ALTERNATIVE MONETARY RULES IN THE OPEN-ECONOMY: A WELFARE-BASED APPROACH

Eric Parrado
New York University

Andrés Velasco
Harvard University and National Bureau of Economic Research

How do central banks choose among alternative monetary policies? In this paper we analyze that question for an open economy following an interest rate rule. Many issues remain controversial in the design of such a rule. If inflation is targeted, as it presumably is, should the domestic interest rate also react to the output gap or to movements in other real variables? Should inflation targeting focus on the consumer price index (CPI), on home prices only, or on some other index? Should the interest rate respond to movements in the nominal exchange rate? Equivalently, should the exchange rate float cleanly?

All such questions can be addressed by considering a particular social loss function and quantitatively analyzing the response of a model economy to several shocks (domestic and foreign, real and nominal) under alternative monetary rules and exchange rate regimes. The best regime is the one that stabilizes the economy and consequently yields lower social losses. That is the approach we take here.

In the analysis that follows, we use a social loss function that includes the variability of the real exchange rate in addition to the variability of inflation and output, as is conventional in closed economy models. The three policy alternatives we consider and the corresponding results are as follows:

—Flexible versus managed exchange rate regimes. In the former, the currency floats freely, while in the latter the central bank adjusts its domestic interest rate in response to fluctuations in the nominal

Inflation Targeting: Design, Performance, Challenges, edited by Norman Loayza and Raimundo Soto, Santiago, Chile. © 2002 Central Bank of Chile.

exchange rate, in addition to reacting to other variables such as inflation and output. We find that the social loss is much higher under managed exchange rates than under flexible rates in the presence of real shocks, while for nominal shocks the reverse is true. This result is consistent with conventional wisdom on the subject.

—CPI versus domestic inflation targeting. In the latter, the inflation target is defined exclusively in terms of the variation of the price index for domestically produced goods.[1] We find that domestic inflation targeting is preferable to CPI inflation targeting, since it minimizes volatility in output at the possible cost of some relatively small additional volatility in the real exchange rate.

—Strict versus flexible inflation targeting. In the former, interest rate policy reacts to inflation only, while in the latter it reacts to output (and possibly the exchange rate) in addition to the target inflation rate. We find that flexible inflation targeting is generally preferable to strict inflation targeting.

We carry out the analysis in a dynamic neo-Keynesian (DNK) model, modified to allow for inflation targeting in an open economy. This framework builds on previous research by Svensson (2000), Galí and Monacelli (2000), Parrado (2000), and Parrado and Velasco (2001), all of which focus on the performance of simple policy rules (whether optimal or not) in open economies. Our model contains three structural blocks: aggregate demand, aggregate supply, and a monetary sector. The aggregate demand block is derived from utility maximization. The same is true of aggregate supply, which also incorporates forward-looking sticky prices à la Calvo (1983).

Studying the welfare consequences of monetary rules has only lately become fashionable among academic economists. The issue was not tackled previously for lack of tools rather than lack of interest. The most recent generation of general equilibrium sticky-price models, based on utility maximization, naturally lends itself to welfare analysis, as evidenced by the number of recent papers on the subject.[2] Our model differs from much recent work in two dimensions. First, it focuses on a small open economy, while most pa-

1. Currently, some inflation targeters target the full CPI (for example, Germany, Israel, Spain, and Sweden). Others use the CPI but exclude volatile prices such as energy and food prices (for example, Australia and New Zealand). Canada, Chile, and the United Kingdom use both types of measure.

2. A partial list of recent papers incorporating an open economy, aside from works mentioned in the text, includes Benigno and Benigno (2001); Ghironi and Rebucci (2001); Monacelli (2000); Parrado (2000); Svensson (2000).

pers—with the important exception of Galí and Monacelli (2000)—focus on a world economy composed of two countries of comparable size. As Lane (2001) points out, much of the literature has been based on a two-country world, since this allows interest rates and asset prices to be endogenously determined. However, this benefit comes at the price of considerable model complexity and may not be of compelling importance for the analysis of issues relevant to a small open economy. Second, we focus on interest rate policies, while most other papers try to characterize the optimal behavior of the nominal quantity of money, starting with the seminal paper of Obstfeld and Rogoff (1995).

The paper is organized as follows. Section 1 outlines the model. Section 2 presents the solution of the model and its parameterization, while section 3 analyzes alternative policy experiments. Section 4 summarizes the results and their implications for models of monetary policy and discusses caveats and directions for future research.

1. A Sticky-Price Model

The model consists of an open economy that comprises a central bank, a fiscal authority (the government), a representative consumer, and monopolistically competitive firms. All goods are tradable. As is standard in the literature, domestic production requires a continuum of differentiated labor inputs that are supplied by home individuals. Time is discrete.

We proceed in three steps. First, we outline the main building blocks of the model and its microeconomic foundations. Second, we derive the main price relationship of the model, namely, inflation rates and exchange rates. Finally, we embed these relationships in an otherwise conventional DNK model.

1.1 Microeconomic Foundations of Demand and Supply

The economy has a continuum of measure 1 of consumer-producers indexed by $j \in (0,1)$. Each consumer-producer has the same intertemporal lifetime utility function,

$$E_t\left[U_{t+k}(j)\right] = E_t\left[\sum_{k=0}^{\infty}\beta^k\left\{u\left[C_{t+k}(j)\right] + h\left[\frac{M_{t+k}(j)}{P_{t+k}}\right] - \int_0^1 v\left[Y_{t+k}(j)dj\right]\right\}\right], \quad (1)$$

where $0 < \beta < 1$ is the discount factor and C_t is a composite consumption index defined by

$$C_t = \left[(1-\gamma)^{1/\eta} \left(C_{H,t}\right)^{(\eta-1)/\eta} + \gamma^{1/\eta} \left(C_{F,t}\right)^{(\eta-1)/\eta} \right]^{\eta/(\eta-1)}, \tag{2}$$

where $\eta > 0$ is the elasticity of substitution between domestic and foreign goods and γ corresponds to the share of domestic consumption allocated to imported goods. The two consumption subindexes, $C_{H,t}$ and $C_{F,t}$, are symmetric, and they are defined, as in Dixit and Stiglitz (1977), by

$$C_{H,t} = \left[\int_0^1 C_{H,t}(j)^{(\theta-1)/\theta} \, dj \right]^{\theta/(\theta-1)} \text{ and} \tag{3a}$$

$$C_{F,t} = \left[\int_0^1 C_{F,t}(j)^{(\theta-1)/\theta} \, dj \right]^{\theta/(\theta-1)}, \tag{3b}$$

where $\theta > 1$ is the price elasticity of demand faced by each monopolist and $C_{H,t}(j)$ and $C_{F,t}(j)$ are the quantities purchased by home agents of home and foreign goods, respectively.

Consumers can store domestic non-interest-bearing money, and they can also hold state-contingent claims, as in Cole and Obstfeld (1991) and Galí and Monacelli (2000). The latter means that ex ante international financial markets are complete and thus there is no need for international portfolio diversification. In equilibrium, it also means that transitory shocks do not have permanent consequences, which sharply simplifies our analysis. The individual household constraint is given by

$$\int_0^1 \left[P_{H,t}(j) C_{H,t}(j) + P_{F,t}(j) C_{F,t}(j) \right] + M_t(j) + E_t \left[F_{t,t+1} B_{t+1} \right]$$
$$= (1-\tau) P_{H,t}(j) Y_{H,t}(j) + M_{t-1}(j) + B_t(j) + TR_t \,, \tag{4}$$

where $F_{t,t+1}$ is the stochastic discount factor, B_{t+1} is the payoff in period $t + 1$ of the portfolio held at the end of period t, TR_t are lump sum transfers, and τ is a proportional tax on nominal income.

The home commodity demand functions resulting from cost minimization are

$$C_{H,t}(j) = \left[\frac{P_{H,t}(j)}{P_{H,t}}\right]^{-\theta} C_{H,t} \text{ and}$$

$$C_{F,t}(j) = \left[\frac{P_{F,t}(j)}{P_{F,t}}\right]^{-\theta} C_{F,t},$$

where $P_{H,t}$ and $P_{F,t}$ are the price indexes for domestic and foreign goods, both expressed in the domestic currency:

$$P_{H,t} \equiv \left[\int_0^1 P_{H,t}(j)^{1-\theta} dj\right]^{1/(1-\theta)} \text{ and}$$

$$P_{F,t} \equiv \left[\int_0^1 P_{F,t}(j)^{1-\theta} dj\right]^{1/(1-\theta)}.$$

Using the definition of total consumption in equation 2, we can derive the demand allocation for home and foreign goods:

$$C_{H,t} = (1-\gamma)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \text{ and}$$

$$C_{F,t} = \gamma\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t, \tag{5}$$

where $P_t \equiv \left[(1-\gamma)(P_{H,t})^{1-\eta} + \gamma(P_{F,t})^{1-\eta}\right]^{1/(1-\eta)}$ is the consumer price index (CPI).

Plugging equation 5 into budget constraint 4, we can obtain a new expression for the latter in terms of the composite good:

$$P_t C_t + M_t(j) + E_t\left[F_{t,t+1}B_{t+1}\right] = (1-\tau)P_{H,t}(j)Y_{H,t}(j) + B_t(j) + M_{t-1}(j) + TR_t. \tag{6}$$

The home agent's problem is to choose paths for consumption, money, and the output of good j. Therefore, the representative consumer chooses his optimal holdings of contingent bonds, $B(j)$, and money, $M(j)$, to maximize his expected utility (equation 1) subject to the budget constraint (equation 6). It follows that the first-order necessary conditions (FONCs) are

$$\beta E_t\left[\frac{u_c(C_{t+1})}{u_c(C_t)}\frac{P_t}{P_{t+1}}\right]=E_t\left[F_{t,t+1}\right] \text{ and} \tag{7}$$

$$u_c(C_t)=h_m\left(\frac{M_t}{P_t}\right)\frac{1}{P_t}+\beta E_t\left[u_c(C_{t+1})\frac{P_t}{P_{t+1}}\right]. \tag{8}$$

Equation 7 represents the traditional intertemporal Euler equation for total real consumption, while equation 8 corresponds to the intertemporal Euler equation for money.

The problem is analogous for the rest of the world, although the crucial assumption here is that the share of goods that are not produced within the economy is insignificant. The Euler equation for the rest of the world would thus be

$$\beta E_t\left[\frac{u_c^*(C_{t+1})}{u_c^*(C_t^*)}\frac{P_t^*}{P_{t+1}^*}\frac{S_t}{S_{t+1}}\right]=E_t\left[F_{t,t+1}\right]. \tag{9}$$

Combining and iterating equations 7 and 9 yields

$$u_c(C_t)=\kappa u_c^*(C_t^*)Q_t\,, \tag{10}$$

where $Q_t=\left(S_tP_t^*\right)/P_t$ is the real exchange rate and κ is a constant that depends on initial wealth differences. The assumption of complete markets thus leads to equation 10, which associates home consumption with the consumption of the rest of the world and with a switching factor given by the real exchange rate.[3]

The model employs a price-setting process that follows Calvo (1983), in which firms are able to change their prices only with some probability, independently of other firms and the time elapsed since the last adjustment. We assume that producers behave as monopolistic competitors. Each firm faces the following demand function:

$$y_{H,t}^d(j)=\left[\frac{p_{H,t}(j)}{P_{H,t}}\right]^{-\theta}C_{H,t}^A\,, \tag{11}$$

3. The assumption of complete markets has the additional advantage of eliminating foreign asset movements from the dynamics of the economy. As a result, the steady state is unique, in that consumption is independent of the past history of shocks. We can thus linearize around that unique steady state. This is not possible in standard models of small open economies.

where $C^A_{H,t} = C_{H,t} + C^*_{H,t}$.

Recall that the economy has a continuum of measure 1 of consumer-producers indexed by $j \in (0,1)$, where each consumer-producer has the same expected profit function. It follows that the objective function can be written as

$$E_{t-1}\left[\sum_{k=0}^{\infty}\alpha^k \beta^k \Lambda_{t+j}\left\{\frac{p_{H,t}(j)}{P_{H,t+k}}\left[\frac{p_{H,t}(j)}{P_{H,t+k}}\right]^{-\theta} C^A_{H,t+k} - \frac{W_{t+k}V\left\{\left[p_{H,t}(j)/P_{H,t+k}\right]^{-\theta} C^A_{H,t+k}\right\}}{P_{H,t+k}\tilde{Z}_{t+k}}\right\}\right], \quad (12)$$

where α is the probability that consumer-producers maintain the same price of the previous period, Λ_{t+j} is the marginal utility of home goods, $V\left(y^d_{H,t}\right)/\tilde{Z}_t$ is the input requirement function, $\tilde{Z}_t$ is an exogenous economywide productivity parameter, and W_t is the price of the composite input.

The problem of the producers, which is solved in appendix A, is to choose $p_{H,t}(j)$ to maximize equation 12.

1.2 Government

We assume the government balances its budget each period. The government budget constraint is thus given by

$$\tau P_{H,t} Y_{H,t} - TR_t + M_t - M_{t-1} = 0 .$$

We restrict our analysis to the case in which $\tau = 1/(1-\theta)$. In this case, the government offsets the market power distortion created by monopolistic competition in the market for differentiated goods. This means that the only distortion in the economy is price rigidity, and offsetting the effects of that distortion is the object of monetary policy.

1.3 Price Relationships

Before moving on to the complete log-linearized model, we define the price relationships involved in the model, in log terms. Let $p_{H,t}$ and $p_{F,t}$ be the stochastic components of (log) levels of domestic and foreign good prices, respectively, in period t. Thus the (log) consumer price index (CPI) can be defined as

$$p_t = (1-\gamma)p_{H,t} + \gamma p_{F,t} , \quad (13)$$

where γ, a parameter of the utility function, is the share of home goods in the CPI, with $0 < \gamma < 1$. Therefore, the (log) CPI inflation can also be defined as

$$\pi_t = (1-\gamma)\pi_{H,t} + \gamma\pi_{F,t}\ , \tag{14}$$

where $\pi_{H,t} = p_{H,t} - p_{H,t-1}$ is domestic inflation and $\pi_{F,t} = p_{F,t} - p_{F,t-1}$ denotes foreign inflation. Depending on the choice of the inflation target (CPI versus domestic inflation), π_t and $\pi_{H,t}$ will be measured as deviations from a constant mean, which equals the constant inflation target.

The (log) real exchange rate can similarly be defined as

$$q_t \equiv s_t + p_t^* - p_t \Rightarrow q_t = (1-\gamma)\left(s_t + p_t^* - p_{H,t}\right), \tag{15}$$

where s_t represents the (log) nominal exchange rate and where we have included the key assumption that the rest of the world behaves as a closed economy, that is, $p_t^* = p_{F,t}^*$. In other words, we assume that the rest of the world's consumption of foreign goods (that is, of the goods produced by the home economy) is negligible.[4]

1.4 The Log-Linearized Model

This section presents the complete log-linearized model of this open economy. Additional details are presented in the appendix. Lower case variables denote percent deviations from the steady state, and ratios of capital letters without time subscript denote steady-state values of the respective ratios. We express the complete log-linearized model in terms of three blocks of equations: aggregate demand, aggregate supply, and monetary policy rules and stochastic processes.

Aggregate Demand

Aggregate demand in this economy is given by

$$\begin{aligned} x_t = {} & E_t\left[x_{t+1}\right] + \phi_\pi E_t\left[\pi_{H,t+1}\right] - \phi_s\left(E_t\left[s_{t+1}\right] - s_t\right) \\ & - \frac{1}{\sigma} i_t - (1-\rho_z) z_t + \gamma\left(1-\rho_{y^*}\right) y_t^* \quad , \end{aligned} \tag{16}$$

4. Galí and Monacelli (2000) use the same approximation.

where $\phi_\pi = \left[(1-\gamma)/\sigma + \gamma\eta(2-\gamma)\right]$, $\phi_s = \gamma\left[\eta(2-\gamma) - 1/\sigma\right]$, $0 \le \rho_z \le 1$, and $0 \le \rho_{y*} \le 1$. Note that $i_t = (P_{t+1}/P_t)E_t\left[F_{t,t+1}\right]$ is the nominal interest rate, while $y_t^* = c_t^*$ is foreign output, which follows a stationary univariate AR(1) process.

