, approaches fixed exchange rate case, welfare decreases. Thus, the analysis does not imply that policy should always aim to eliminate exchange rate gaps. Some exchange rate gap may well be necessary to avoid large output gaps. The key reason behind this unconventional yet important result is the presence of current account dynamics affecting not only the real exchange rate behavior via imperfect risk sharing due to incomplete asset markets, but also the output gap via the risk premium term in the interest parity relationship. This result is quite robust and holds regardless of the welfare criterion used: whether it includes real exchange rate movements, or focuses only on output gap and inflation movements. Also, the result remains unchanged

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considered incomplete in the sense that agents can not undo the effects of sticky prices [see, Devereux and Engel (2001) and Engle (2002)].

[5] Other approaches include Mendoza (1991), which assume that the rate of time preference is a decreasing function of consumption; Schmitt-Grohe and Uribe (2001a), Kollmann (2001), and Bergin (2002), which assume an exogenous risk premium term; Smets and Wouters (2002), which incorporate Blanchard's (1985) overlapping generations model in which domestic agents face a non-zero probability of death at each point in time; Ghironi (2001) and Cavallo and Ghironi (2002), which uses Weil's (1989) specification of an overlapping generation set-up (where agents are born on different dates with no assets) to attain determinacy. The choice among different stationarity-generating approaches is quite ad hoc and difficult to distinguish quantitatively as shown by Schmitt-Grohe and Uribe (2001b).

whether the central bank adopts flexible inflation targeting or strict inflation targeting.

The rest of the paper is organized as follows. Section 2 develops the dynamic general equilibrium model elaborating the behavior of households and firms, and incorporates incomplete asset markets and staggered nominal price rigidities. Section 3 linearizes the optimality conditions around the steady state and expresses the dynamics of key macroeconomic variables such as output, domestic inflation, real exchange rate, and current account. Section 4 studies the behavior of the monetary authority and discusses the welfare criterion—the optimal monetary policy—in addition to alternative monetary-exchange rate policy rules. Section 5 calibrates the model and analyzes the performance of domestic and CPI inflation targeting (both flexible and strict) with varying degree of exchange rate flexibility under taste and foreign output shocks. Section 6 summarizes and provides the concluding remarks.

2. The Model

There are three types of economic agents in the economy: households, firms and the monetary authority. Given their preferences, households decide how much to consume (both domestically produced goods and imported goods) and how to allocate time between leisure and work. The firms, operating in a monopolistically competitive environment, take two decisions: how much to produce using the labor services of the households and how to set the price for their output. The monetary authority issues money and employs nominal interest rates as an instrument of monetary policy to achieve well-specified goals.

2.1. Households

The economy consists of a continuum of identical households. The model is described in terms of a representative household making decisions in the presence of uncertainties about the future with preferences defined over a composite consumption good C_t, a taste shock u_t, and leisure $1-N_t$. This representative household seeks to maximize the expected present discounted value of utility:

$$E_t \sum_{k=0}^{\infty} \beta^k \left[\frac{u_t C_{t+k}^{1-\sigma}}{1-\sigma} - \psi \frac{N_{t+k}^{1+\phi}}{1+\phi} \right] \qquad (1)$$

where 'β' captures rate of time preference, 'σ' represents the intertemporal elasticity of substitution, 'ϕ' is the elasticity of substitution between consumption and leisure, and thus measures the elasticity of labor supply, and 'ξ' is the interest rate elasticity of money demand. All parameters are assumed to be positive.

The composite consumption index is a function of domestic and foreign goods, and is defined as:

$$C_t = \left[(1-a)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + a^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \qquad (2)$$

where 'η' is a measure of the elasticity of substitution between domestic and foreign goods and parameter 'a' represents the share of foreign (imported) goods in the consumption index. I have assumed that consumption is differentiated at the individual goods level. Thus, the domestic and foreign goods consumption indices, $C_{H,t}$ and $C_{F,t}$ respectively, can be written as CES (constant elasticity of substitution) aggregators of the quantities consumed of each type of good: $C_{H,t} = \left(\int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$ and $C_{F,t} = \left(\int_0^1 C_{F,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}$, where 'ε' is the elasticity of substitution within each category.[6]

By maximizing Equation (2) subject to the total expenditure on home and foreign goods, the demand functions for home and foreign consumption goods can be

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[6] The demand functions for goods within each category can be determined by maximizing $C_{H,t}$ and $C_{F,t}$ expressions individually, with respect to the total expenditure on the respective category of good, given as $Z_{H,t} = \int_0^1 P_{H,t}(j) C_{H,t}(j) dj$ and $Z_{F,t} = \int_0^1 P_{F,t}(j) C_{F,t}(j) dj$. $P_{H,t}(j)$ and $P_{F,t}(j)$ are the prices of the consumption goods $C_{H,t}(j)$ and $C_{F,t}(j)$ respectively. The demand functions that emerge from this maximization exercise are given as: $C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t}$ and $C_{F,t}(j) = \left(\frac{P_{F,t}(j)}{P_{F,t}} \right)^{-\varepsilon} C_{F,t}$, where $P_{H,t}$ and $P_{F,t}$ are the price indices for domestic and foreign (imported) goods respectively that satisfy the expenditure equations that can be expressed as $Z_{H,t} = P_{H,t} C_{H,t}$ and $Z_{F,t} = P_{F,t} C_{F,t}$. The expressions for $P_{H,t}$ and $P_{F,t}$ are given as: $P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$ and $P_{F,t} = \left(\int_0^1 P_{F,t}(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$

derived. The total expenditure equation can be written as: $Z_t = P_{H,t}C_{H,t} + P_{F,t}C_{F,t}$. The optimality condition yields the following equations:

$$C_{H,t} = (1-a)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \quad (3)$$

$$C_{F,t} = a\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t \quad (4)$$

where P_t is the overall price index (CPI) and is given as:

$$P_t = \left[(1-a)P_{H,t}{}^{1-\eta} + aP_{F,t}{}^{1-\eta}\right]^{\frac{1}{1-\eta}} \quad (5)$$

In the rest of the world a representative household faces a problem identical to the domestic household's problem. It is assumed that a foreign household's utility function is analogous to that of a domestic household with the exception that foreign households do not face any taste shocks. Thus, relationships similar to Equations (3) and (4) hold for the foreign country. Following Clarida et al. (2002), I have assumed that the foreign country is very large relative to the domestic economy. One way to think of it is to consider the foreign country as the rest of the world. This assumption implies that the share of domestic goods consumed by the rest of the world is negligible; so $P^*_{F,t} = P^*_t$ as $a^* \to 0$, 'a^*' being the share of foreign goods (domestic economy's exports) in the overall consumption index of the foreign country. Thus, the relationship linking the terms of trade and the real exchange rate ca be written as:

$$Q_t = ToT_t \frac{P_{H,t}}{P_t} \quad (6)$$

where real exchange rate is defined as: $Q_t = \frac{S_t P^*_t}{P_t}$ and terms of trade (price of imported goods relative to domestic goods) is defined as: $ToT_t = \frac{P_{F,t}}{P_{H,t}} = \frac{S_t P^*_{F,t}}{P_{H,t}}$. S_t is the nominal exchange rate.