Equation 16 represents a nontraditional IS curve that relates the output gap not only to the interest rate, but also to the expected future output gap and current and expected future nominal exchange rates. A nominal depreciation, and consequently a real depreciation, raises aggregate demand, because it shifts demand from foreign goods to domestic output (foreign prices are given, and any repercussion effects from the home economy to the rest of the world are neglected).

Aggregate Supply

Aggregate supply is obtained by log-linearizing the first-order condition of the price setting problem. It follows that

$$\pi_{H,t} = \beta E_t\left[\pi_{H,t+1}\right] + \lambda_x x_t + \lambda_q\left(s_t + p_t^* - p_{H,t}\right) \text{ and} \tag{17}$$

$$\pi_t = \gamma\pi_{H,t} + (1-\gamma)(s_t - s_{t-1}), \tag{18}$$

where $\lambda_x = \left\{\left[(1-\alpha)(1-\alpha\beta)\right]/\alpha(1+\varepsilon\theta)\right\}\xi$, $\lambda_q = \lambda_x\gamma$, and z_t is an economywide productivity shock.

Equation 17 embeds the staggered price setting formulation of Calvo (1983) described earlier, giving rise to the dynamic version of the aggregate supply schedule for domestic goods. Current domestic inflation depends on expected future domestic inflation, current domestic output, and the terms of trade. This reflects the forward-looking nature of price setting, stemming from the implicit costs of changing prices.

Equation 18 defines CPI inflation in terms of domestic inflation and accumulated nominal exchange rate depreciation. Derivation of this equation assumes that foreign prices are constant.

Uncovered Interest Parity Condition

The uncovered interest parity condition is given by

$$i_t = i_t^* + E_t\left[s_{t+1}\right] - s_t, \tag{19}$$

which relates the movements of the interest rate differentials to the expected variations in the nominal exchange rate.

Monetary Policy Rules and Stochastic Processes

We assume that the central bank manages a short-term nominal interest rate according to an open economy variant of the Taylor rule. Specifically, we consider a rule in which the central bank adjusts the current nominal interest rate in response to expected inflation, the current output gap, the current exchange rate, and the lagged interest rate. In general, this kind of rule describes the variation of short-term interest rates relatively well.[5]

As Clarida, Galí, and Gertler (1998) show, the current interest rate typically depends on the interest rate target and the lagged interest rate, that is, there is a degree of interest rate smoothing given by ρ_i. The assumption behind this point is that monetary authorities are concerned about interest rate volatility, because it is presumably costly in terms of financial market health and also investment and growth. Thus we have

$$i_t = (1-\rho_i)\bar{i}_t + \rho_i i_{t-1}, \tag{20}$$

where $\bar{i}_t$ is the nominal interest target toward which the central bank gradually adjusts the interest rate, given by

$$\bar{i}_t = \chi_\pi E_t\left[\tilde{\pi}_{t+k} - \bar{\pi}\right] + \chi_x x_t + \chi_s s_t, \tag{21}$$

where $\chi_\pi > 1$, $\chi_x \geq 0$, and $\chi_s \geq 0$ and where $\pi_{t+k} = \tilde{\pi}_{t+k} - \bar{\pi}, \tilde{\pi}_{t+k}$ denotes the percent change in the price level between periods t and $t + k$ and $\bar{\pi}$ is the inflation target. The policy rule used by the monetary authority depends on expected future inflation. Higher expected future inflation raises the current nominal interest rate target. Batini and Haldane (1998) also consider this kind of policy rule. They conclude that policy rules based on inflation forecasts embody all information that is useful for predicting future inflation, and such rules can achieve a high degree of output smoothing.

Including the term χ_s in the policy rule helps to reproduce the behavior of nominal exchange rates. This rule implies the type of exchange regime chosen by the country, depending on the degree of control that the central bank exercises over the nominal exchange rate

5. See Clarida, Galí, and Gertler (1998, 1999); Rotemberg and Woodford (1998a).

(the value of χ_s). If $\chi_s = 0$, the central bank does not care about deviations of the nominal exchange rate, that is, the economy reproduces a flexible exchange rate behavior. On the other hand, if $\chi_s \in (0,\infty)$, the central bank acts in response to the deviation of the nominal exchange rate from its current target or steady-state value. This case corresponds to a managed exchange rate and, in the limit as χ_s goes to infinity, to a fixed exchange rate.

By plugging equation 21 into equation 20, we determine that the monetary policy rule is given by[6]

$$i_t = \rho_i i_{t-1} + \upsilon_\pi E_t\left[\pi_{t+k}\right] + \upsilon_x x_t + \upsilon_s s_t + \in_t , \tag{22}$$

where $\upsilon_\pi = (1 - \rho_i)\chi_\pi$, $\upsilon_x = (1 - \rho_i)\chi_x$, $\upsilon_s = (1 - \rho_i)\chi_s$, and $\in_t$ is an interest rate shock. This shock has two interpretations: it may capture deliberate decisions to deviate temporarily from its systematic rule, or it may represent erratic monetary policy (if there is another monetary policy instrument, for example).

Finally, equations 23, 24, 25, and 26 describe the evolution of foreign interest rate, foreign output, technology, and domestic interest rate shocks, respectively.

$$r_t^* = \rho_{r^*} r_{t-1}^* + \varepsilon_t^{r^*} , \tag{23}$$

$$y_t^* = \rho_{y^*} y_{t-1}^* + \varepsilon_t^{y^*} , \tag{24}$$

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z \text{, and} \tag{25}$$

$$\in_t = \rho_\in \in_{t-1} + \varepsilon_t^\in , \tag{26}$$

where $\varepsilon_t^{r^*}$, $\varepsilon_t^{y^*}$, ε_t^z and $\varepsilon_t^\in$ are independent and identically distributed (i.i.d.) shocks with zero mean and variance $\sigma_{r^*}^2 = 0.25$, $\sigma_{y^*}^2 = 1$, $\sigma_z^2 = 1$, and $\sigma_\in^2 = 0.25$.

6. An important consideration is in order with regard to the definition of inflation targeting. Some authors argue, based on McCallum and Nelson (1999) and Batini and Haldane (1998), that inflation targeting is the case in which monetary policy responds to inflation in addition to other variables such as output and real exchange rates. Alternatively, Svensson (2000) defines inflation targeting as the minimization of a loss function that is increasing in the deviation between the target variable(s) and the target level(s). He points out that "the best way to minimize such a loss function is then to respond optimally with the instrument to the determinants of the target variables, that is, the state variables of the economy." These two definitions are equivalent only if there is a one-to-one relation between the variables in the reaction function and the loss function.

1.5 Welfare Criterion

To evaluate the welfare implications of alternative monetary policy rules and exchange rate regimes, we need a welfare criterion. This welfare criterion is based on expected social loss. Social loss is, in turn, assumed to depend on the deviations of output and inflation from their steady-state values, and possibly on other variables. Our assumptions on social loss may be seen as an approximation of some aggregate of the welfare of consumer-producers.

Therefore, the welfare criterion of the home country, disregarding liquidity effects, is defined broadly as[7]

$$L_t = \psi_\pi \pi_{H,t}^2 + \psi_x x_t^2 + \psi_q q_t^2 . \tag{27}$$

After taking unconditional expectations, the loss function becomes

$$E\left[L_t\right] = \psi_\pi \operatorname{Var}\left[\pi_{H,t}\right] + \psi_x \operatorname{Var}\left[x_t\right] + \psi_q \operatorname{Var}\left[q_t\right],$$

where $\operatorname{Var}[\pi_{H,t}]$, $\operatorname{Var}[x_t]$, and $\operatorname{Var}[q_t]$ are the unconditional variances of domestic inflation, the output gap, and the real exchange rate, respectively.

The fact that we attribute social costs to domestic inflation can be justified in the context of the Calvo (1983) staggered setup. As Woodford (1996, 1999, 2001), Rotemberg and Woodford (1998a, 1998b), and Benigno (2000) show in detail, staggering inflation causes the dispersion of relative prices, which is costly for output and welfare. Since domestic prices are sticky in our model, ongoing domestic inflation causes such relative price distortions.

Designing the optimal monetary policy involves minimizing equation 27.[8] The strategy of this paper is to compare alternative (nonoptimal) policy rules using this benchmark criterion. We assume that the welfare criterion for the small open economy includes not only variations in output and inflation, as is standard in the closed economy case, but also changes in the real exchange rate. In particular, we analyze the broad case in which the loss function considers the following weights: $\psi_\pi = 1.5$; $\psi_x = 0.5$; and $\psi_q = 0.5$.

7. The instrument of the monetary authority is the short nominal interest rate. This implies that the behavior of monetary aggregates plays no essential role in the analysis.

8. See Svensson (2000) for a detailed derivation of an optimal reaction function under the Calvo (1983) scheme. See also Parrado and Velasco (2001) for solution methods similar to those based on Obstfeld and Rogoff (1995).

To make sure that our results do not depend on the particular specification of the loss function, we experimented with different weights for inflation, output gap, and the real exchange rate. In general, the main conclusions do not differ with alternative reasonable parameter values.

2. Model Simulations

We now turn to some quantitative experiments indicating how inflation targeting can influence business cycle dynamics within the DNK framework. Specifically, we consider three types of exercises. First, we compare flexible versus managed exchange rates, considering both CPI and domestic inflation targeting. Second, we study how the choice between the CPI and domestic inflation indexes influences the behavior of output, inflation, interest rates, and exchange rates. Finally, we contrast differences between strict and flexible inflation targeting.

2.1 Model Parameterization

For parameter values, we choose standard values that appear in the traditional related literature. These values are in line with Chilean estimations. The first subsection presents estimates of the Central Bank of Chile's feedback rule found in Parrado (2000), while the second subsection considers the choice of parameter values from the traditional literature.

Monetary Policy Rule

Empirical research suggests that many countries have used anticipated future inflation rather than current or lagged inflation. Parrado (2000) employs generalized method of moments (GMM) to show that the Central Bank of Chile's actions during the 1990s were driven mainly by an inflation-forecast-based policy rule. Table 1 reports GMM estimates of coefficients χ_π, χ_x, χ_s, and ρ using monthly time series from 1990:12 to 1999:02. These estimates yield several results. First, the coefficient associated with expected inflation is greater than one; this indicates that whenever expected inflation rose, the Central Bank reacted by increasing real interest rates aggressively. Second, the coefficient that captures interest inertia is low ($\rho \cong 0.5$), which suggests that the monetary authority reacted independently of the level of past interest rates. Third, the coefficient associated with output does not have the expected sign, but it is not significant. We therefore cannot reject the hypothesis that χ_x is 0. Finally,

Table 1. GMM Estimations of the Central Bank of Chile's Reaction Function[a]

Reaction to inflation	υ_π	υ_x	υ_s	ρ	p
Expected inflation (6 periods ahead)	1.98 (0.61)	–0.18 (2.16)	3.34 (1.92)	0.50 (0.15)	0.06
Expected inflation (3 periods ahead)	2.03 (0.63)	–0.22 (1.97)	3.33 (1.90)	0.50 (0.15)	0.06
Current inflation	3.50 (2.77)	3.01 (5.02)	1.45 (4.06)	0.73 (0.18)	0.07

Source: Parrado (2000).

a. The set of instruments includes one to six, nine, and twelve lags of inflation, output, the interest rate, commodity price inflation, and money growth. Standard deviations are in parentheses.

estimates of χ_s (the coefficient that measures the sensitivity to the exchange rate) are high and significant. This indicates that the Central Bank was trying to stabilize exchange rates during the 1990s.

In sum, we can infer from the estimates that during the sample period the Chilean Central Bank tried to stabilize only inflation (ignoring output), directly through the inflation target and indirectly through the nominal exchange rate and current account.[9]

Other Parameter Values

The following parameter values are selected both from traditional related literature and from current Chilean data. The quarterly discount factor is set at $\beta = 0.99$. We take the share of home goods in total home consumption to be $\gamma = 0.29$, which is equivalent to the average share of Chilean imports in its GDP over the period 1998–2000. We let the probability that a firm does not change its price within a given period, α, equal 0.75, which implies that the frequency of price adjustment is four quarters. The price demand elasticity or the degree of monopolistic competition, θ, is set at 4.33. We set $\sigma = 1$, which corresponds to log utility, and we assume that the elasticity of substitution between domestic and foreign goods, η, equals 1.5.

In the policy rule (equation 22), the degree of interest rate smoothing, ρ_i, is equal to 0.7 and the coefficient of inflation, χ_π, is 1.5. In the

9. The estimates in Parrado (2000) do not differ significantly between CPI and domestic inflation.

simulations, we compare rules with $\chi_x = 0.5$ against $\chi_x = 0.0$ and rules with $\chi_s = 0$ against $\chi_s = 3.34$.

Finally, the serial correlation parameters for foreign interest rate, foreign output, productivity, and domestic interest rate shocks, ρ_{r^*}, ρ_{y^*}, ρ_z, and $\rho_\in$, respectively, are set equal to 0.8.

2.2 Model Solution

The dynamic system is given by equations 16, 17, 19, and 22 and by the definition of domestic inflation, $\pi_{H,t} = p_{H,t} - p_{H,t-1}$. In matrix form, the system is the following:

$$E_t\left[\mathbf{k}_{t+1}\right] = \mathbf{A}\mathbf{k}_t + \mathbf{B}\mathbf{v}_t, \tag{28}$$

where $\mathbf{k}_t$ is a vector of endogenous variables, $\mathbf{k}_t = \left(y_t, \pi_{H,t}, s_t, i_{t-1}, p_{H,t-1}\right)'$, $\mathbf{A}$ is a five-by-five matrix of coefficients, $\mathbf{B}$ is a five-by-four matrix of coefficients, and $\mathbf{v}_t = \left(r_t^*, y_t^*, z_t, \in_t\right)'$.

The dynamic system has two predetermined variables, i_{t-1} and $p_{H,t-1}$, and three nonpredetermined variables, y_t, $\pi_{H,t}$, and s_t. As shown in Blanchard and Kahn (1980), if the number of eigenvalues of $\mathbf{A}$ outside the unit circle is equal to the number of nonpredetermined variables —in our case three— then there exists a unique rational expectations solution to system 28.

The strategy is to transform the model into canonical form. Let $\mathbf{A} = \mathbf{QJQ}^{-1}$, where $\mathbf{J}$ is the Jordan matrix associated with $\mathbf{A}$, and $\mathbf{Q}$ is the corresponding matrix of eigenvectors. We can define the vector of canonical variables as $\mathbf{w}_t = \mathbf{Q}^{-1}\mathbf{k} = (a_t, b_t)$, where a_t and b_t are associated with the unstable and stable eigenvalues, respectively. Let $\mathbf{J}$ and $\mathbf{Q}$ be the corresponding partition of the Jordan matrix and matrix of eigenvectors, respectively, with

$$\mathbf{J} = \begin{bmatrix} J_a & 0 \\ 0 & J_b \end{bmatrix} \text{ and } \mathbf{Q} = \left(Q_a,\ Q_b\right).$$

Thus we can rewrite system 28 as

$$E_t\begin{bmatrix} a_{t+1} \\ b_{t+1} \end{bmatrix} = \begin{bmatrix} J_a & 0 \\ 0 & J_b \end{bmatrix} \begin{bmatrix} a_t \\ b_t \end{bmatrix}. \tag{29}$$

The canonical system requires that we set $a_t = 0, \forall_t$, to rule out explosive solutions. If the number of eigenvalues outside the unit circle is equal to the number of nonpredetermined variables, the appropriate normalization choice is

$$b_t = \begin{bmatrix} i_{t-1} \\ p_{H,t-1} \end{bmatrix}$$

We know that i_{t-1} and $p_{H,t-1}$ are predetermined, and therefore $b_{t+1} = E_t[b_{t+1}]$. This implies that $b_t = \boldsymbol{\varphi}_b b_{t+1}$, where $\boldsymbol{\varphi}_b$ is a two-by-two matrix with the two stable eigenvalues in the diagonal. This type of equilibrium implies that output, inflation, the real exchange rate, and the interest rate converge monotonically toward their steady states.