In nominal terms the representative household 'h's intertemporal budget constraint is given as[7]:

$$W_t^h N_t^h + P_t TR_t^h + P_t \Pi_t^h + M_{t-1}^h + B_{H,t-1}^h + S_t B_{F,t-1}^h = \\ P_t C_t^h + M_t^h + \frac{B_{H,t}^h}{\left(1+i_t\right)} + \frac{S_t B_{F,t}^h}{\left(1+i_t^*\right)\phi\left(S_t B_{F,t} / P_t\right)} \tag{7}$$

The left hand side represents the resources the consumer has at his disposal at the beginning of period t. These consist of wage earnings $W_t^h N_t^h$, obtained by supplying labor services to the firm, transfers $P_t TR_t^h$ from the monetary authority, share of profits $P_t \Pi_t^h$ from firms', amount of money M_{t-1}^h held, the amount of one-period risk-free domestic bonds $B_{H,t-1}^h$, and the amount of one-period risk-free foreign currency denominated bonds $B_{F,t-1}^h$ purchased. The right hand side corresponds to the uses of these resources. The household can use these to consume goods, acquire new money balances or purchase new bonds. The important point to note is that the price of foreign currency denominated bond is proportional to its gross nominal interest rate, $(1+i_t^*)$. Following Benigno (2001) and Selaive and Tuesta (2003), $\phi(.)$ is assumed to be a decreasing function of the economy's stock of real foreign assets, $b_t = S_t B_{F,t} / P_t$, and is given as:

$$\phi(b_t) = \kappa(e^{\bar{b}-b_t} - 1) \tag{8}$$

where κ is some constant and $\bar{b}$ is the steady state level of real foreign assets. Thus, $\phi(.)$ is the risk premium term representing the cost of participating in the international assets market and allows us to obtain a well-defined steady state.

The following optimality conditions [derived by maximizing Equation (1) subject to Equation (7)] must hold for this household in equilibrium:

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[7] It can be assumed that the initial wealth is the same across all the domestic economy's households and that they all work for all the firms sharing the profits in equal proportion. This set of assumptions implies that all the households in the domestic economy face the same budget constraint and that in their consumption decision will choose the same consumption path. Thus index h can be dropped and a representative household's behavior can be considered.

$$\beta E_t\left(\frac{u_{t+1}}{u_t}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)=(1+i_t)^{-1} \tag{9}$$

$$\beta E_t\left(\frac{u_{t+1}}{u_t}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)\left(\frac{S_{t+1}}{S_t}\right)=\frac{\left(1+i^*\right)^{-1}}{\phi(b_t)} \tag{10}$$

$$\frac{W_t}{P_t}=\psi\left(u_t^{-1}C_t^{\sigma}\right)N_t^{\phi} \tag{11}$$

$$\frac{S_t B_{F,t}}{\left(1+i_t^*\right)\phi(b_t)}=S_t B_{F,t-1}+P_{H,t}C_{H,t}+S_t P_{H,t}^* C_{H,t}^* - P_t C_t \tag{12}$$

Equation (9) is the standard Euler equation for the holding of domestic bond. It has the usual interpretation that at a utility maximum, the household cannot gain from feasible shifts of consumption between periods. Similarly, Equation (10) is the efficiency condition for the holding of foreign bonds. Equation (11) represents the labor supply decision. Equation (12) represents the resource constraint of the domestic economy, which is obtained by aggregating the equilibrium budget constraint of the households with that of the government.[8]

By combining Equations (9) and (10), I have derived, after some approximations, the familiar uncovered interest parity condition depicting the optimal portfolio choices of the economic agent:

$$(1+i_t)=(1+i_t^*)\phi(b_t)E_t\,\frac{S_{t+1}}{S_t} \tag{13}$$

Analogous to the domestic household's optimization problem, similar optimality conditions hold for the representative household in the foreign country. For example, the counterpart of Equation (9) can be written as:

[8] Assuming zero government spending and imposing the condition that domestic bonds are in zero-net supply implies that for the government budget constraint to hold, all the seigniorage revenue associated with money creation must be returned to the households in the form of lump-sum transfers in each period, that is, $M_t - M_{t-1} = P_t TR_t$. Also, in equilibrium, we have: $W_t N_t + P_t \Pi_t = P_{H,t}C_{H,t} + e_t P_{H,t}^* C_{H,t}^*$

$$\beta E_t \left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\sigma} \left(\frac{P^*_t}{P^*_{t+1}} \right) = (1 + i^*_t)^{-1} \tag{14}$$

Combining Equation (14) with (10) and using the definition of real exchange rate yields the following relationship:

$$E_t \left(\frac{u_{t+1}}{u_t} \right) \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \phi(b_t) = E_t \left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\sigma} \left(\frac{Q_t}{Q_{t+1}} \right) \tag{15}$$

This equilibrium condition reflects how the representative households in each country share consumption risk. An important point to note is that both the interest parity relationship [Equation (13)] and the international risk-sharing equilibrium condition [Equation 15)] are affected by net foreign asset position of domestic households.

2.2. Firms

In order to clearly explain the mechanics of monopolistic competition in a dynamic general equilibrium setting I have defined two types of firms. The first operates in a monopolistically competitive environment and are called intermediate-good-producing firms, and the other operates in competitive markets and are called final-good-producing firms. In maximizing their profits, a representative intermediate-good-producing firm 'j' is subject to a number of constraints. First is the specification of the production function. Following McCallum and Nelson (1999), I have assumed that there is no capital in the economy and so the firm only employs the labor input, $N_t(j)$, supplied by households to produce the differentiated good:

$$Y_t(j) = A_t N_t(j) \tag{16}$$

where $Y_t(j)$ is the intermediate-good produced by firm 'j', and $A_t = \exp(z_t)$ where 'z_t' represents aggregate technology shock.

The representative firm 'j' supplies its output to the final good-producers. If the output of the final good, which is produced by using the inputs supplied by a continuum of intermediate-goods-producing firms indexed by $j \in [0,1]$, is denoted by Y_t, then the production function for the final output can be written as: $Y_t = \left[\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}$. Profit maximization by final-goods-producers (*maximize:* $P_{H,t}Y_t - \int_0^1 P_{H,t}(j)Y_t(j)dj$) yields the input demand function: $Y_t(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}}\right]^{-\varepsilon} Y_t$. This input demand function describes the second constraint faced by the intermediate-goods-producing firm ‘ j ’.

The third constraint introduces staggered price adjustment behavior based on Calvo (1983). Firms are assumed to face a constant probability $1-\rho$ in every period to alter their price in an optimal fashion. This probability is independent of how long their prices have been fixed, therefore, the fraction of firms adjusting price optimally in a period is equal to the probability of price adjustment $1-\rho$. The remaining fraction of firms ‘ ρ ’ do not adjust their price. Thus, the parameter ‘ ρ ’ captures the degree of nominal price rigidity.

To facilitate the tractability of the model, I have initially assumed that all firms can adjust their prices every period, that is, the third constraint is not binding yet.[9] Then, the profit function for a representative firm ‘ j ’ can be written as:

$$\pi_{H,t}(j) = P_{H,t}(j)Y_t(j) - W_t N_t(j) \tag{17}$$

The differentiated-good-producing firm chooses $P_{H,t}(j)$ and $N_t(j)$ to maximize these profits subject to the conditional demand for their variety of output and the production function. The expressions for $P_{H,t}(j)$ and $N_t(j)$ are given respectively as:

$$P_{H,t}(j) = \frac{\varepsilon}{\varepsilon - 1} MC_t \tag{18}$$

[9] Put differently, I have assumed that the firm’s price-setting decisions are completely independent from their factor demand decisions. One way to interpret this separation of decisions is to think of firms as having two departments; one that decides what price to set each period, and the other that decides how much output to produce taking the prices of the inputs as given.

and $\frac{W_t}{P_{H,t}(j)} = \frac{\varepsilon - 1}{\varepsilon} F_N$ (19)

where $\left(\frac{\varepsilon}{\varepsilon - 1}\right) = \upsilon$ is the constant mark-up and MC_t is the minimized nominal marginal cost. F_N is the marginal product of labor which, given the production function, is simply A_t.

Equation (18) depicts the relationship between the 'flexible' price chosen by all firms and the minimized marginal cost of production under monopolistic competition; it does not say anything about prices being sticky. Combining Equations (18) and (19), the expression for minimized nominal marginal cost is written as:

$$MC_t = \frac{W_t}{A_t} \tag{20}$$

Price stickiness is introduced by assuming that price adjustment does not take place simultaneously for all firms. Following Rotemberg (1987), suppose that a representative firm 'j' that is allowed to change its price, set its price to minimize the expected present discounted value of deviations between the price it sets and the minimized nominal marginal cost.

$$\sum_{k=0}^{\infty} \rho^k \beta^k E_t (P_{H,t}(j) - MC_{t+k})^2 \tag{21}$$

where MC_t is the minimized nominal marginal cost. Note that there are two parts to discounting. The first, β represents a conventional discount factor, and the second, ρ reflects the fact that the firm that has not adjusted its price after 'k' periods, still has the same price in period $t + k$ that she set in period t. The first order condition with respect to $P_{H,t}(j)$ gives the following optimal value denoted by $\tilde{P}_{H,t}(j)$:[10]

[10] It is reasonable to set $\tilde{P}_{H,t}(j) = \tilde{P}_{H,t}$ because all firms are identical except for the timing of their price adjustment.

$$\widetilde{P}_{H,t} = (1-\rho\beta)MC_t + \rho\beta E_t \widetilde{P}_{H,t+1} \tag{22}$$

Thus, the optimally chosen price in period t is a weighted average of nominal marginal cost and expected value of optimal price in the future. However, in period t, only a fraction $1-\rho$ of firms set their price according to Equation (20). The remaining firms are stuck with the prices set in previous periods. Since the fraction of firms that are able to optimally set their price is randomly chosen, the average price of the previous period will be the price of the fraction of firms that are unable to adjust their price this period. Therefore, the overall aggregate price level in period t is a weighted average of current optimally chosen and past prices.

$$P_{H,t} = [\rho^{1-\varepsilon} P_{H,t-1} + (1-\rho)^{1-\varepsilon} \widetilde{P}_{H,t}]^{\frac{1}{1-\varepsilon}} \tag{23}$$

where $\widetilde{P}_{H,t}$ is the price chosen by all adjusting domestic firms in period t.

3. Log-linearized Model

In this section, the model is log-linearized around the steady state. A variable in lower case represents the log deviation with respect to the steady state. In equilibrium firms are assumed to be symmetric and taking identical decisions. This implies that prices are equal for each variety of good; that is, $P_{H,t}(j) = P_{H,t}, P_{F,t}(j) = P_{F,t}$.

3.1. Output Dynamics— The New IS-curve

Assuming that the economy's output can either be consumed domestically or exported to the rest of the world, then $Y_t = C_{H,t} + C^*_{H,t}$. Log-linearizing around the steady state gives:

$$y_t = (1-a)c_{H,t} + ac^*_{H,t} \tag{24}$$

where, parameter 'a' captures the share of the exports in aggregate output.

Similarly, the log-linearized version of Equation (2) can be written as:

$$c_t = (1-a)c_{H,t} - ac_{F,t} \tag{25}$$

Now, consider Equations (3) and (4)—the demand curves for the domestic and foreign goods. The log-linearized version of the two equations are: $c_{H,t} = c_t - \eta(p_{H,t} - p_t)$ and $c_{F,t} = c_t - \eta(p_{F,t} - p_t)$, where the price differentials are given as: $p_{H,t} - p_t = -a(tot)_t$ and $p_{F,t} - p_t = (1-a)(tot)_t$ derived by using the log-linear version of Equation (5), $p_t = (1-a)p_{H,t} + ap_{F,t}$, and the log-linear version of the definition of the terms of trade, $tot_t = p_{F,t} - p_{H,t}$. Moreover, the log-linearized version of equation (6) is given as: $q_t = (1-a)(tot)_t$. Thus, using these relationships a simple expression linking the two demand curves is derived:

$$c_{H,t} - c_{F,t} = \left(\frac{\eta}{1-a}\right)q_t \tag{26}$$

Noting that as $a^* \to 0$, $c^*_{F,t} = c^*_t = y^*_t$, an expression analogous to Equation (26) for the rest of the world can be derived:

$$c^*_{H,t} - y^*_t = \left(\frac{\eta}{1-a}\right)q_t \tag{27}$$

Combining Equations (24)–(27):

$$y_t = (1-a)c_t + ay^*_t + \left(\frac{a\eta(2-a)}{1-a}\right)q_t \tag{28}$$

Thus, domestic output is a weighted average of domestic and foreign expenditures, plus an 'expenditure-switching factor' which is proportional to the real exchange rate.

In order to derive an IS-type relationship that relates output to the real interest rate, I used the Euler equations for domestic consumption [Equation (9)], foreign consumption [Equation (14)] and the uncovered interest parity condition [Equation (13)]. The log-linearized versions of these relationships are:

$$c_t = E_t c_{t+1} - \frac{1}{\sigma}\left[i_t - \left\{ \pi_{H,t+1} + \left(\frac{a}{1-a} \right) E_t \Delta q_{t+1} \right\} \right] - \frac{1}{\sigma}\left(E_t u_{t+1} - u_t \right) \quad (29)$$

$$y_t^* = E_t y_{t+1}^* - \frac{1}{\sigma}\left[i_t^* - E_t \pi_{t+1}^* \right] \quad (30)$$

$$i_t - \pi_{H,t+1} = i_t^* - E_t \pi_{t+1}^* + \left(\frac{1}{1-a} \right) E_t \Delta q_{t+1} - \kappa b_t \quad (31)$$

Note that in deriving Equations (29) and (30), I have used the relationship between CPI inflation, π_t, and domestic inflation, π_H, given as: $\pi_t = \pi_{H,t} + \left(\frac{a}{1-a} \right) \Delta q_t$.

Thus, after substituting Equations (29)–(31) in Equation (28), a relationship that resembles an IS equation is reached:

$$y_t = E_t y_{t+1} - \left(\frac{1+w}{\sigma} \right)\left(i_t - E_t \pi_{H,t+1} \right) + \left(\frac{w}{\sigma} \right)\left(i_t^* - E_t \pi_{t+1}^* \right) - \kappa \left(\frac{w+a}{\sigma} \right) b_t - \left(\frac{1-a}{\sigma} \right)\left(E_t u_{t+1} - u_t \right) \quad (32)$$

where, $w = a(2-a)(\eta\sigma - 1)$.