3. Results and Numerical Comparisons

We consider four types of aggregate shocks: foreign interest rate shocks, foreign output shocks, technology shocks, and domestic interest rate shocks. Each shock is a first-order process, as described above. As Rotemberg and Woodford (1998a) stress, one has to present unconditional standard deviations to obtain a policy evaluation criterion that is not subject to any problem of time consistency. In other words, we do not want to condition on the current state of the economy at the particular date at which the policy action is to be taken. Selected unconditional standard deviations for each shock are reported in appendix B for all exercises.

The foreign interest rate shock has effects on both regions: our open economy and the rest of the world. Therefore, whenever we experience an unanticipated increase of 25 basis points in the foreign nominal interest rate, we also include a negative shock in foreign output with variance 3.76.[10]

Finally, each subsection presents the impulse response functions of key variables to different stochastic disturbances for different exchange rate regimes and inflation targeting regimes.

3.1 Flexible versus Managed Exchange Rates

Figures 1 and 2 display the responses of our economy to different types of shocks under two different scenarios: a floating exchange rate regime

10. To obtain the variance of the rest of the world's variables, we compute the dynamic behavior of the rest of the world assuming that the consumption of domestic goods is negligible. We also assume that the foreign monetary authority follows a traditional Taylor rule with parameters $\chi_{\pi^*} = 1.5$ and $\chi_{y^*} = 0.5$.

Figure 1. Flexible versus Managed Exchange Rate: Domestic Inflation Targeting[a]

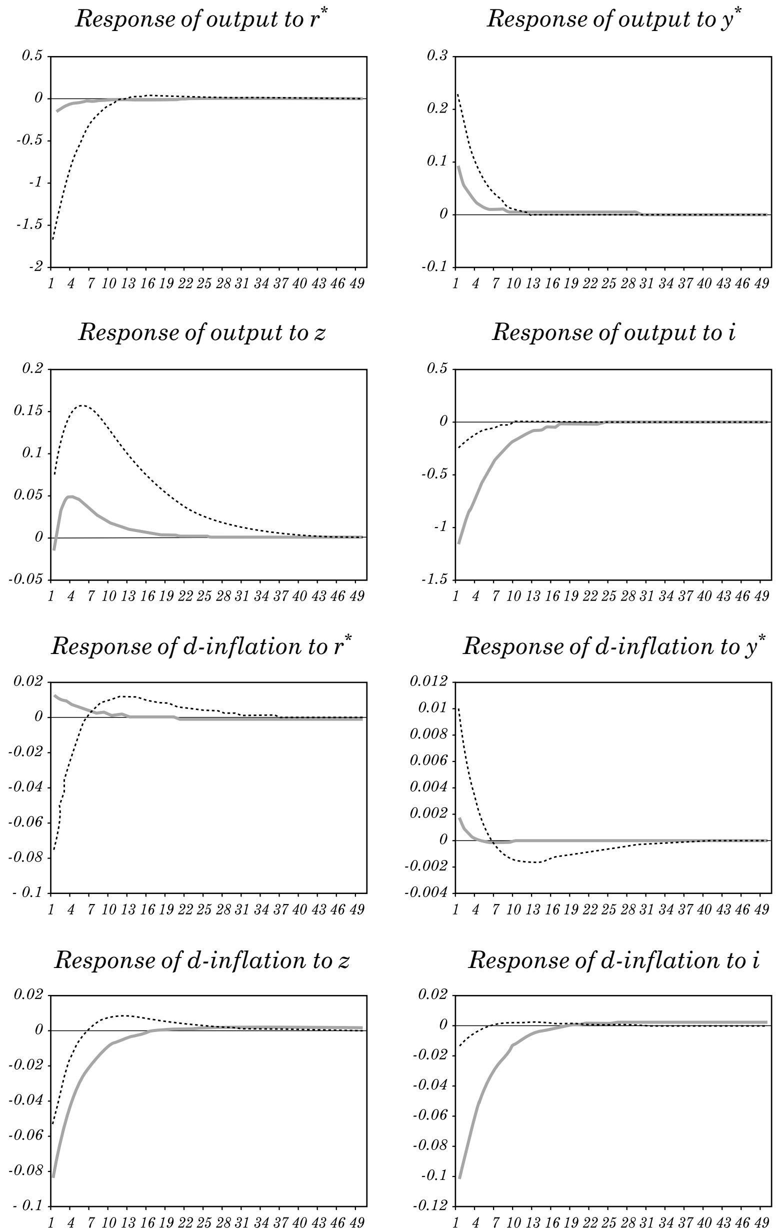


Figure 1. (continued)

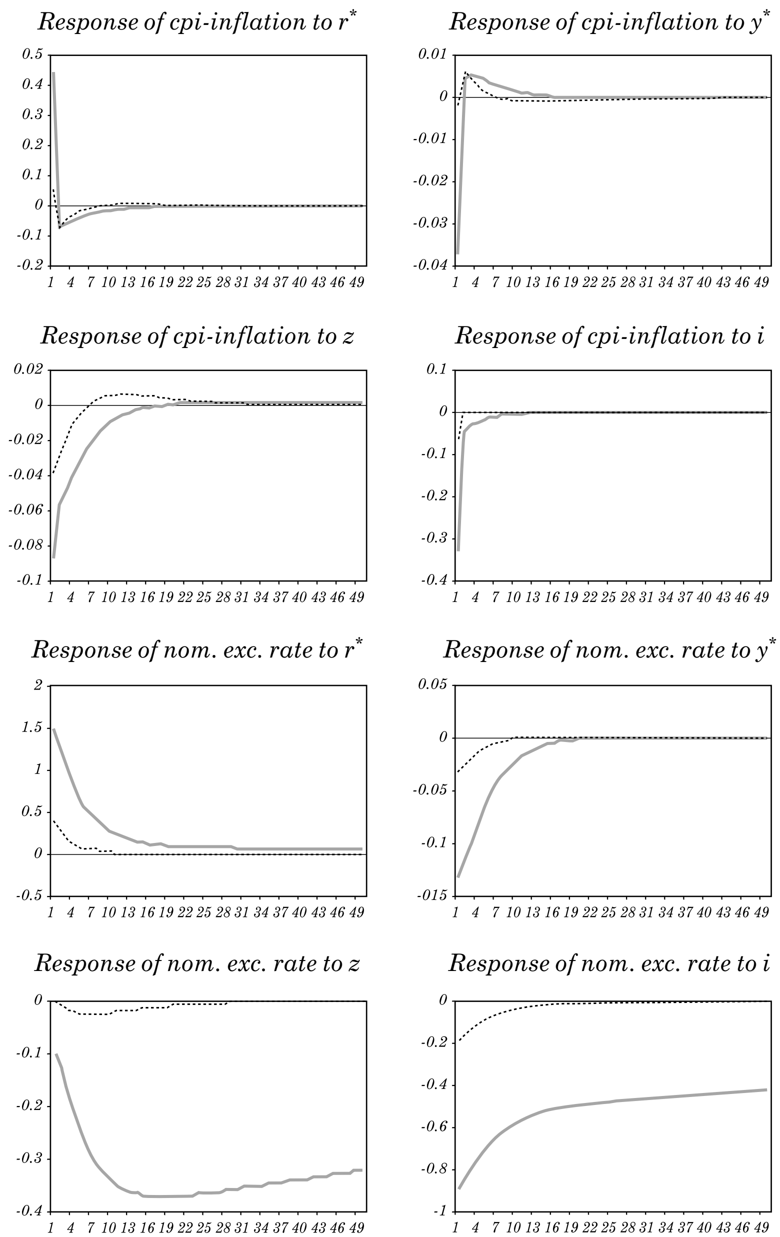


Figure 1. (continued)

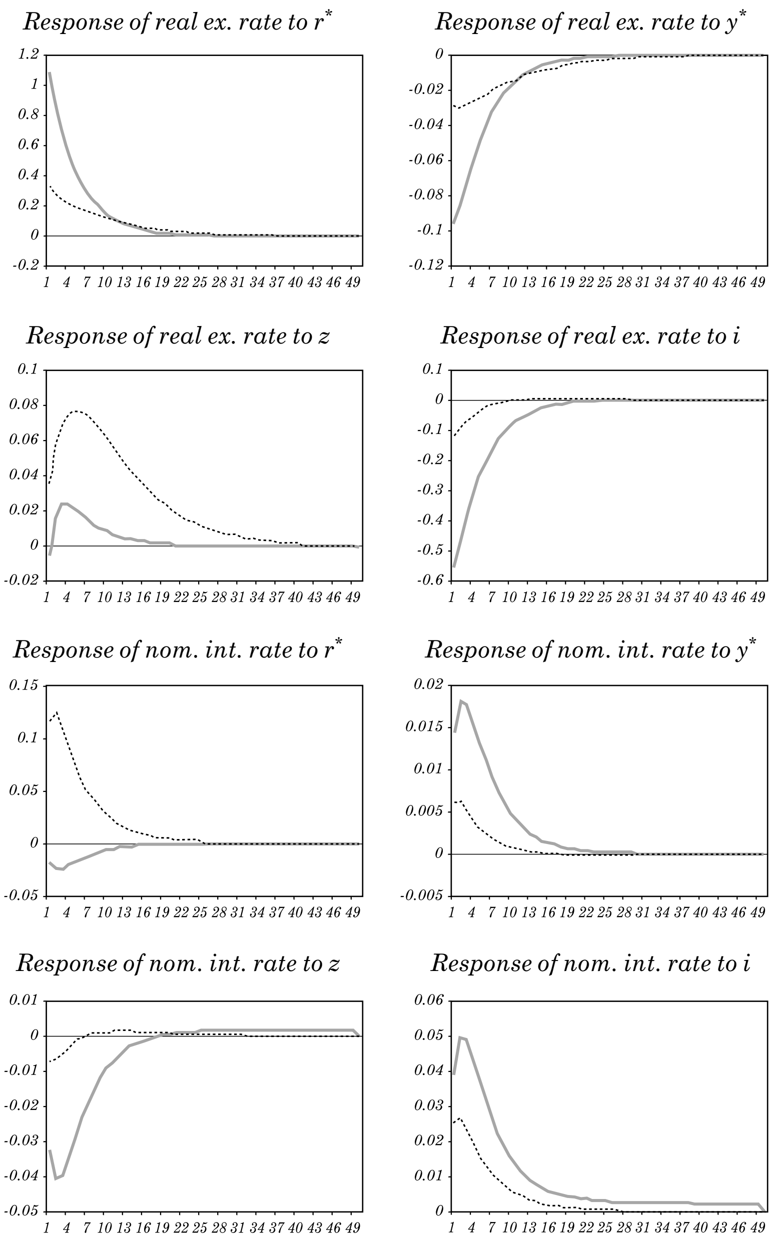
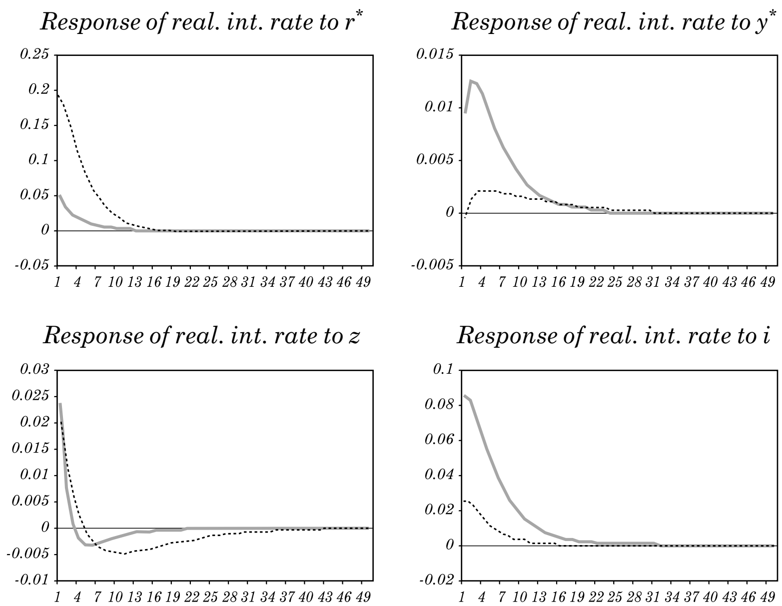


Figure 1. (continued)



a. The first graph for each variable presents impulse responses to a twenty-five-basis-point temporary innovation in the foreign interest rate; the second to a 1 percent foreign output shock; the third to a 1 percent total factor productivity shock; and the fourth to a twenty-five-basis-point temporary innovation in the domestic interest rate. The solid line corresponds to a flexible exchange rate and the dashed line to a managed exchange rate.

and a managed exchange rate regime. In addition, figure 1 presents the impulse response functions in the presence of domestic inflation targeting, whereas figure 2 takes into consideration CPI inflation targeting.

Recall that under the managed exchange rate, the monetary authority gives some weight to exchange rate stabilization in its policy rule, that is, $\chi_s \in (0,\infty)$. Since we are not allowing for a pure fixed exchange rate, the policy instrument is still the nominal interest rate. In the flexible exchange rate case, the central bank adopts a feedback rule that adjusts the nominal rate to variations in output and inflation only, that is, $\chi_s = 0$.

To demonstrate the dynamic properties of the model, we use the example of a foreign disturbance that hits the economy. Our results are consistent with previous studies and conventional wisdom. Under managed exchange rates, the domestic interest rate rises to match the

Figure 2. Flexible versus Managed Exchange Rate: CPI Inflation Targeting[a]

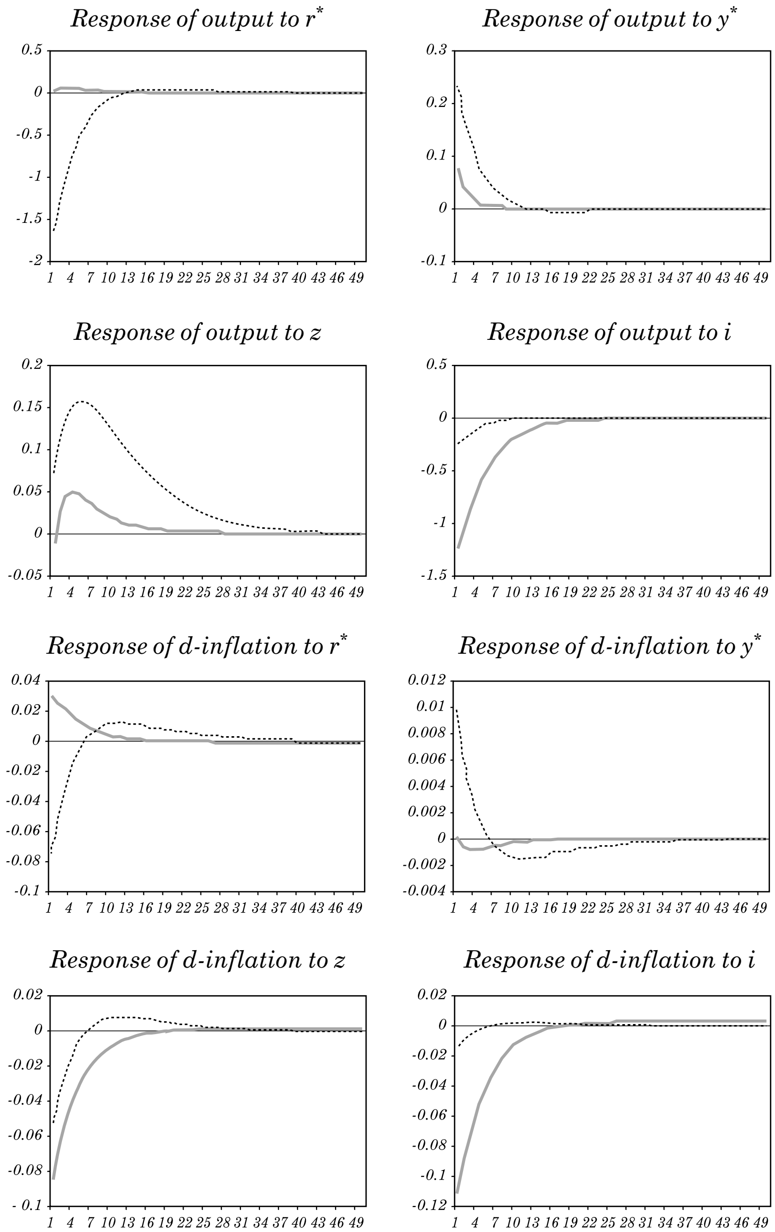


Figure 2. (continued)

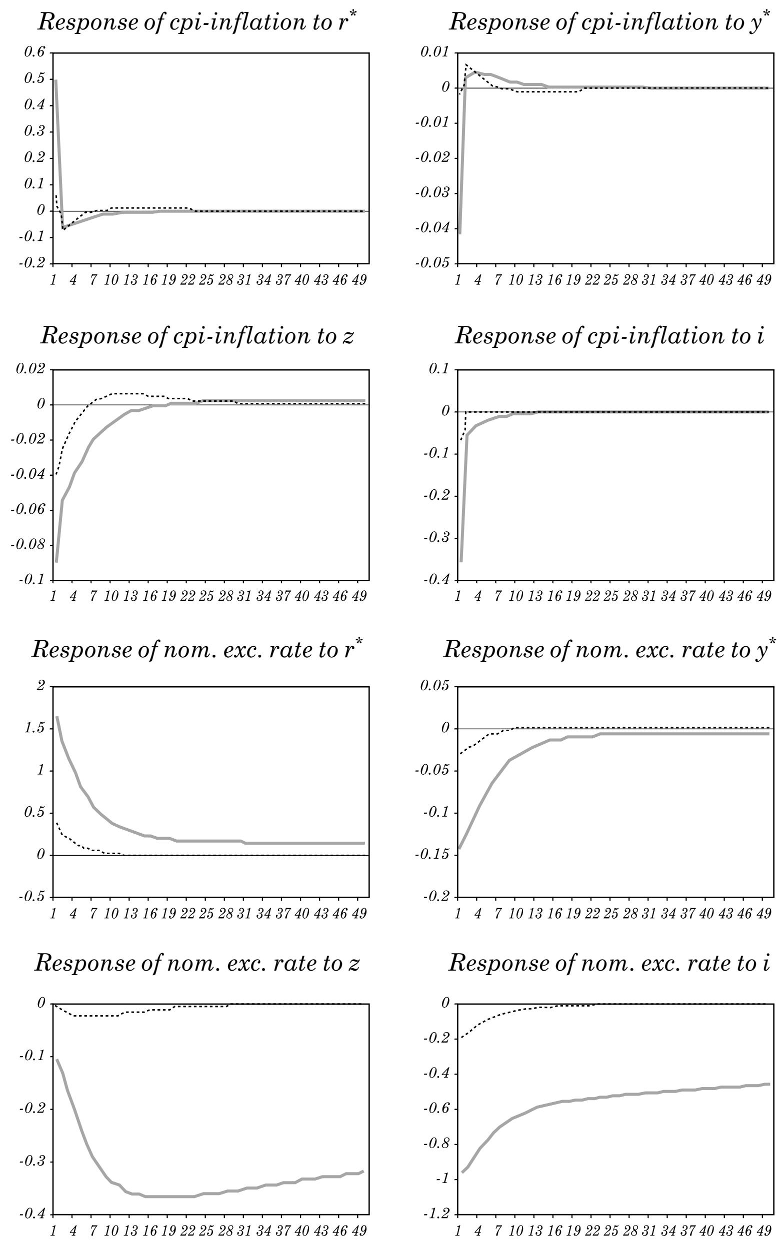


Figure 2. (continued)

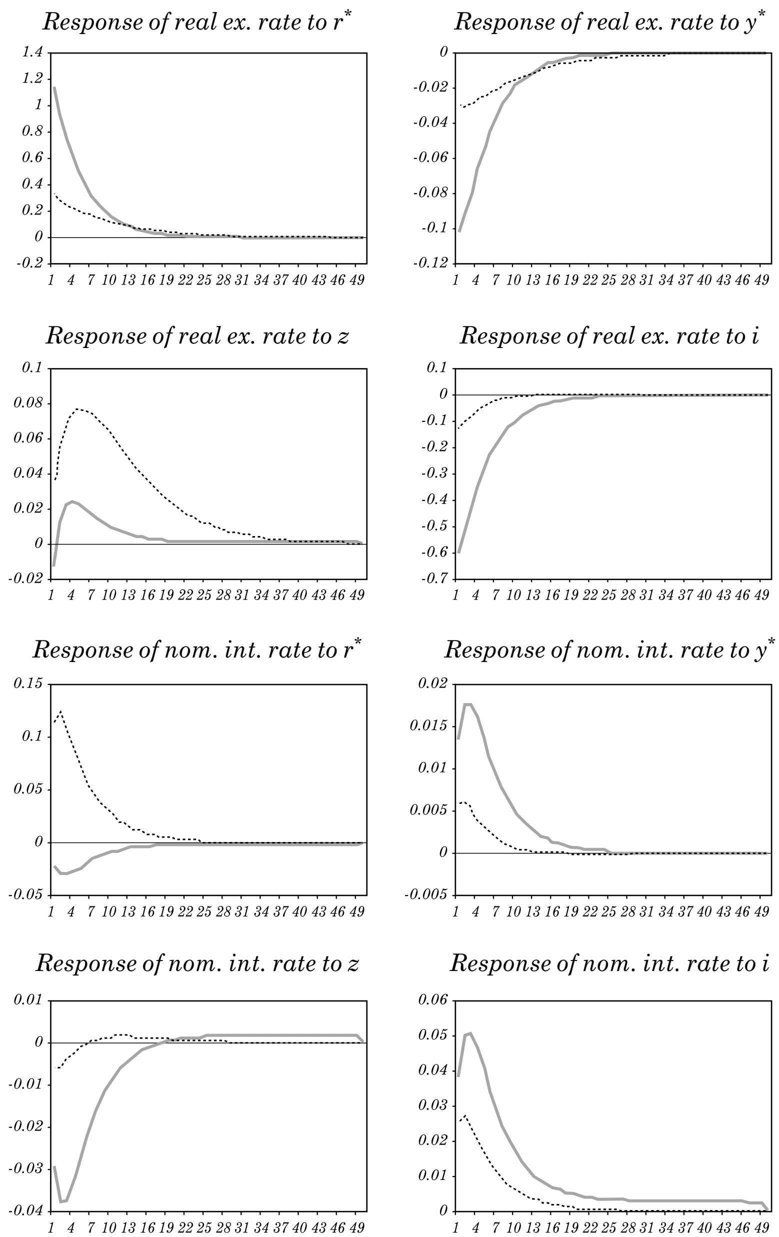
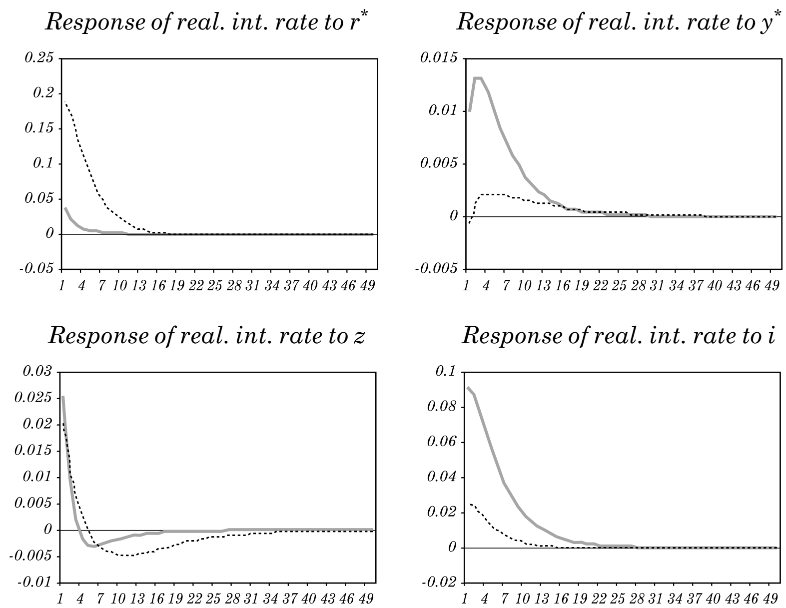


Figure 2. (continued)



a. The first graph for each variable presents impulse responses to a twenty-five-basis-point temporary innovation in the foreign interest rate; the second to a 1 percent foreign output shock; the third to a 1 percent total factor productivity shock; and the fourth to a twenty-five-basis-point temporary innovation in the domestic interest rate. The solid line corresponds to a flexible exchange rate and the dashed line to a managed exchange rate.

foreign rate movement, at least partially. Nominal rigidities further cause a significant rise in the real interest rate, which, in turn, induces a contraction in output.

Under flexible exchange rates, the domestic nominal interest rate is no longer tied to the foreign interest rate. The foreign interest rate shock thus produces a considerable nominal depreciation, which has a significant impact on CPI inflation. Output volatility is lower in the flexible case than in the managed case because adjustment is immediately reached through changes in the nominal exchange rate and not through changes in the price level. CPI inflation also differs across exchange rate regimes. If this economy has pegged exchange rates, inflation volatility is consistently lower than in an economy with flexible exchange rates.

Table 2. Welfare Loss

	Type of shock			
Targeting case	*Foreign interest rate* (r_t^*)	*Foreign output* (y_t^*)	*Technology* (z_t)	*Nominal interest rate* ($\in_t$)
Flexible CPI inflation targeting				
Flexible exchange rate	1.8722	0.0229	0.0347	2.9785
Managed exchange rate	3.4804	0.0601	0.1578	0.0920
Strict CPI inflation targeting				
Flexible exchange rate	2.9837	0.0642	0.0964	96.6302
Managed exchange rate	4.5803	0.0800	0.1857	0.1263
Flexible domestic inflation targeting				
Flexible exchange rate	1.5876	0.0229	0.0345	2.5242
Managed exchange rate	3.5089	0.0602	0.1581	0.0884
Strict domestic inflation targeting				
Flexible exchange rate	1.4537	0.0745	0.0718	45.5737
Managed exchange rate	4.5890	0.0796	0.1861	0.1203

Welfare Comparisons

Table 2 compares the welfare loss associated with alternative monetary policies and different unanticipated innovations. The main result is that flexible exchange rates dominate managed exchange rates if the economy is hit by foreign interest, foreign output, and productivity innovations, while the reverse is true for nominal interest rate shocks. This confirms the conventional wisdom that flexibility is better in the case of foreign and real shocks, while pegging is preferable in the case of nominal shocks.

3.2 CPI versus Domestic Inflation Targeting

Figures 3 and 4 present impulse response functions comparing CPI and domestic inflation targeting. Figure 3 considers the responses in the presence of flexible exchange rates, while figure 4 covers the managed exchange rate case.

If the economy has a managed exchange rate, the distinction between CPI and domestic inflation targeting is not relevant, since volatility in all variables is equivalent. This result is obvious, because targeting the CPI is equivalent to targeting both domestic inflation and the nominal exchange rate; it is also equivalent to targeting domestic inflation with managed exchange rates.

Figure 3. CPI versus Domestic Inflation Targeting: Flexible Exchange Rate[a]

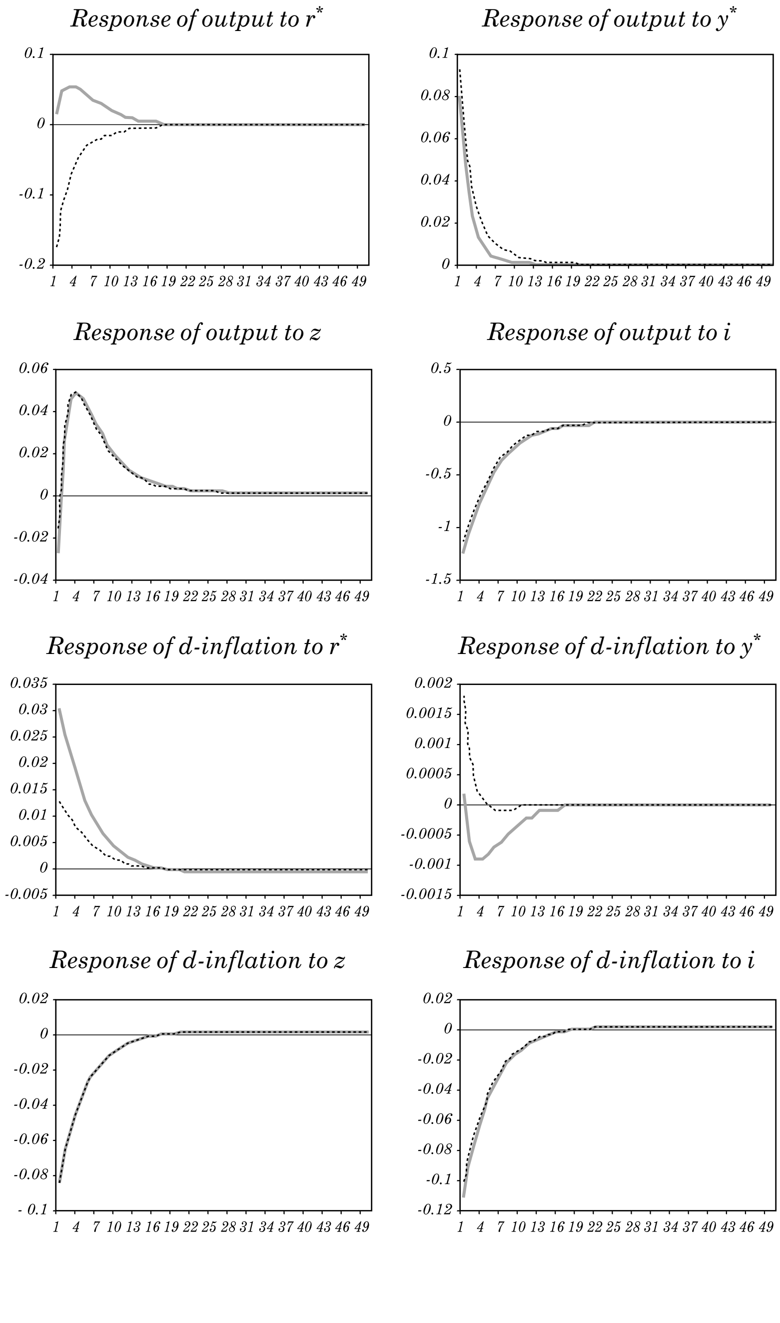


Figure 3. (continued)