Following Clarida, Gali and Gertler (2001), let $x_t = y_t - y_t^0$ be defined as the output gap, where y_t^0 is the level of output that arises with perfectly flexible prices. Similarly, let r_t^0 and r_t^* be the real interest rates for the domestic and foreign economy respectively that arise in the frictionless equilibrium. Also, b_t^0 (which equals zero) corresponds to the net asset holdings in the complete asset market case. Then, Equation (32) can be written as:

$$x_t = E_t x_{t+1} - \left(\frac{1+w}{\sigma} \right)(i_t - E_t \pi_{H,t+1} - r_t^0) - \kappa \left(\frac{w+a}{\sigma} \right) b_t \quad (33)$$

where,

$$r_t^0 = \left(\frac{\sigma}{1+w}\right) E_t(y_{t+1}{}^0 - y_t{}^0) + \left(\frac{w}{1+w}\right) r_t^* - \left(\frac{1-a}{1+w}\right)\left(E_t u_{t+1} - u_t\right) \tag{34}$$

The expression for y_t^0 can be calculated by equating log-linear expression for labor demand [Equation (19)], $w_t - p_{H,t} = z_t$ with log-linear expression for labor supply [Equation (11)], $w_t - p_t = \sigma c_t + \phi n_t - u_t$, and using production function [Equation (16)], $y_t = z_t + n_t$, the relationship, $p_{H,t} - p_t = -\left(\frac{a}{1-a}\right) q_t$, and the resource constraint [Equation (28)] to eliminate c_t and n_t.

$$y_t^0 = \left(\frac{1-a}{\sigma + \phi(1-a)}\right)\left[(1+\phi) z_t + \left(\frac{a\sigma}{1-a}\right) y_t^* + \left(\frac{w+a}{(1-a)^2}\right) q_t^0 + u_t\right] \tag{35}$$

q_t^0 is the real exchange rate under flexible prices and complete asset markets, and is derived below.

3.2. Domestic Inflation Dynamics— The New Phillips Curve

The log-linearized version of Equation (22), $\tilde{p}_{H,t} = (1-\rho\beta)(mc_t + p_{H,t}) + \rho\beta E_t \tilde{p}_{H,t+1}$ (mc_t stands for minimized real marginal costs) and Equation (23), $p_{H,t} = \rho p_{H,t-1} + (1-\rho) p_{H,t}$, can be combined to produce the following Phillips curve type relationship:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \theta mc_t \tag{36}$$

where $\theta = \dfrac{(1-\rho)(1-\rho\beta)}{\rho}$.

The expression for mc_t can be computed by combining the log-linear expressions for Equation (20), (expressed in real terms), $mc_t = w_t - p_{H,t} - z_t$, labor supply [Equation (11)]: $w_t - p_t = \sigma c_t + \phi n_t - u_t$, production function [Equation (16)], $y_t = z_t + n_t$, the relationship, $p_{H,t} - p_t = -\left(\frac{a}{1-a}\right) q_t$, and the resource constraint [Equation (28)]:

$$mc_t = \left(\frac{\sigma}{1-a} + \phi\right) y_t - \left(\frac{a\sigma}{1-a}\right) y_t^* - \left(\frac{w+a}{(1-a)^2}\right) q_t - (1+\phi) z_t - u_t \qquad (37)$$

Note that by setting $mc_t = 0$, the same expression for y_t^0 given in Equation (35) above is reached. Thus, subtracting Equation (37) from Equation (35):

$$mc_t = \left(\frac{\sigma}{1-a} + \phi\right) x_t - \theta\left(\frac{w+a}{(1-a)^2}\right)\left(q_t - q_t^0\right) \qquad (38)$$

Equation (36), therefore, can be written as:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \theta\left(\frac{\sigma}{1-a} + \phi\right) x_t - \theta\left(\frac{w+a}{(1-a)^2}\right)\left(q_t - q_t^0\right) \qquad (39)$$

3.3. Real Exchange Rate Dynamics

The equation describing the dynamic behavior of the real exchange rate is derived by combining the log–linearized version of Equation (15) with Equation (28). The log-linearized Equation (15) is:

$$E_t\left(c_{t+1} - c_t\right) = E_t\left(c_{t+1}^* - c_t^*\right) + \frac{1}{\sigma} E_t\left(q_{t+1} - q_t\right) - \frac{\kappa}{\sigma} b_t + \frac{1}{\sigma} E_t\left(u_{t+1} - u_t\right) \quad (40)$$

Writing Equation (28) one period forward and substituting in Equation (40) to get:

$$q_t = E_t q_{t+1} - \left(\frac{\sigma(1-a)}{1+w}\right) E_t\left(y_{t+1} - y_t\right) + \left(\frac{\sigma(1-a)}{1+w}\right) E_t\left(y^*_{t+1} - y^*_t\right) - \left(\frac{\kappa(1-a)^2}{1+w}\right) b_t + \left(\frac{(1-a)^2}{1+w}\right) E_t\left(u_{t+1} - u_t\right) \tag{41}$$

Expressing Equation (41) in gap-form provides a dynamic equation for the real exchange rate:

$$q_t = E_t q_{t+1} - \left(\frac{\sigma(1-a)}{1+w}\right) E_t\left(x_{t+1} - x_t\right) - \left(\frac{\kappa(1-a)^2}{1+w}\right) b_t - E_t\left(q^0_{t+1} - q^0_t\right) \tag{42}$$

Where, q^0_t is given as:

$$q^0_t = \left(\frac{\sigma(1-a)}{1+w}\right)\left(y^0_t - y^*_t\right) - \left(\frac{(1-a)^2}{1+w}\right) u_t \tag{43}$$

3.4. Net Foreign Assets— Current Account Dynamics

Finally, the dynamic equation for net foreign assets can be computed by log-linearizing Equation (12). First, it would be convenient to re-write Equation (12) in real terms as:

$$\frac{b_t}{\left(1 + i^*_t\right)\phi\left(b_t\right)} = b_{t-1}\left(1 + \pi_t\right)^{-1} + NX_t \tag{44}$$

where, NX_t stands for net exports and equals:

$$NX_t = \frac{P_{H,t}}{P_t} Y_t - C_t \tag{45}$$

The log-linearized version of Equation (44), after making use of the relationship, $\pi_t = \pi_{H,t} + \left(\frac{a}{1-a}\right)\Delta q_t$, is given as:

$$\beta(1+\kappa)b_t = \beta i_t^* + b_{t-1} - \pi_{H,t} - \left(\frac{a}{1-a}\right)\Delta q_t + (\beta - 1)nx_t \tag{46}$$

The log-linearized version of Equation (45), after making use of Equation (28) to eliminate c_t, is:

$$nx_t = \left(\frac{1-2a}{(1-a)^2}\right)y_t + \left(\frac{a}{1-a}\right)^2 y_t^* + \left(\frac{h}{(1-a)^3}\right)q_t \tag{47}$$

where, $h = a^2\eta(2-a) - a(1-a)$.