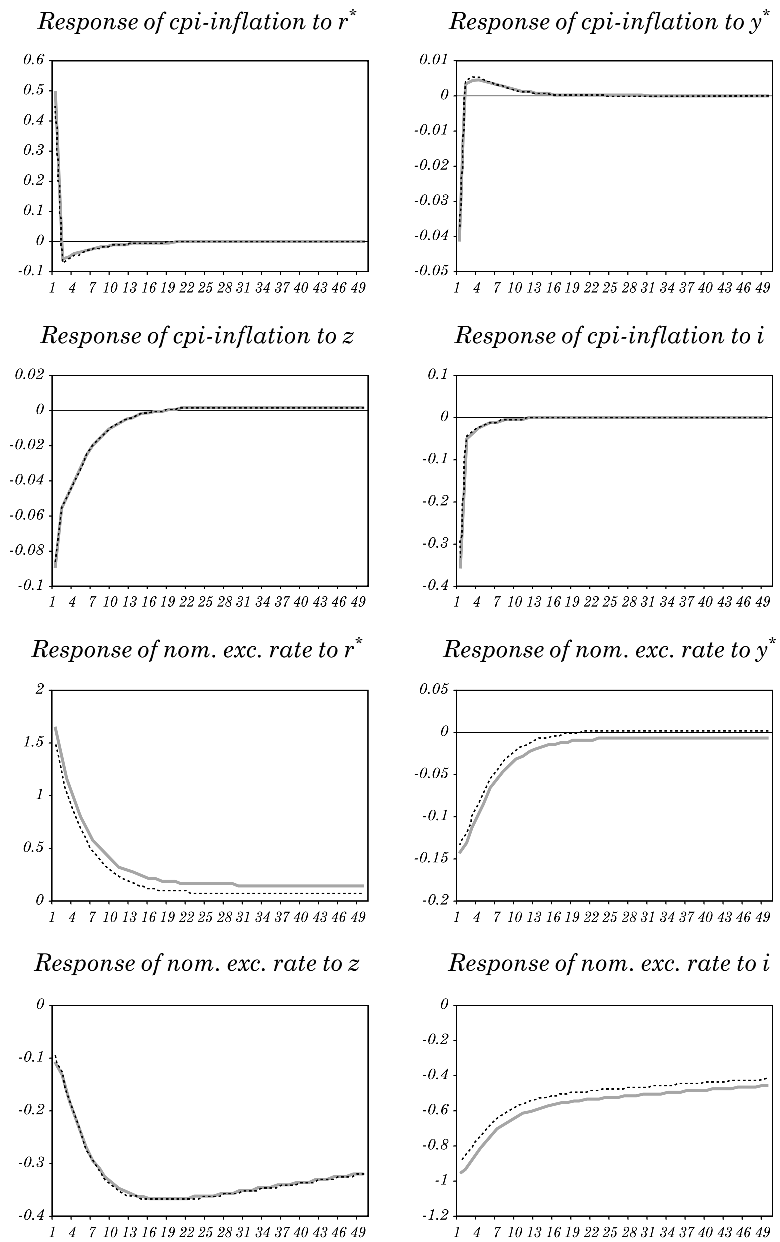


Figure 3. (continued)

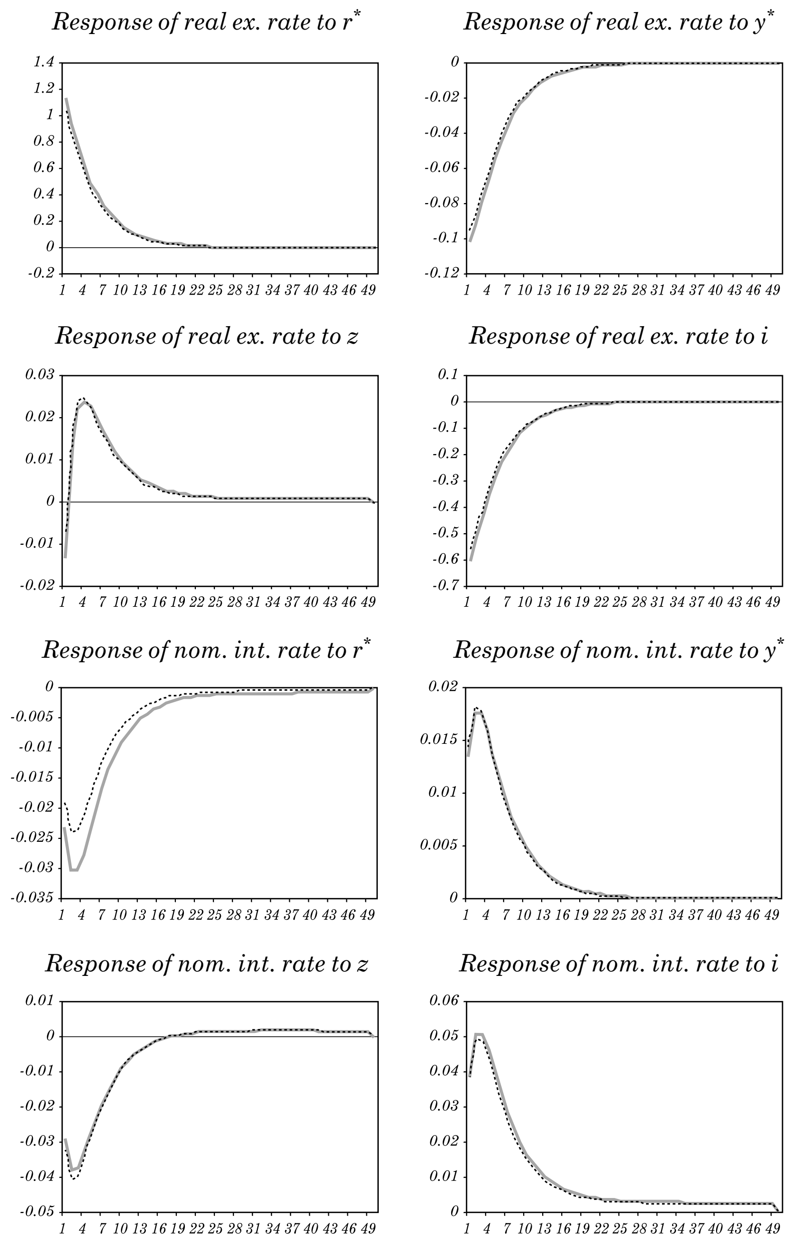
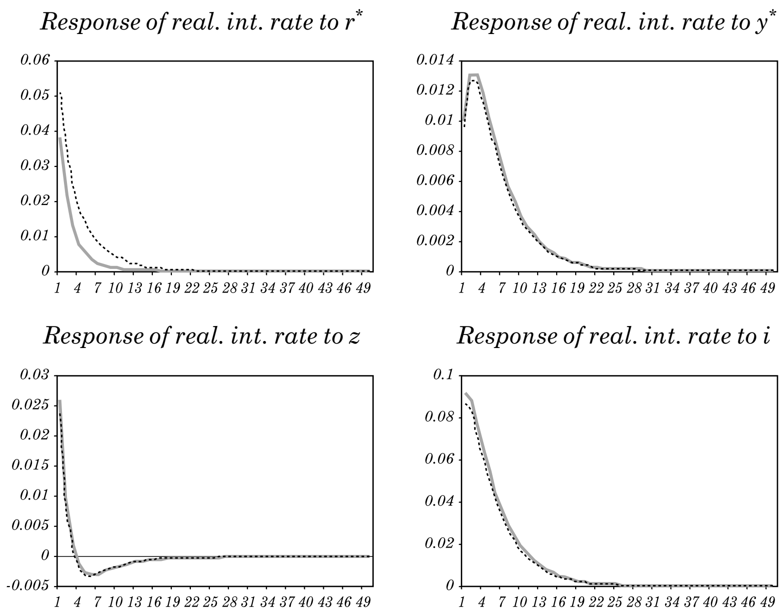


Figure 3. (continued)



a. The first graph for each variable presents impulse responses to a twenty-five-basis-point temporary innovation in the foreign interest rate; the second to a 1 percent foreign output shock; the third to a 1 percent total factor productivity shock; and the fourth to a twenty-five-basis-point temporary innovation in the domestic interest rate. The solid line corresponds to CPI inflation targeting and the dashed line to domestic inflation targeting.

Focus, then, on the flexible exchange rate case, considering the effects of a foreign interest rate innovation. (The same conclusions hold across different shocks.) Dynamic responses are similar to those in the previous subsection. The key result in this comparison is that for all shocks, targeting domestic inflation is preferable to targeting CPI inflation. The intuition is that the domestic inflation target allows the exchange rate to move more in response to disturbances, thereby stabilizing output to a greater degree. The variability of domestic inflation (obviously) and output is therefore lower under domestic inflation targeting, while the variability of the real exchange rate can be higher, though it need not be. The beneficial welfare impact of the former two always outweighs the welfare costs of higher real exchange rate volatility (when it exists), so that welfare losses are lower under domestic inflation targeting than under the CPI targeting regime.

Figure 4. CPI versus Domestic Inflation Targeting: Managed Exchange Rate[a]

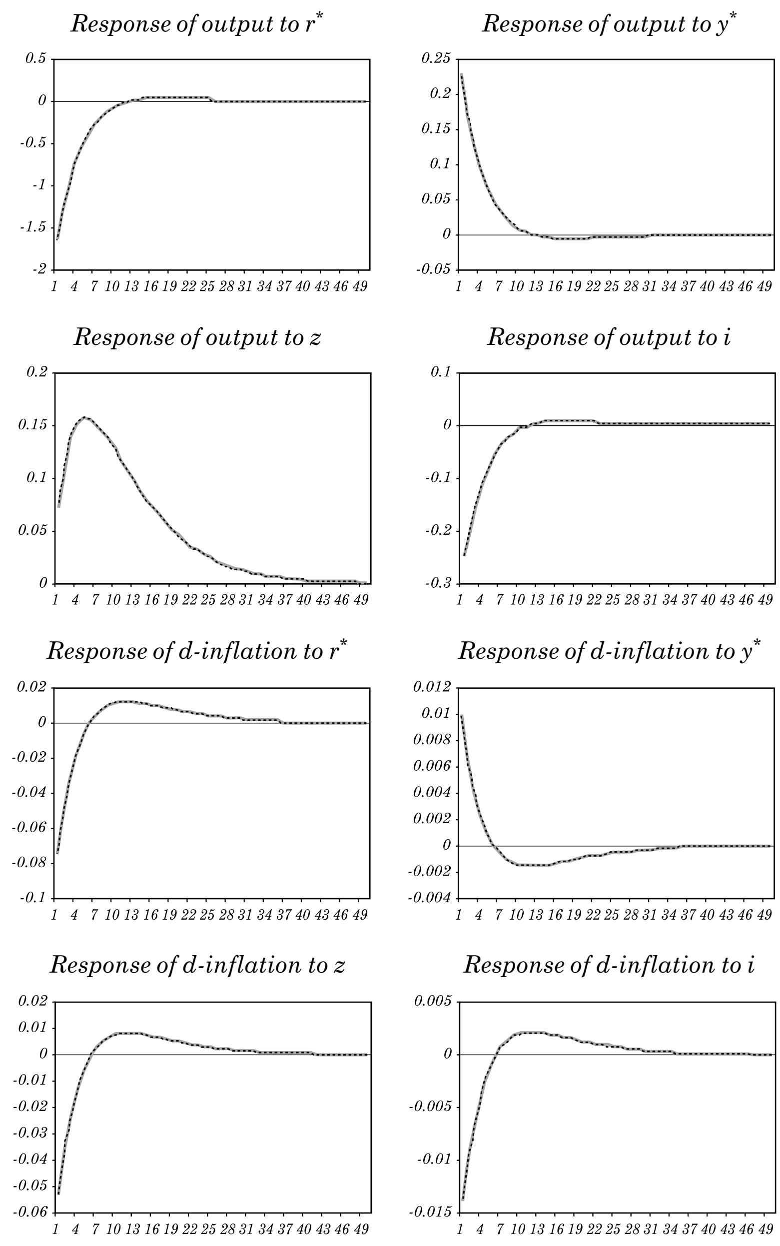


Figure 4. (continued)

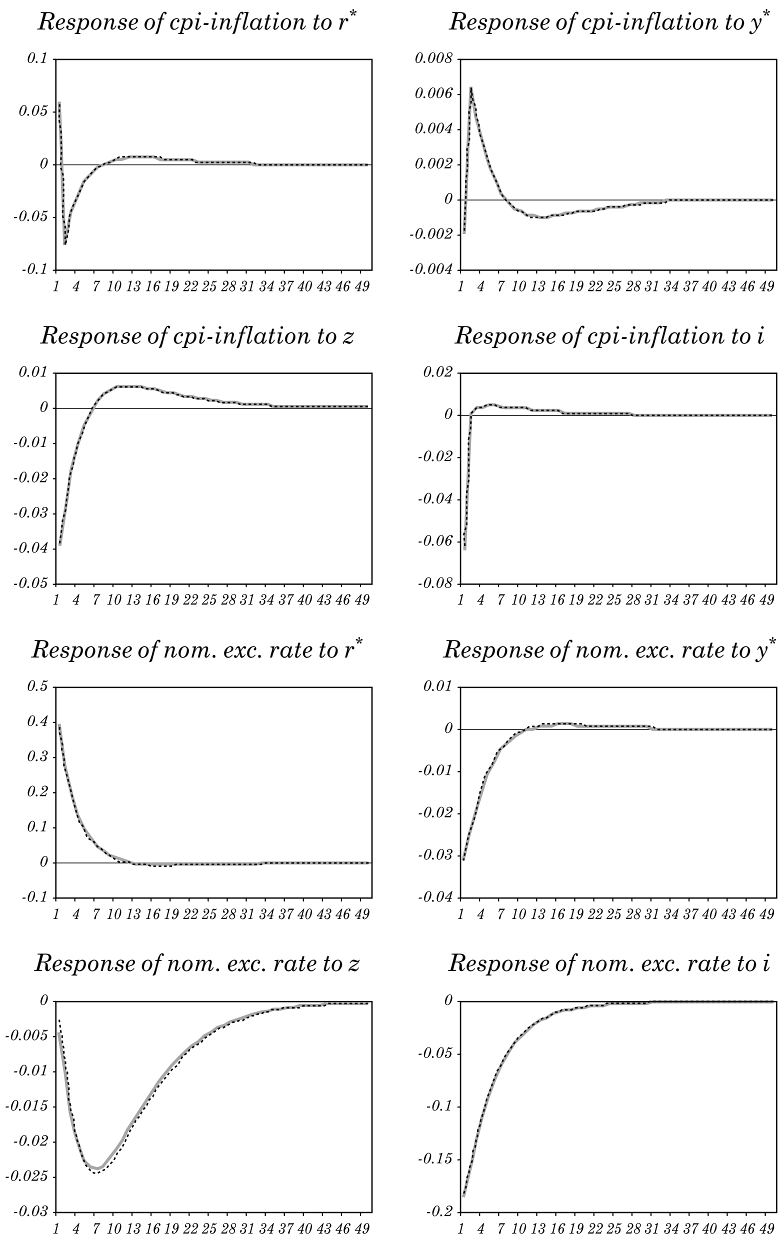


Figure 4. (continued)

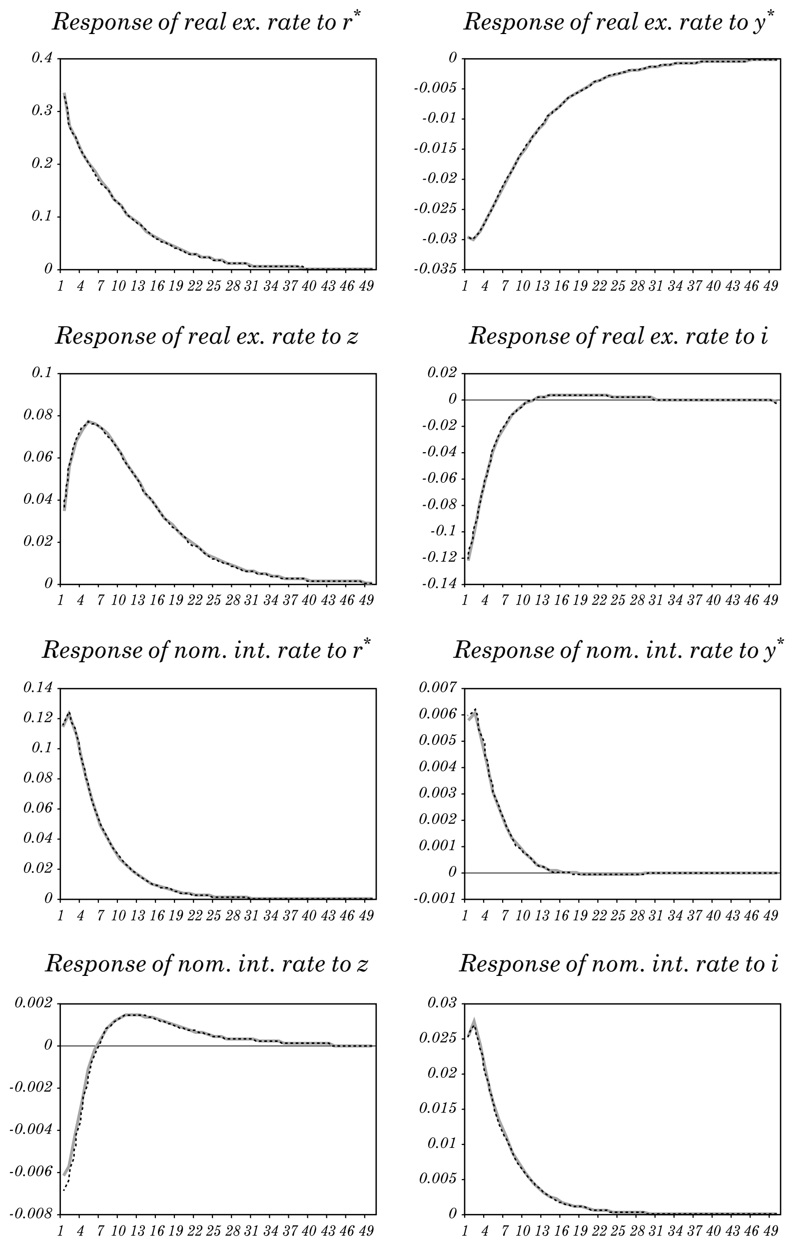
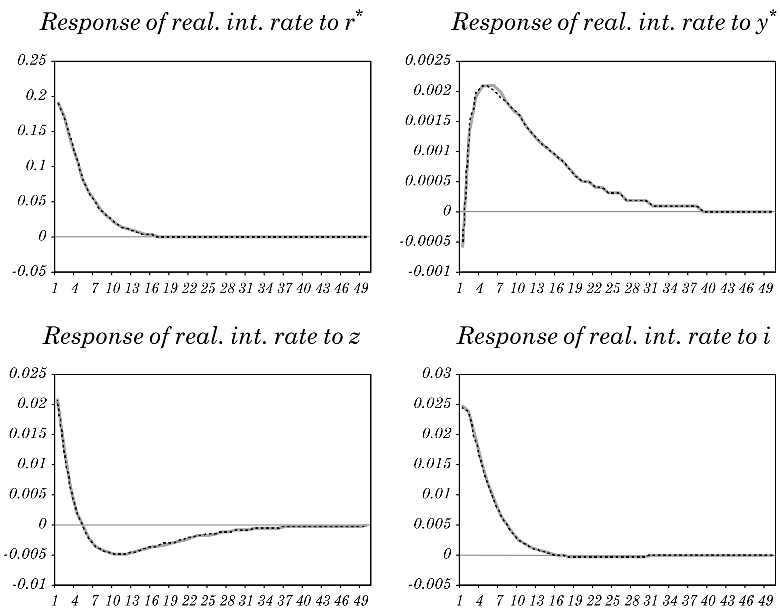


Figure 4. (continued)



a. The first graph for each variable presents impulse responses to a twenty-five-basis-point temporary innovation in the foreign interest rate; the second to a 1 percent foreign output shock; the third to a 1 percent total factor productivity shock; and the fourth to a twenty-five-basis-point temporary innovation in the domestic interest rate. The solid line corresponds to CPI inflation targeting and the dashed line to domestic inflation targeting.

Welfare Comparisons

Social loss is larger under CPI inflation targeting than under domestic inflation targeting (see table 2). In the flexible exchange rate case, which is the relevant regime for comparing CPI and domestic inflation targeting, the same conclusion holds, irrespective of the targeting case and source of the shock.[11] A monetary policy that considers domestic inflation is far more stabilizing compared with one that takes CPI inflation into account in the inflation targeting regime.

11. The only exception is in the case of strict inflation targeting in the presence of productivity shocks. In this case, however, the difference between the CPI and domestic inflation targeting is negligible.

3.3 Flexible versus Strict Inflation Targeting

Flexible inflation targeting, in the nomenclature of Svensson (2000), occurs when a central bank seeks to stabilize output, inflation, and the exchange rate. By contrast, strict inflation targeting occurs when the monetary authority only attempts to stabilize inflation and the exchange rate without considering the effects on output. Figures 5 and 6 compare the impulse response functions of flexible and strict inflation targeting under flexible and managed exchange rates, respectively.

A number of interesting results emerge from these figures. First, independently of the source of disturbance, output volatility is higher in the strict case than in the flexible case. Second, the results are ambiguous in terms of inflation stability and depend on the type of shock. For instance, if the source of disturbance is the domestic interest rate, flexible inflation targeting dominates strict inflation targeting. If there is a productivity shock, however, the impact on CPI and domestic inflation is higher under flexible inflation targeting. As Svensson (2000) points out, strict CPI inflation targeting relies on the use of the exchange rate channel to stabilize CPI inflation. The real exchange rate thus exhibits lower volatility under strict targeting than under the flexible case, and this results in higher volatility of output and domestic inflation. These differences decrease under managed exchange rates, since in this case the monetary authority seeks to stabilize the nominal exchange rate as well and hence introduces less adjustment to nominal interest rates and, in turn, less volatility in output and inflation.

Welfare Comparisons

As mentioned above, we found mixed evidence regarding inflation volatility in the two cases. The conclusion is quite clear, however, with regard to the social loss, which combines inflation, domestic inflation, and real exchange rate volatility: social loss is lower under flexible inflation targeting than under strict inflation targeting (see table 2).

4. Conclusions

In this paper we have developed a simple dynamic neo-Keynesian model of a small open economy and used it to examine the effects of different exchange rate regimes and inflation target indicators, in the context of simple forecast-based monetary policy rules. The main findings of the paper are that the effects of inflation targeting on output

Figure 5. Flexible versus Strict CPI Inflation Targeting: Flexible Exchange Rate[a]

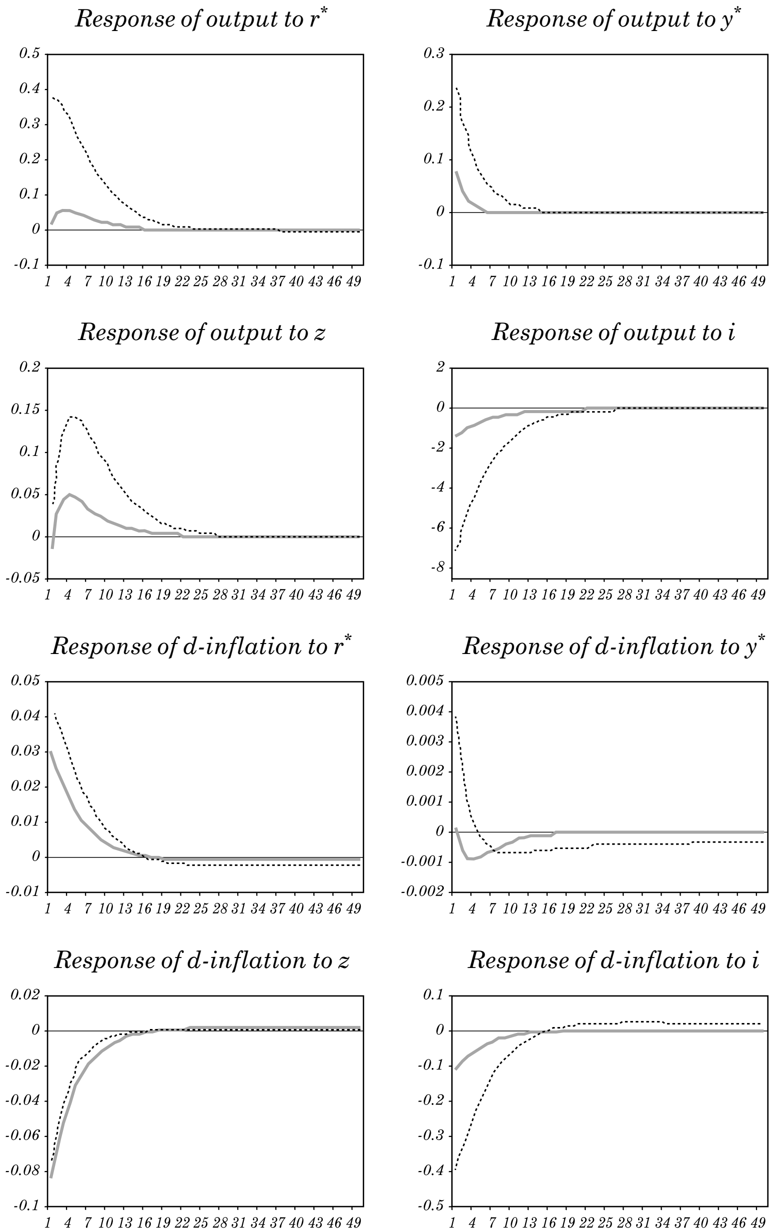


Figure 5. (continued)

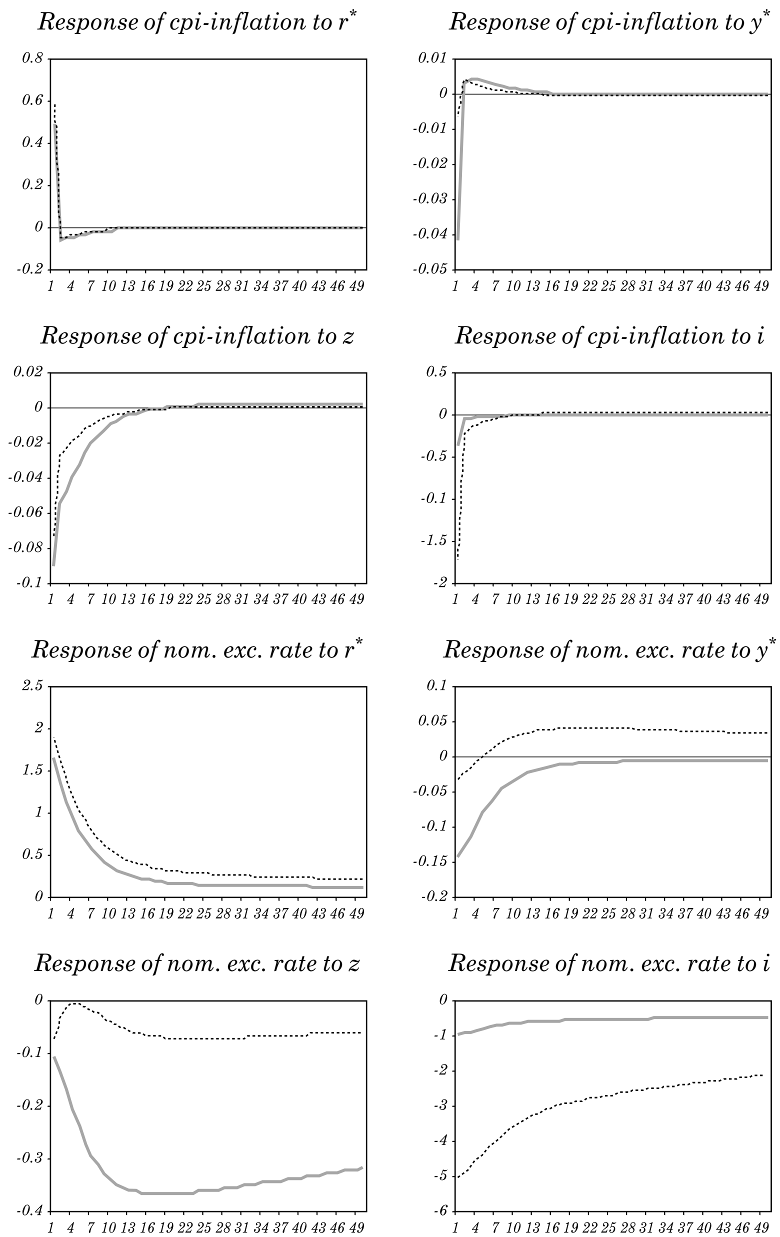


Figure 5. (continued)

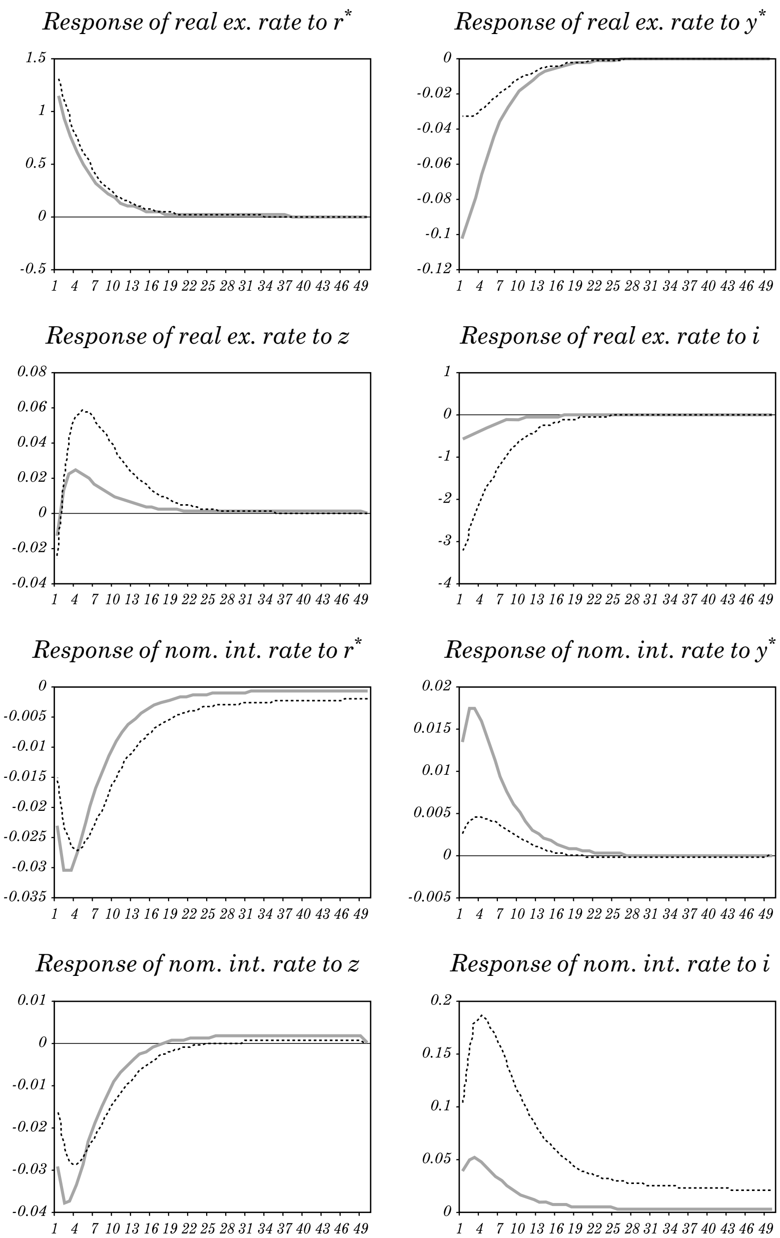
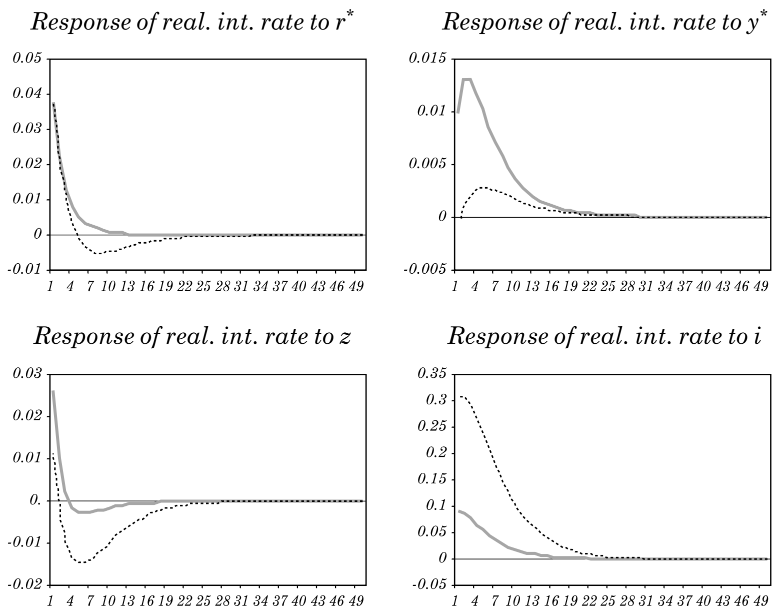


Figure 5. (continued)



a. The first graph for each variable presents impulse responses to a twenty-five-basis-point temporary innovation in the foreign interest rate; the second to a 1 percent foreign output shock; the third to a 1 percent total factor productivity shock; and the fourth to a twenty-five-basis-point temporary innovation in the domestic interest rate. The solid line corresponds to flexible CPI inflation targeting and the dashed line to strict CPI inflation targeting.

and inflation volatility depend crucially on the exchange rate regime and the inflation index being targeted, as well as on the type of shocks affecting this economy. With regard to the exchange rate, we find that the social loss is much higher under managed exchange rates than under flexible rates if there are foreign and real shocks, while for nominal shocks, the reverse is true. As far as the definition of the inflation targeting index is concerned, domestic inflation appears to outperform the CPI. Finally, and somewhat predictably, flexible inflation targeting is superior to strict inflation targeting.