To be consistent with the rest of the model, Equations (46) and (47) are expressed in gap-form to get:

$$b_t = nb_{t-1} - n\pi_{H,t} + \left(\frac{n(\beta-1)}{\beta}\right)\left(nx_t - nx_t^0\right) - \left(\frac{na}{1-a}\right)\left[\left(q_t - q_{t-1}\right) - \left(q_t^0 - q_{t-1}^0\right)\right] \tag{48}$$

where, $n = \dfrac{1}{\beta(1+\kappa)}$.

$$nx_t = \left(\frac{1-2a}{(1-a)^2}\right)x_t + \left(\frac{h}{(1-a)^3}\right)(q_t - q_t^0) + nx_t^0 \tag{49}$$

where,

$$nx_t^0 = \left(\frac{1-2a}{(1-a)^2}\right)y_t^0 + \left(\frac{a}{1-a}\right)^2 y_t^* + \left(\frac{h}{(1-a)^3}\right)q_t^0 \tag{50}$$

4. The Behaviour of Monetary Authority

To evaluate the welfare implications of alternative monetary policy rules and exchange rate regimes, a welfare criterion (SW) is defined in terms of the central bank's loss or objective function, which can be derived as an approximation of the representative household's utility function. The objective function thus serves as a guide for the monetary authority to evaluate alternative monetary policies. Section 4.2 compares a variety of alternative (non-optimal) policy rules using this benchmark criterion.

4.1. Optimal Monetary Policy

In simple words optimal monetary policy means that, given the dynamic general equilibrium structure, the effects of all sources of sub-optimality/economic distortions are fully neutralized and the constrained efficient equilibrium is restored. There are numerous sources of economic distortions present in the model summarized above with incomplete asset markets and sticky prices.

First is market power distortion caused by monopolistically competitive firms that charge a constant mark-up. Following Rotemberg and Woodford (1999) and Gali and Monacelli (2002), I have assumed that the government fully offsets the market power distortion by subsidizing employment, which is financed through lump sum tax on households. This assumption ensures that the central bank has no incentive to increase the economy's output beyond the level corresponding to flexible prices and thus the classic inflation bias problem is assumed away.

Second is nominal rigidity in goods prices introduced in a staggered fashion that causes suboptimal variation in prices across firms. In this case the optimal policy would require that real marginal costs (and thus mark-ups) are stabilized at their steady state level, which in turn implies that domestic prices be fully stabilized. The intuition for that result is straightforward but holds only in a closed economy setting: by stabilizing mark-ups at their "frictionless" level, nominal rigidities cease to be binding, since firms do not feel any desire to adjust prices. By construction, the resulting equilibrium allocation is efficient, and the price level remains constant.

In an open economy, there is an additional factor that distorts the incentives of the monetary authority (beyond the presence of market power and nominal rigidities): the possibility of influencing the terms of trade and thus the real exchange rate in a way beneficial to domestic consumers. This possibility, pointed out by Corsetti and Pesent (2001a), is a consequence of the imperfect substitutability between domestic and foreign goods. However, following from Woodford's (2002) derivation of a benevolent monetary policy-maker's objective function from agents utility, a number of papers [Aoki (2002), Sutherland (2002), Clarida, Gali and Gertler (2001), Batini, Harrison and Millard (2003), and De Paoli (2004)] have suggested that policy in an open economy should have the same objectives as in a closed economy, and in particular that the exchange rate should play no role. For example, Aoki (2002) considers a two-sector model, where prices in one sector are completely flexible, and shows that it is only inflation in the non-flexible sector that is relevant for welfare. He explicitly suggests that imported goods in an open economy are akin to the flexible price sector, and that therefore the price of imported goods (and by implication the exchange rate) should not appear in the objective function of the central bank representing welfare.

However, all these papers invoke the assumption of complete asset markets. What would happen in case of incomplete and imperfect international asset markets? Presence of incomplete asset markets causes imperfect risk-sharing and may lead to shifts in wealth across countries. Kirsonova, et al. (2004) derive the objective function of the central bank from the utility function of the households and show that when there are shocks to international risk sharing, the exchange rate appears alongside output and inflation in the social welfare function. Benigno (2001) reached a similar conclusion in a model with incomplete asset markets and argued that since there are trade-offs among several distortions, it is optimal to distribute the losses across different uses.

Based on the above discussion, the social welfare function is thus defined as:

$$SW = -\frac{1}{2} E_t \left[\sum_{k=0}^{\infty} \beta^k L_{t+k} \right] \tag{51}$$

where L_t stands for the period 't' loss function of the central bank that takes the output gap x_t, domestic inflation $\pi_{H,t}$, and the real exchange rate gap, $q_t - q_t^0$ as the target variables:

$$L_t = \left(\alpha_x x_t^2 + \alpha_{\pi_H} \pi_{H,t}^2 + \alpha_q (q_t - q_t^0)^2 \right) \tag{52}$$

where α_x, α_{π_H} and α_q' is the weight that the policy authority places on output, domestic inflation, and real exchange rate deviation from their respective level under flexible prices and complete asset markets.

After taking unconditional expectations, the loss function becomes:

$$E(L_t) = \left(\alpha_x \ \mathrm{var}(x_t) + \alpha_{\pi_H} \ \mathrm{var}(\pi_{H,t}) + \alpha_q \ \mathrm{var}(q_t - q_t^0) \right) \tag{53}$$

where, $\text{var}(x_t), \text{var}(\pi_{H,t})$ and $\text{var}(q_t - q_t^0)$ are the unconditional variances of domestic inflation, output gap and real exchange rate gap, respectively.

An important point to note about the real exchange rate term is that it is in the form of deviation from the level that would occur without any nominal price rigidities and zero net foreign assets. That is, the exchange rate gap term in the loss function is the difference between actual exchange rate disequilibrium and the disequilibrium that would occur without distortions, not the change in the exchange rate (the assumption normally employed in the literature, e.g., Kollmann (2002)]. A change in exchange rate term makes no attempt to allow for 'warranted' exchange rate movements, i.e. natural disequilibrium.

4.2. Monetary Policy Rules

Faced with different kinds of shocks, the monetary authority uses the short-term nominal interest rate i_t as its policy instrument to maximize the social welfare subject to the constraints implied by the structure of the model. The central bank manages this interest rate according to an open economy variant of the Taylor-type feedback rule.[11] In particular, I have analyzed the macroeconomic implications of two alternative monetary policy regimes: domestic inflation targeting and CPI inflation targeting, and considered both flexible and dirty floating regimes. The analysis also contrasts differences between strict and flexible inflation targeting. The general form of the open economy Taylor-rule is given as:

$$i_t = \lambda_x x_t + \lambda_\pi \pi_t^j + \lambda_q \left(q_t - q_t^0\right) \qquad (54)$$

where π_t^j could be domestic inflation or CPI inflation depending on the targeting regime considered. λ_x, λ_π and λ_q are the weights associated with stabilizing output gap, inflation rate (around zero) and the real exchange rate around the flexible price/complete asset market real exchange rate level respectively.