These results, while suggestive, are subject to many caveats. Here we highlight three. First, we are dealing with simulation results. Conclusions about policy dominance and welfare consequences depend on a specific parameterization, and they should not be taken as general propositions. We chose parameters that conform to the Chilean economy, so

Figure 6. Flexible vs. Strict Domestic Inflation Targeting: Flexible Exchange Rate[a]

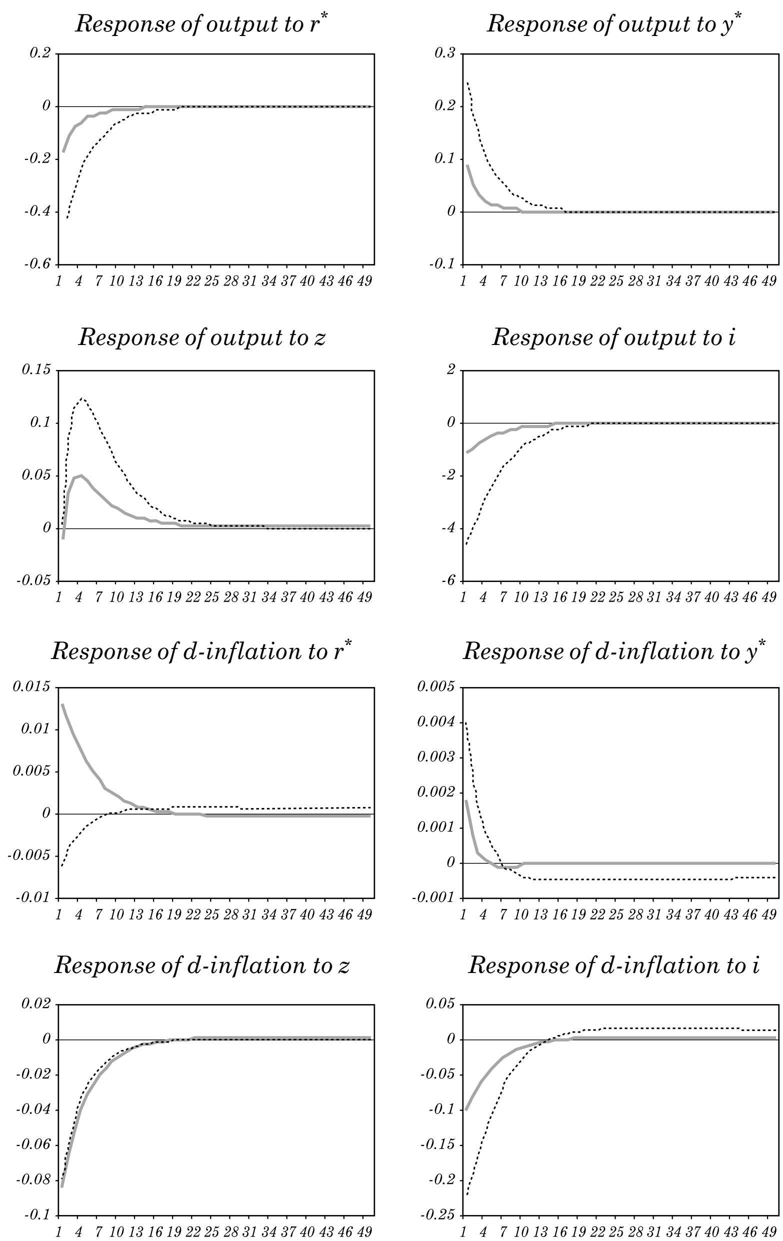


Figure 6. (continued)

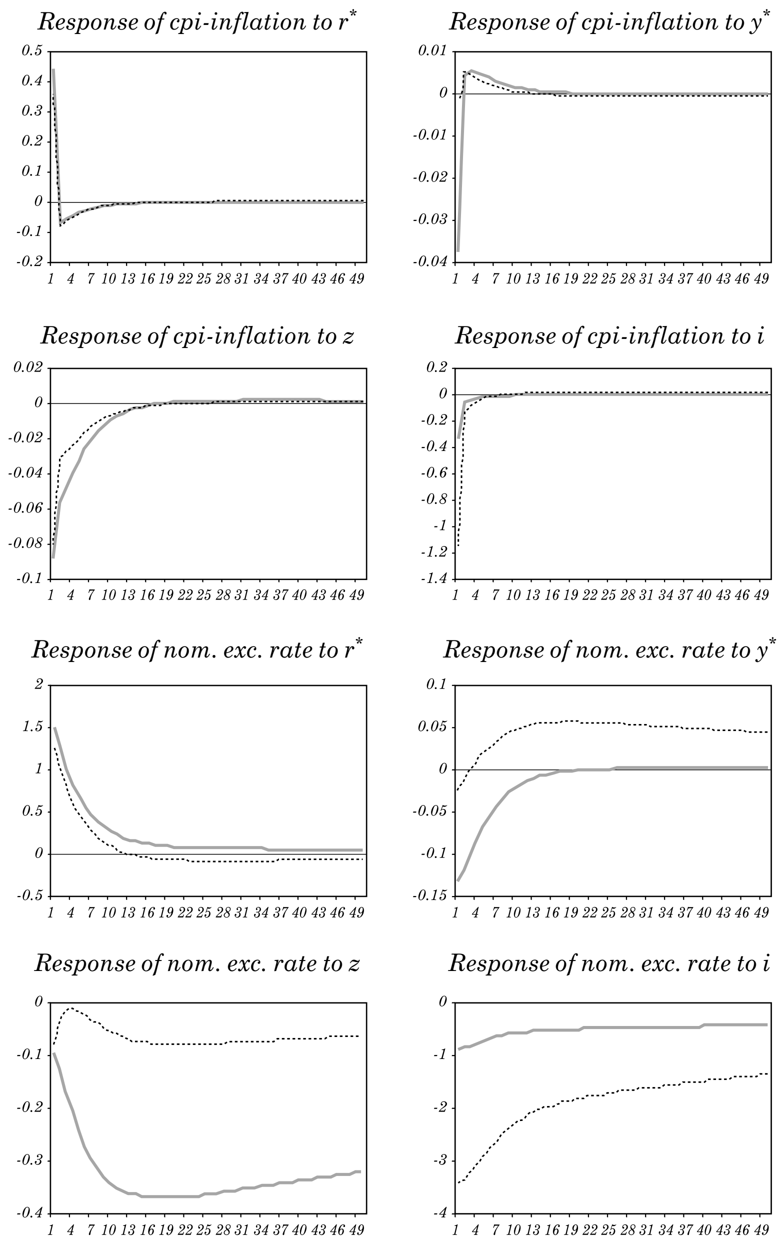


Figure 6. (continued)

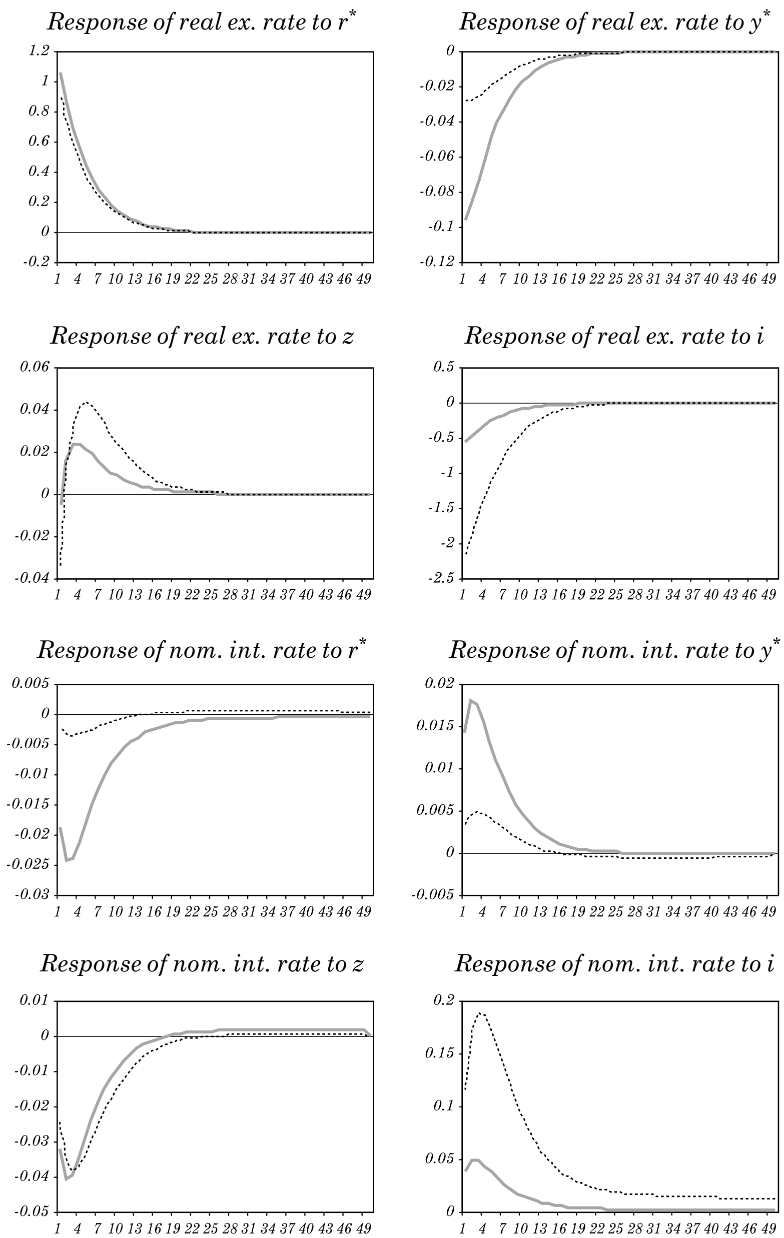
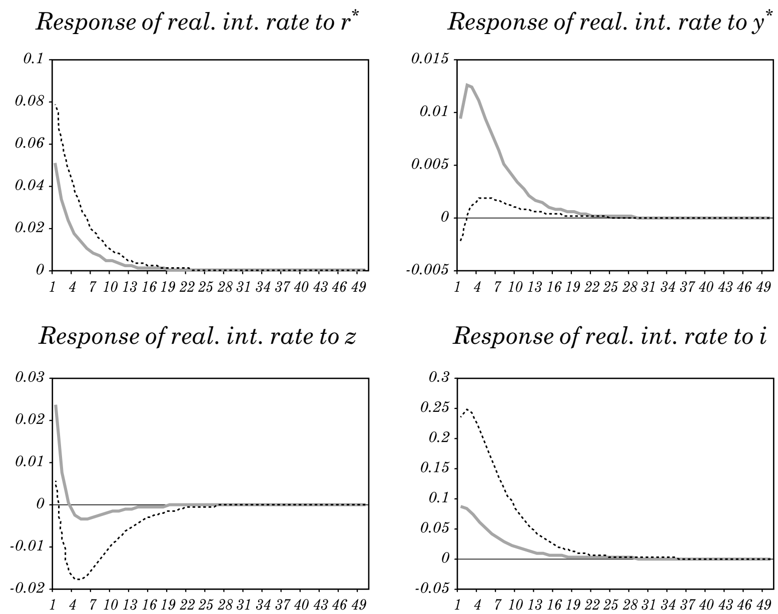


Figure 6. (continued)



a. The first graph for each variable presents impulse responses to a twenty-five-basis-point temporary innovation in the foreign interest rate; the second to a 1 percent foreign output shock; the third to a 1 percent total factor productivity shock; and the fourth to a twenty-five-basis-point temporary innovation in the domestic interest rate. The solid line corresponds to flexible domestic inflation targeting and the dashed line to strict domestic inflation targeting.

the conclusions should have some empirical relevance. In addition, we 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 we can come to confident policy recommendations. The second caveat has to do with those aspects the model omits. Much of the recent discussion of exchange rate policy in developing countries is concerned with the impact of exchange rate changes on financial variables: balance sheets, creditworthiness, risk premiums, and so forth. These effects become important when there are imperfections in financial markets; borrowing constraints and dollarization of liabilities are two that have received much recent attention. By contrast, the model here assumes not just well-functioning financial markets, but a full set of state-contingent assets. We have two justifications for this omission: it makes sense to analyze the performance of alternative rules in a more-or-less standard model before moving on to add financial imperfections, and work including financial imperfections in simpler macroeconomic models (see, for instance, Céspedes, Chang, and Velasco, 2000; Chang and Velasco, 2000) shows that in spite of the presence of balance sheet effects and liability dollarization, the qualitative ranking of alternative monetary policies may be quite similar to that found in more standard sticky price models, such as the one studied here.

Finally, a natural next step is to base the analysis on the consumer's utility and not on ad hoc welfare criteria. This important step implies not only aggregating the behavior of individuals, but also finding a tractable way to do so. This extension is not straightforward for a small open economy, since an additional variable—the terms of trade—makes it difficult to arrive at the quadratic formulation based on Taylor approximations developed by Woodford (1996, 2000) and Rotemberg and Woodford (1998a, 1998b).