The value of parameter λ_q implies the type of exchange rate regime that the monetary authority chooses. For example, $\lambda_q = 0$ means that the central bank does not care about deviations of the real exchange rate from the target, i.e. the

[11] For similar work, see Guender (2001), Leitmo and Soderstorm (2001), and Taylor (2001).

economy has a flexible exchange rate. On the other hand, $\lambda_q > 0$ means that the central bank responds by changing the interest rate if there is some deviation of the real exchange rate from its target value. Thus, this case corresponds to a managed exchange rate, and as $\lambda_q \to \infty$, to a fixed exchange rate.

5. A Numerical Analysis of Alternative Monetary-Exchange Rate Policies

This section presents quantitative results based on a calibrated version of the model economy.[12] In particular, the variances for key variables and the expected loss of the central bank under alternative monetary-exchange rate regimes are reported. These experiments allows us to compare the effects of alternative targeting regimes on key macroeconomic variables (output gap, inflation and real exchange rate) within the dynamic general equilibrium framework developed in the paper.

5.1. Calibration

For parameter values, standard baseline values that appear in the related literature [e.g. Gali and Monacelli (2002)] are chosen. The value for $\beta = 0.99$ implies a risk-less annual return of about 4 percent in the steady state. $\sigma = 1$ is the elasticity of intertemporal substitution which corresponds to log utility. $\phi = 3$, implies a labor supply elasticity of 1/3. The elasticity of substitution between domestic and foreign goods, η, equals 1.5. The baseline value for 'a' (or degree of openness) is assumed to be 0.4, which roughly corresponds to the import/GDP ratio in a typical small open economy. Parameter ρ is set equal to 0.75, a value consistent with an average period of one year between price adjustments. 'κ.' is assumed to equal 0.0007. In general, the main conclusions do not differ with alternative reasonable parameter values.

The variances for the white noise taste, technology and foreign output shocks are taken to be 0.000175 with a persistence parameter of $\rho_u = 0.5, \rho_z$ and $\rho_{y^*} = 0.65$. Taken together these numbers imply an annualized standard deviation of approximately 6 percent for the model economy. The values chosen for the variances of the shock have a direct effect on the absolute

[12] The model is calibrated and simulated by using the technique provided by Soderlind (1999). The software used for this purpose is MATLAB.

magnitude of expected losses, but do not influence the relative magnitudes of the losses; it is the relative losses that are relevant for comparison.

5.2. Analysis: Discussion of Results

Two types of aggregate shocks are considered: taste and foreign output shocks.

Table 1 reports the results for domestic inflation targeting (DIT) with alternative exchange rate policies in response to taste shocks. A number of very interesting results can be observed between flexible domestic inflation targeting (FDIT) and strict domestic inflation targeting (SDIT).

First, managed exchange rate regime is superior to flexible exchange rate regime under domestic inflation targeting: the expected loss goes down as the central bank places some weight on stabilizing the real exchange rate. However, it is important to note that as the central bank tries to stabilize the real exchange rate 'too much', that is, approaches fixed exchange rate case, loss increases. This result is quite robust and holds regardless of the welfare criterion used: loss1, which includes real exchange rate movements, or loss2, which focuses only on output gap and inflation movements.

Table 1. Taste Shock — Domestic Inflation Targeting (DIT)

	var (x_t)		var $(\pi_{H,t})$		var (q_t)		*Loss 1*		*Loss 2*	
	FDIT	SDIT	FDIT	SDIT	FDIT	SDIT	FDIT	SDIT	FDIT	SDIT
λ_q =0	3.60	5.09	0.150	0.070	431.8	418.89	215.99	212.10	0.405	2.65
λ_q =0.5	0.052	2.31	0.015	0.192	344.02	273.03	172.06	137.96	0.049	1.44
λ_q =1.0	0.750	31.93	0.173	2.52	283.44	207.80	124.35	123.64	0.634	19.75
λ_q =1.5	5.292	83.54	1.276	8.12	239.96	170.64	142.54	139.27	4.561	53.95

Note: λ_q = 0 corresponds to the **flexible exchange rate regime**, while λ_q = 0.5, 1.0, and 1.5 capture alternative degrees of **dirty floating** or managed exchange rate regime. FDIT stands for **flexible DIT** with λ_x = 0.5 and λ_{π_H} = 1.5 while SDIT stands for **strict DIT** with λ_x = 0 and λ_{π_H} = 1.5. *Loss 1* corresponds to the value of social welfare function with α_x = 0.5, $\alpha_{\pi H}$ = 1.5 and α_q = 0.5, whereas *Loss 2* corresponds to the case when α_x = 0.5, $\alpha_{\pi H}$ = 1.5, and α_q =0.

Also, the result remains unchanged whether the central bank adopts flexible inflation targeting or strict inflation targeting. For example, under both flexible and strict inflation targeting, as the parameter 'λ_q' changes from 0 to 1.0 loss1 decreases, but, as 'λ_q' approaches 1.5 or higher, loss1 increases. In case where welfare criterion, loss2, is considered, increasing 'λ_q' from 0 to 0.5 decreases, but as 'λ_q' approaches 1.0 or higher, it increases. In other words, whether central bank cares about real exchange rate movements or not, placing some positive weight on stabilizing it pays off as it lowers the volatility in output gap and domestic inflation. At the same time, stabilizing real exchange rate too much increases their volatility.

The key reason behind this unique and powerful result is the presence of current account dynamics affecting not only the real exchange rate behavior via imperfect risk sharing due to incomplete asset markets, but also the output gap via the risk premium term in the interest parity relationship. The intuition is as follows. Suppose the economy experiences a positive taste shock that tends to push up both output gap and domestic inflation and causes some appreciation of the real exchange rate. A typical response would be to increase the nominal interest rate, which leads to further appreciation that helps the transmission mechanism. In a model without current account dynamics (zero net foreign assets) the analysis would stop here and predict that the central bank can completely stabilize shocks that push up output gap and domestic inflation in the same direction implying flexible domestic inflation targeting with completely flexible exchange rate as the optimal monetary policy [e.g. Clarida, Gali and Gertler (2001)]. On the other hand, in the presence of net foreign assets, there would be 'excess' appreciation due to a taste shock: an appreciation improves the net foreign asset position that in turn causes further appreciation [see, Equations (42) and (48)]. In this case, increasing the interest rates would exacerbate the excess appreciation. Therefore, placing some positive weight on stabilizing real exchange rate, by lowering the interest rate, eliminates this excess appreciation leading to welfare improvements. Put differently, appreciation (caused by increasing the interest rate) may eliminate the impact of the taste shock on the output gap, but a consumption gap would remain due to incomplete risk sharing, and so a less aggressive response by the policy authority (a slight cut in interest rates to moderate the appreciation) will enhance welfare. However, the policy should not try to eliminate the real exchange rate gap completely by lowering the interest rates too much as it may lead to large output gaps; some exchange rate gap may well be necessary to avoid these gaps and improve welfare.

This result also challenges the conventional wisdom—the famous insulation property of flexible exchange rate regime—that flexible exchange rate is better compared to ‘targeted’ exchange rate in case of real shocks such as taste shocks. Some exchange rate targeting—a dirty float—turns out to be a superior outcome.

Another stark result reported in table 1 is that strict domestic inflation targeting is slightly better than flexible domestic inflation targeting or at least the difference is very small compared to what is usually reported in the literature. The intuition for this result is simple. Strict domestic inflation targeting means that the central bank does not care about output gap movements. Thus, the implications of an ‘excess’ appreciation for the output gap, as discussed above, is not binding, which induces the central bank to stabilize the real exchange rate gap more. This implies lower losses if the welfare criterion used is loss1. If the welfare criterion used is loss2, as in Clarida, Gali and Gertler (2001), however, the opposite result would hold not so surprisingly.

Apart from comparing social welfare across alternative monetary-exchange rate policies, a careful inspection of output volatility and domestic inflation volatility also reveals some unconventional results. For example, a conventional model predicts that in the presence of nominal price rigidities, flexibility of exchange rates (the famous over-shooting result) ensures lower output volatility. However, the volatility of output decreases, in my model, as the central bank moves to dirty floating. The reason is as follows. A positive taste shock leads to excess appreciation via dynamic interaction between real exchange rates and net foreign assets, which causes output volatility. Eliminating this excess appreciation, by stabilizing the real exchange rate slightly, therefore, would reduce output volatility. Similarly, the predictions of the model regarding inflation volatility are also unconventional. A standard model suggests that inflation volatility goes down as the economies move towards fixed exchange rates. Indeed, a famous argument in favor of fixed exchange rate regime is that it pins down the inflation expectations leading to lower inflation volatility. This is not the case in my model that boasts rich dynamic interactions among net foreign assets and inflation, real exchange rates and output gap (see last row in table 1).

Table 2 reports the results for CPI inflation targeting with alternative exchange rate policies in response to a taste shock. Before discussing any result, an important point needs to be made regarding the difference in CPI inflation targeting and domestic inflation targeting with managed exchange rates. In line with conventional wisdom, Parrado (2004) argues that if an economy has a managed exchange rate, there is no difference in CPI and domestic inflation targeting as the volatility in key macroeconomic variables is the same across these

Table 2. Taste Shock — CPI Inflation Targeting

	var (x_t)		var (π_t)		var (q_t)		*Loss 1*		*Loss 2*	
	FCPI	SCPI	FCPI	SCPI	FCPI	SCPI	FCPI	SCPI	FCPI	SCPI
λ_q =0	9.83	84.95	17.30	11.66	253.75	205.72	157.74	162.82	30.87	59.96
λ_q =0.5	19.11	124.13	15.50	13.19	222.26	175.87	143.92	169.78	32.80	81.85
λ_q =1.0	32.30	169.78	15.77	17.04	197.16	153.73	138.38	187.31	39.80	110.4
λ_q =1.5	49.34	220.08	17.65	23.06	176.80	136.61	139.54	212.93	51.14	144.6

Note: λ_q = 0 corresponds to the **flexible exchange rate regime**, while λ_q = 0.5, 1.0, and 1.5 capture alternative degrees of **dirty floating** or managed exchange rate regime. FCPI stands for **flexible CPI Inflation Targeting** with λ_x = 0.5 and λ_π = 1.5 while SCPI stands for **strict CPI Inflation Targeting** with λ_x = 0 and λ_π = 1.5. *Loss 1* corresponds to the value of social welfare function with α_x = 0.5, $\alpha_{\pi H}$ = 1.5 and α_q = 0.5, whereas *Loss 2* corresponds to the case when α_x = 0.5, $\alpha_{\pi H}$ = 1.5, and α_q =0.

regimes. The reason, pointed out by Parrado (2004), is that targeting the CPI inflation is the same thing as targeting both domestic inflation and the exchange rate, which is equivalent to targeting domestic inflation with managed exchange rates.

However, an important point needs to be noted about the real exchange rate term as it appears in the policy rule in this paper. The point is that, like output, it is in the form of deviation from the level that would occur with no nominal price rigidities and international risk sharing shocks like net foreign assets, and not in change form. That is, unlike the traditional models that study CPI inflation targeting and role of exchange rates in policy rules, the analysis presented in the paper suggests terms in exchange rate ‘gap’: the difference between actual exchange rate disequilibrium and the disequilibrium that would occur without any distortions. Not only is the dimension of this expression different from the change in the exchange rate, but a change in exchange rate term does not attempt to allow for ‘warranted’ exchange rate movements, i.e. natural disequilibrium. This distinction is important in understanding the results reported in Table 2.

The first result is that flexible CPI inflation targeting with managed exchange rates is superior to flexible CPI inflation targeting with completely floating exchange rates. That is, responding to real exchange rate gap in addition to CPI inflation (that implicitly incorporates response to exchange rate changes) is welfare improving. Put differently, responding to exchange rate changes alone (as embedded in the response to CPI inflation) is not enough to improve welfare. An additional response to exchange rate gap leads to better outcomes. However, this result does not hold when either an alternative welfare criterion, loss2, is used or strict CPI inflation targeting is pursued. Thus, the case for dirty floating is not that strong as was the case with domestic inflation targeting. The reason for this is not too difficult to understand. In the case of domestic inflation targeting, stabilizing real exchange rate eliminates the excess appreciation that follows due to a taste shock, and thus improves welfare. On the other hand, with CPI inflation targeting, response to real exchange rate is already included in the regime; responding to real exchange rate gap on top of this would be harmful as it leads to excess output volatility.

Another result is that, unlike the domestic inflation targeting case, flexible CPI inflation targeting is always superior to strict CPI inflation targeting regardless of the welfare criterion used because strict inflation targeting dramatically increases the output volatility. Similarly, in line with conventional wisdom, output volatility indeed goes up as the economy moves towards more managed exchanged rates. However, a point worth noting is that no noticeable gain is made on the volatility of CPI inflation.

Note that a direct comparison between domestic inflation targeting and CPI inflation targeting can not be made because their respective loss functions involve different arguments (domestic inflation in one and CPI inflation in other).

Table 3 reports the results for foreign output shock with domestic inflation targeting. A positive foreign output shock, by decreasing the flexible price real interest rate leads to a negative output gap and thus lower domestic inflation. Also, it causes real exchange rate appreciation. The central bank responds by lowering the nominal interest rate that leads to real depreciation. This, in turn, pushes up the output gap and domestic inflation to their original level. Thus, both output and domestic inflation are completely stabilized under flexible exchange rates. Unlike the response to taste shocks, this policy does not lead to ‘excess’ appreciation due to dynamics of real exchange rate and net foreign assets because a cut in the interest rate dampens the real appreciation rather than exacerbating it. Therefore, as the central bank moves towards the managed exchange rate regime volatility of exchange rate decreases, but at the same time output and domestic inflation volatility increases. Thus, the difference between loss1 across alternative exchange rate regimes is very insignificant. Obviously, if loss2 is used as a welfare criterion then flexible exchange rate regime would be superior.