APPENDIX A

1. Aggregate Demand

For all differentiated goods, market clearing implies

$$Y_t(j) = C_{H,t}(j) + C^*_{H,t}(j).$$

Log-linearization around a steady state with balanced trade implies

$$y_t(j) = (1-\gamma)c_{H,t}(j) + \gamma c^*_{H,t}(j).$$

Define $Y_t(j) \equiv \int_0^1 Y_t(j)dj$ as the aggregate domestic output. Then, log-linearizing this expression around the steady state, we get $y_t = \int_0^1 y_t(j)dj.$

An analogous expression for $c_{H,t}(j)$ and $c^*_{H,t}(j)$ can be obtained to get the following expression: $y_t = (1-\gamma)c_{H,t} + \gamma c^*_{H,t}$. Combining this expression with a log-linearized version of equation 2, namely, $c_t = (1-\gamma)c_{H,t} + \gamma c_{F,t}$, we obtain

$$y_t = (1-\gamma)c_t + \gamma c^*_t + \gamma\eta(2-\gamma)q_t$$

$$= (1-\gamma)c_t + \gamma c^*_t + \gamma\eta(2-\gamma)(s_t + p^*_t - p_{H,t}).$$

Finally, assuming that $u(C) = C^{1-\sigma}/(1-\sigma)$ and using the log-linearization version of the Euler equation 7, we obtain an expression for the domestic output gap (equation 16 in the main text):

$$x_t = E_t[x_{t+1}] + \phi_\pi E_t[\pi_{H,t+1}] - \phi_s(E_t[s_{t+1}] - s_t)$$
$$-\frac{1}{\sigma}i_t - (1-\rho_z)z_t + \gamma(1-\rho_{y^*})y^*_t,$$

where x_t is the domestic output gap, $\phi_\pi = [(1-\gamma)/\sigma + \gamma\eta(2-\gamma)]$, $\phi_s = \gamma[\eta(2-\gamma) - 1/\sigma]$, $0 \le \rho_z \le 1$ and $0 \le \rho_{y^*} \le 1$.

2. Aggregate Supply

The FONC of the firm is:

$$E_t\left[\sum_{k=0}^{\infty}\alpha^k\beta^k\Lambda_{t+k}\left\langle\frac{p_{H,t}(j)}{P_{H,t+k}}-\frac{\theta W_{t+k}V'\left\{\left[p_{H,t}(j)/P_{H,t+k}\right]^{-\theta}C^A_{H,t+k}\right\}}{\theta-1P_{H,t+k}\tilde{Z}_{t+k}}\right\rangle\left[\frac{p_{H,t}(j)}{P_{H,t+k}}\right]^{-\theta}C^A_{H,t+k}\right]=0\,.$$

Define $G_t\equiv p_{H,t}(j)/P_{H,t}$, $\Pi_{H,t}\equiv P_{H,t}/P_{H,t-1}$ and $\zeta\equiv\theta/(\theta-1)$, then

$$E_t\left[\sum_{k=0}^{\infty}\alpha^k\beta^k\Lambda_{t+k}\left\{\frac{G_t}{\prod_{s=1}^{k}\Pi_{H,t+s}}-\zeta\frac{W_{t+k}V'\left[\left(G_t\Big/\prod_{s=1}^{k}\Pi_{H,t+s}\right)^{-\theta}C^A_{H,t+k}\right]}{P_{H,t+k}\tilde{Z}_{t+k}}\right\}\left(\frac{G_t}{\prod_{s=1}^{k}\Pi_{H,t+s}}\right)^{-\theta}C^A_{H,t+k}\right]=0.$$

In equilibrium, each consumer-producer that chooses a new price in period *t* will choose the same new price and the same level of output. Then the (aggregate) price of domestic goods will obey

$$p_{H,t}=\left[\alpha\,p_{H,t-1}+(1-\alpha)\,p_{H,t}(j)\right]^{1/(1-\theta)}.$$

Therefore,

$$\Pi_{H,t}=\alpha^{1/(1-\theta)}\left[1-(1-\alpha)G_t^{1-\theta}\right]^{1/(\theta-1)},$$

log-linearizing around the steady state. We allow bounded fluctuations in $C^A_{H,t}$, $\Pi_{H,t}$, G_t, Λ_t, and $W_t/P_{H,t}$ around a steady state (y^d, 1, 1, Λ, and 1). Thus,

$$v'_t=\xi\,y^d_t\,,$$

$$w_t=(1-\delta)\,p_{H,t}+\delta\,p^*_t\,,\text{ and}$$

$$\pi_{H,t}=\frac{1}{(\theta-1)}\,\frac{-(1-\alpha)}{\left[1-(1-\alpha)\right]}(1-\theta)\,g_t=\frac{1-\alpha}{\alpha}\,g_t\,,$$

where $\xi>0$ is the elasticity of V' with respect to Y^d_t and $1\geq\delta\geq 0$ is the share of tradable goods in the composite input.

$$E_t\left[\sum_{k=0}^{\infty}\alpha^k\beta^k\left\{g_t-\sum_{s=1}^{k}\pi_{H,t+s}-w_{t+k}+p_{H,t+k}-\xi\left[y_{t+k}^d-\theta\left(g_t-\sum_{s=1}^{k}\pi_{H,t+s}\right)\right]+\tilde{z}_{t+k}\right\}\right]=0\,.$$

$$E_t\left[\sum_{k=0}^{\infty}\alpha^k\beta^k\left[(1+\xi\theta)\left(g_t-\sum_{s=1}^{\infty}\pi_{H,t+s}\right)-\xi y_{t+k}^d-\gamma q_{t+k}+\tilde{z}_{t+k}\right]\right]=0\,.$$

However, $\sum_{k=0}^{\infty}\alpha^k\beta^k\sum_{\tau=1}^{k}\pi_{H,t+s}=\sum_{\tau=1}^{\infty}\pi_{H,t+s}\sum_{k=\tau}^{\infty}\alpha^k\beta^k=\sum_{\tau=1}^{\infty}\pi_{H,t+\tau}\frac{\alpha^\tau\beta^\tau}{1-\alpha\beta}$, and this is equal to

$$\frac{1}{1-\alpha\beta}\sum_{k=1}^{\infty}\alpha^k\beta^k\pi_{H,t+k}\,.$$

Then we can rewrite

$$E_t\left[\frac{1+\xi\theta}{1-\alpha\beta}g_t-\frac{1+\xi\theta}{1-\alpha\beta}\sum_{k=1}^{\infty}\alpha^k\beta^k\pi_{H,t+k}-\sum_{k=0}^{\infty}\alpha^k\beta^k\left(\xi y_{t+k}^d+\gamma q_{t+k}-\tilde{z}_{t+k}\right)\right]=0\,.$$

Thus,

$$g_t=\mathrm{E}_t\left\{\alpha\beta\pi_{H,t+1}+\frac{1-\alpha\quad\beta}{1+\xi\quad\theta}\left[\xi y_{t+k}^d+\gamma s_{t+k}-z_{t+k}\right]+\alpha\beta\mathrm{E}_t\left[x_{t+1}\right]\right\},$$

$$g_t=E_t\left[\sum_{k=1}^{\infty}\alpha^k\beta^k\pi_{H,t+s}+\frac{1-\alpha\beta}{1+\xi\theta}\sum_{k=0}^{\infty}\alpha^k\beta^k\left(\xi y_{t+k}^d+\gamma q_{t+k}-\tilde{z}_{t+k}\right)\right],$$

but $\pi_{H,t}=\frac{1-\alpha}{\alpha}g_t$. Hence,,

$$\frac{\alpha}{1-\alpha}\pi_{H,t}=E_t\left[\alpha\beta\pi_{H,t+1}+\frac{1-\alpha\beta}{1+\xi\theta}\left(\xi y_{t+k}^d+\gamma q_{t+k}-\tilde{z}_{t+k}\right)+\alpha\beta\frac{\alpha}{1-\alpha}E_t\left[\pi_{H,t+1}\right]\right],$$

and finally

$$\pi_{H,t}=\beta E_t\left[\pi_{H,t+1}\right]+\lambda_x x_t+\lambda_q q_t\,,$$

where we let $z_t=\xi\tilde{z}_t$, and hence the output gap is defined as $x_t=y_t^d-z_t$. Recalling that $q_t=s_t+p_t^*-p_{H,t}$, we get an expression for the aggregate supply (equation 17 in the main text):

$$\pi_{H,t} = \beta E_t\left[\pi_{H,t+1} \right] + \lambda_x x_t + \lambda_q \left(s_t + p_t^* - p_{H,t} \right),$$

where $\lambda_x = \dfrac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\xi\theta)}\xi$ and $\lambda_q = \lambda_x \gamma$.

Appendix B

Supplemental Tables

Table B1. Unconditional Standard Deviations: Foreign Interest Rate Shock

Targeting case	*Output*	*Domestic inflation*	*CPI inflation*	*Real exchange rate*	*Nominal interest rate*	*Real interest rate*
Flexible CPI inflation targeting						
Flexible exchange rate	0.8466	0.0957	0.6972	2.4209	0.1419	0.7433
Managed exchange rate	2.4270	0.1236	0.1651	0.8473	0.5965	0.7073
Strict CPI inflation targeting						
Flexible exchange rate	4.2840	0.2026	1.1340	4.0510	0.0863	1.1273
Managed exchange rate	2.9132	0.1248	0.1254	0.6447	0.6698	0.7534
Flexible domestic inflation targeting						
Flexible exchange rate	0.3504	0.0712	0.6314	2.1916	0.1866	0.7019
Managed exchange rate	2.4483	0.1248	0.1615	0.8383	0.6013	0.7107
Strict domestic inflation targeting						
Flexible exchange rate	0.9913	0.0314	0.7161	2.5534	0.0794	0.7402
Managed exchange rate	2.9289	0.1254	0.1227	0.6387	0.6744	0.7572

Table B2. Unconditional Standard Deviations: Foreign Output Shock

Targeting case	*Output*	*Domestic inflation*	*CPI inflation*	*Real exchange rate*	*Nominal interest rate*	*Real interest rate*
Flexible CPI inflation targeting						
Flexible exchange rate	0.0950	0.0021	0.0429	0.1957	0.0402	0.0513
Managed exchange rate	0.3337	0.0163	0.0104	0.0853	0.0116	0.0070
Strict CPI inflation targeting						
Flexible exchange rate	0.3536	0.0060	0.0102	0.0794	0.0123	0.0099
Managed exchange rate	0.3988	0.0163	0.0113	0.0633	0.0011	0.0108
Flexible domestic inflation targeting						
Flexible exchange rate	0.1327	0.0036	0.0367	0.1745	0.0394	0.0439
Managed exchange rate	0.3329	0.0163	0.0105	0.0854	0.0120	0.0071
Strict domestic inflation targeting						
Flexible exchange rate	0.3751	0.0078	0.0120	0.0700	0.0140	0.0073
Managed exchange rate	0.3976	0.0163	0.0113	0.0634	0.0015	0.0105

Table B3. Unconditional Standard Deviations: Productivity Shock

Targeting case	*Output*	*Domestic inflation*	*CPI inflation*	*Real exchange rate*	*Nominal interest rate*	*Real interest rate*
Flexible CPI inflation targeting						
Flexible exchange rate	0.1181	0.1361	0.1341	0.0577	0.0860	0.0944
Managed exchange rate	0.4529	0.0697	0.0523	0.2212	0.0098	0.0462
Strict CPI inflation targeting						
Flexible exchange rate	0.3792	0.1095	0.0879	0.1571	0.0746	0.0841
Managed exchange rate	0.5585	0.0705	0.0490	0.2727	0.0046	0.0466
Flexible domestic inflation targeting						
Flexible exchange rate	0.1600	0.1153	0.1108	0.0781	0.0699	0.0781
Managed exchange rate	0.4526	0.0698	0.0522	0.2210	0.0111	0.0453
Strict domestic inflation targeting						
Flexible exchange rate	0.2836	0.1173	0.0948	0.1055	0.0877	0.0876
Managed exchange rate	0.5590	0.0704	0.0486	0.2730	0.0063	0.0453

Table B4. Unconditional Standard Deviations: Domestic Interest Rate Shock

Targeting case	*Output*	*Domestic inflation*	*CPI inflation*	*Real exchange rate*	*Nominal interest rate*	*Real interest rate*
Flexible CPI inflation targeting						
Flexible exchange rate	4.4134	0.3791	0.7371	2.1553	0.2455	0.8113
Managed exchange rate	0.7382	0.0452	0.1323	0.3605	0.1102	0.1581
Strict CPI inflation targeting						
Flexible exchange rate	25.4384	1.4824	3.5524	12.0738	1.1190	3.7836
Managed exchange rate	0.9111	0.0453	0.1540	0.4449	0.1361	0.1861
Flexible domestic inflation targeting						
Flexible exchange rate	3.7255	0.3441	0.6634	1.8194	0.2724	0.7268
Managed exchange rate	0.7368	0.0452	0.1321	0.3598	0.1098	0.1579
Strict domestic inflation targeting						
Flexible exchange rate	16.6473	0.9681	2.3801	7.7738	0.8745	2.5862
Managed exchange rate	0.8890	0.0442	0.1505	0.4342	0.1330	0.1820

References

Batini, N., and A. G. Haldane. 1998. "Forward-Looking Rules for Monetary Policy." Working Paper 6543. Cambridge, Mass.: National Bureau of Economic Research.

Benigno, P. 2000. "Optimal Monetary Policy in a Currency Area." Princeton University. Mimeographed.

Benigno, P., and G. Benigno. 2001. "Price Stability in Open Economies." New York University. Mimeographed.

Blanchard, O., and C. Kahn. 1980. "The Solution of Linear Difference Models under Rational Expectations." *Econometrica* 48: 1305–11.

Céspedes, L. F., R. Chang, and A. Velasco. 2000. "Balance Sheets and Exchange Rate Policy." Working Paper 7840. Cambridge, Mass.: National Bureau of Economic Research.

Chang, R., and A.Velasco. 2000. "Liquidity Crises in Emerging Markets." Working Paper 7272. Cambridge, Mass.: National Bureau of Economic Research.

Calvo, G. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12(3): 383–98.

Clarida, R., J. Galí, and M. Gertler. 1998. "Monetary Policy Rules in Practice: Some International Evidence." *European Economic Review* 42 (June): 1033–68.

————. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature* 37(4): 1661–707.

Cole, H.L., and M. Obstfeld. 1991. "Commodity Trade and International Risk Sharing: How Much Do Financial Markets Matter?" *Journal of Monetary Economics* 28(1): 3–24.

Dixit, A. K., and J. E. Stiglitz. 1977. "Monopolistic Competition and Optimum Product Diversity." *American Economic Review* 67(3): 297–308.

Galí, J., and T. Monacelli. 2000. "Optimal Monetary Policy and Exchange Rate Volatility in a Small Open Economy." Boston College. Mimeographed.

Ghironi, F., and A. Rebucci. 2001. "Monetary Rules for Emerging Market Economies." Working Paper 476. Economics Department, Boston College.

Lane, P. R. 2001. "The New Open Economy Macroeconomics: A Survey." *Journal of International Economics* 54(2): 235–66.

McCallum, B. T., and E. Nelson. 1999. "Nominal Income Targeting in an Open-Economy Optimizing Model." *Journal of Monetary Economics* 43 (June): 553–78.

Monacelli, T.. 2000. "Relinquishing Monetary Independence." Boston College. Mimeographed.

Obstfeld, M., and K. Rogoff. 1995. "Exchange Rate Dynamics Redux." *Journal of Political Economy* 103: 624–60.

Parrado, E. 2000. "Inflation Targeting and Exchange Rate Rules in an Open Economy." New York University. Mimeographed.

Parrado, E., and A. Velasco. 2001. "Optimal Interest Rate Policy in a Small Open Economy." Harvard University. Mimeographed.

Rotemberg, J. J., and M. Woodford. 1998a. "An Optimization Based Econometric Framework for the Evaluation of Monetary Policy." In *NBER Macroeconomics Annual 1997*, edited by B. S. Bernanke and J. J. Rotemberg. MIT Press

————. 1998b. "Interest-Rate Rules in an Estimated Sticky Price Model." In *Monetary Policy Rules*, edited by J. B. Taylor. University of Chicago Press.

Svensson, Lars E. O. 2000. "Open Economy Inflation Targeting." *Journal of International Economics* 50(1): 155–83.

Woodford, M. 1996. "Control of the Public Debt: A Requirement for Price Stability." Working Paper 5684. Cambridge, Mass.: National Bureau of Economic Research.

————. 1999. "Optimal Monetary Policy Inertia." Working Paper 7261. Cambridge, Mass.: National Bureau of Economic Research.

————. 2001. "Inflation Stabilization and Welfare." Working Paper 8071. Cambridge, Mass.: National Bureau of Economic Research.