Table 3. Foreign Output Shock — Domestic Inflation Targeting (DIT)

	var (x_t)		var $(\pi_{H,t})$		var (q_t)		*Loss 1*		*Loss 2*	
	FDIT	SDIT	FDIT	SDIT	FDIT	SDIT	FDIT	SDIT	FDIT	SDIT
λ_q =0	0	0	0	0	17.721	17.56	8.861	8.778	0	0
λ_q =0.5	0.001	0.038	0.002	0.009	15.251	13.891	7.629	6.978	0.003	0.033
λ_q =1.0	0.020	0.335	0.020	0.076	13.417	11.642	6.749	6.103	0.040	0.282
λ_q =1.5	0.091	0.903	0.075	0.241	11.976	10.185	6.147	5.905	0.160	0.812

Note: λ_q = 0 corresponds to the **flexible exchange rate regime**, while λ_q = 0.5, 1.0, and 1.5 capture alternative degrees of **dirty floating** or managed exchange rate regime. FDIT stands for **flexible DIT** with λ_x = 0.5 and λ_{π_H} = 1.5 while SDIT stands for **strict DIT** with λ_x = 0 and λ_{π_H} = 1.5. *Loss 1* corresponds to the value of social welfare function with α_x = 0.5, $\alpha_{\pi H}$ = 1.5 and α_q = 0.5, whereas *Loss 2* corresponds to the case when α_x = 0.5, $\alpha_{\pi H}$ = 1.5, and α_q =0.

Comparing flexible DIT with strict DIT under managed exchange rates reveal a rather surprising result. Volatility of domestic inflation increases under the strict case. With lower real exchange rate volatility and higher output volatility, loss1 is actually slightly lower under strict DIT compared to flexible DIT. This is the same result as observed in case of taste shocks. Essentially, central bank trades-off some inflation volatility for lower real exchange rate volatility in case the welfare criterion includes real exchange rate gap terms, such as loss1. Needless to say, flexible DIT would be superior if welfare criterion, loss2 is used.

Similar results hold in the case of CPI inflation targeting, except that output and inflation are not completely stabilized and inflation volatility does not increase in case of strict CPI targeting. As before, dirty floating is slightly better than flexible exchange rates but the result is not quite robust if the welfare criterion, loss2, is used.

Table 4. Foreign Output Shock — CPI Inflation Targeting

	var (x_t)		var (π_t)		var (q_t)		*Loss 1*		*Loss 2*	
	FCPI	SCPI	FCPI	SCPI	FCPI	SCPI	FCPI	SCPI	FCPI	SCPI
λ_q =0	0.16	1.168	0.633	0.507	12.843	11.667	7.451	7.177	1.03	1.344
λ_q =0.5	0.293	1.655	0610	0.564	11.678	10.428	6.901	6.887	1.062	1.673
λ_q =1.0	0.489	1.886	0.658	0.612	10.709	10.013	6.586	6.868	1.231	1.861
λ_q =1.5	0.703	0.197	0.745	0.689	10.013	9.848	6.476	6.852	1.470	1.88

Note: λ_q = 0 corresponds to the **flexible exchange rate regime**, while λ_q = 0.5, 1.0, and 1.5 capture alternative degrees of **dirty floating** or managed exchange rate regime. FCPI stands for **flexible CPI Inflation Targeting** with λ_x = 0.5 and λ_π = 1.5 while SCPI stands for **strict CPI Inflation Targeting** with λ_x = 0 and λ_π = 1.5. *Loss 1* corresponds to the value of social welfare function with α_x = 0.5, $\alpha_{\pi H}$ = 1.5 and α_q = 0.5, whereas *Loss 2* corresponds to the case when α_x = 0.5, $\alpha_{\pi H}$ = 1.5, and α_q =0.

6. Concluding Remarks

The paper developed and analyzed a dynamic general equilibrium model with staggered price rigidities and incomplete and imperfect international asset markets. The key contribution of the paper is that it allows for the dynamic relationship between real exchange rate and net foreign assets to affect the dynamics of domestic inflation and output gap. Thus, unlike other similar open economy models, for example, Gali and Monacelli (2002) and Clarida et al. (2001), this paper has shown that the dynamics of domestic inflation and output gap does not have a canonical representation analogous to closed economy models, and therefore the optimal monetary policy design problem for an open economy is not 'isomorphic' to a closed economy. Furthermore, relying on the recent literature that formally derives the welfare criterion or the loss function for an open economy [e.g. Kirsonova et al. (2004), Benigno and Woodford (2004) and Benigno (2001)] as an approximation to the representative agents' utility function, the paper has also shown that this loss function is not analogous to the one applying to the corresponding closed economy. In particular, due to the current account dynamics, the loss function also includes the real exchange rate gap term in addition to domestic inflation and output gap. This implies that in general targeting domestic inflation with flexible exchange rate would not be the welfare maximizing optimal monetary policy.

The framework is then used to study various monetary-exchange rate policies using Taylor-type interest rate-based rules. In particular, the performance of domestic inflation targeting and CPI inflation targeting with flexible and managed exchange rate regimes is compared. Moreover, flexible and strict inflation targeting considering both inflation indices is also studied. The main results of the paper are: (1) Managed exchange rate regime (dirty floating) is superior to flexible exchange rate regime under domestic inflation targeting. Volatility in both output and domestic inflation goes down and so does the volatility in real exchange rate. Put differently, there is no trade-off between stabilizing the real exchange rate and domestic inflation and output gap: welfare improves as the central bank places some weight on stabilizing the real exchange rate and pursues domestic inflation targeting. (2) As the central bank tries to stabilize the real exchange rate 'too much', that is, approaches fixed exchange rate case, loss increases. (3) In case of a taste shock, this result is quite robust and holds regardless of the welfare criterion used: whether it includes real exchange rate movements, or focuses only on output gap and inflation movements. (4) Also, the result remains unchanged whether the central bank adopts flexible inflation targeting or strict inflation targeting. (5) Strict domestic inflation targeting outperforms flexible domestic inflation target regardless of the exchange rate regime. This result is sensitive, however, to the welfare criterion used. (6) With CPI inflation targeting, there is some evidence in favor of 'dirty floating', however, the result is not that robust when alternative welfare criterion is used. (7) Flexible CPI inflation targeting dominates strict CPI inflation targeting, and is not sensitive to the welfare criterion used.

The bottom line is that the dynamic relationship between net foreign asset position and the real exchange rate plays a crucial role in obtaining the above mentioned results.

These results, while suggestive, are subject to some limitations. For instance, introducing imports as production inputs, *à la* McCallum and Nelson (2000), with rigidities in the import prices could alter the conclusions as to the appropriate exchange rate regime or price index to target. Similarly, introducing labour market rigidities could alter the results as well. After all, as pointed out by Erceg, Henderson and Levin (2000), the simultaneous presence of both forms of nominal rigidity introduces an additional trade-off that renders 'goods' price inflation targeting policies suboptimal. Therefore, it may be interesting to analyze how that trade-off would affect the ranking across monetary-exchange rate policy regimes evaluated in the present paper. These results would also need to be qualified, if one considers differences in price-setting across various markets, as in the case of less than complete exchange rate pass-through of nominal exchange rate changes to prices of imported (or exported) goods. Moreover, after the various currency crisis episodes in the 1990s, much of the discussion on exchange rate policy in emerging market economies is concerned with the interaction of exchange rate with balance sheets, borrowing constraints, dollarization of liabilities, and creditworthiness of firms. Incorporating such consideration in a model with imperfections in the financial markets, such as the one developed in this paper, should certainly be the focus of future research.

Finally, the paper deals with calibrated results. Conclusions about policy dominance and welfare consequences depend on a specific parameterization, and they should not be taken as general propositions. The paper experimented sufficiently with alternative parameterization to be confident that the results presented here are robust to relatively minor changes in assumptions. More work is clearly warranted, however, before making general policy recommendations.

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