Monetary Policy Trade-offs in the Open Economy

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ABSTRACT

Recent work on monetary policy has focused on the trade-off between output volatility and inflation volatility. This literature is based largely on models of closed economies. Three conclusions about optimal policy characterize these models. First, the central bank faces an inflation-output gap volatility trade-off only in the presence of cost-push shocks. Second, aggregate demand shocks should be completely stabilized. Third, even in the absence of any under discretionary policy, there are still gains from commitment (or a conservative central banker), but these gains depend on the serial correlation properties of the cost-push shock only. In this paper, I show that none of these results carry over to the open economy.

1 Introduction

A theme in recent work on monetary policy is that policy makers face a trade-off between output volatility and inflation volatility; greater inflation stability can only be achieved at the cost of greater real output instability. A large literature has grown up that has explored the shape of this trade-off, both in theoretical models and in empirical work (see, for example, Rudebusch and Svensson 1997, Fuhrer 1997, McCallum and Nelson 1998, Cecchetti 1999, Haldane and Batini 1998, Conway, Drew, Hunt, and Scott 1998, Clarida, Galí, and Gertler 1999, Erceg, Henderson, and Levin 1999). While a number of authors have argued that price stability is optimal even in models based on monopolistic competition and price stickiness (King and Wolman 1999, Woodford 1999), most of the literature has focused on the need to trade-off some inflation variability to achieve more stable output.

The literature on this new policy trade-off is based largely on theoretical models of closed economies. Three conclusions about optimal policy characterize these models. First, the central bank faces an inflation-output gap volatility trade-off only in the presence of cost-push shocks[1]. Second, ag-

[1] Clarida, Galí, and Gertler (1999) label disturbances that affect inflation for a given level of the output gap and expectations as cost-push shocks. Woodford (1999) criticizes this label, arguing that these disturbances are fluctuations in the "degree of inefficiency of the natural rate of output."

gregate demand shocks should be completely stabilized. Third, even in the absence of the standard Barro-Gordon inflation bias under discretionary policy, there are still gains from commitment (or a conservative central banker), but these gains depend on the serial correlation properties of the cost-push shock and not on those of the aggregate demand shock (Clarida, et. al. 1999). In this paper, I show that none of these results carry over to the open economy.

The open economy differs from the closed economy environment because the real exchange rate affects both aggregate demand and inflation. If the exchange rate acted purely as a demand shock, optimal policy would completely stabilize the domestic economy from exchange rate disturbances. But when exchange rates also affect inflation, stabilizing aggregate demand in the face of an exchange rate disturbances leads to fluctuations in inflation. As a consequence, the optimal policy trades off some output variability for reduced inflation variability. And unlike the case in a closed economy, aggregate demand disturbances also force the central bank to trade-off output and inflation variability. If the central bank adjusts the interest rate (or a monetary conditions index) to neutralize the output effects of a demand shock, the exchange rate will move. This generates fluctuations in inflation. As a consequence, the potential gains from a central bank that puts special weight on inflation stability depends on the time series properties of demand and exchange rate disturbances as well as on those of the cost-push shock.

The rest of the paper is organized as follows. The basic model is presented in Section 2. Policy preferences are introduced in Section 3, and optimal policy under discretion is derived. In Section 4, policy conducted by a central bank whose preferences do not match those of society is evaluated. Section 5 considers whether the conclusions of the model would be altered if the loss function used to evaluate policy were derived from the representative agents utility function. Conclusions are summarized in Section 6.

2 The basic model

A number of authors have recently employed forward-looking models to analyze monetary policy issues. These models incorporate expected future output as a determinant of current aggregate demand and expected future inflation as a determinant of current inflation. Examples include Kerr and King (1996), McCallum and Nelson (1997), Clarida, Galí, and Gertler (1997, 1999), Bernanke and Woodford (1997), Svensson (1998, 1999), Haldane and

Batini (1998), Rotemberg and Woodford (1999), Woodford (1998), and McCallum and Nelson (1999a, 1999b).

When extended to the open economy, this generic policy model takes the form[2]

$$y_t = E_t y_{t+1} - \sigma r_t + \phi e_t + u_t \tag{1}$$

$$\pi_t = \beta E_t \pi_{t+1} + \theta\gamma\left(y_t - y_t^n\right) + \theta\mu e_t + \varepsilon_t \tag{2}$$

$$r_t = E_t e_{t+1} - e_t + \varphi_t \tag{3}$$

where y is output, y^n reflects any stochastic variation in the economy's natural rate of output, r is the real rate of interest, π is the rate of inflation in the domestic output deflator, and e is the real exchange rate. The nominal rate of interest is given by

$$R_t = r_t + E_t \pi_{t+1} \tag{4}$$

Equation (1) gives current aggregate demand as a function of future expected income, the real rate of interest, and the real exchange rate. This is a simple extension of the basic forward looking specification that can be derived as a log-linear approximation to the standard Euler condition for the optimal consumption path which links the marginal utility of current consumption, the expected marginal utility of future consumption, and the expected real return. The real exchange rate appears, as in Svensson (1998) and McCallum and Nelson (1999b), through its role on the relative cost of foreign and domestic goods.

Equation (2) is based on a Calvo (1983) model of staggered price adjustment in which firms set prices as a constant markup over marginal unit cost. Marginal unit costs depend on the level of output relative to potential and on the real exchange rate. The later affects unit costs because the relevant real wage from the perspective of workers depends on the consumer price index. The parameter θ is a function of the discount rate β and the probability each period that a firm re-adjusts its price (details are provided in the Appendix. Less frequent price adjustment or greater weight placed on the future reduce the impact of current unit costs on inflation (i.e., θ falls). The parameter γ gives the direct effect of the output gap on unit costs, while μ is the share of imports in domestic spending. The final component of the model is an interest parity condition given by equation (3).

[2] McCallum and Nelson (1999b) provide a detailed development of an open economy model that is based explicitly on the decision problems of the agents in the model. The present model is designed to provide a direct comparison with commonly used closed economy models of monetary policy.

The model employed in this paper is similar to other forward looking models used to analyze monetary policy issues, differing in the incorporation of open economy considerations. It is similar to the open economy models of Svensson (1998), McCallum and Nelson (1999b), Haldane and Batini (1998), although the focus here differs from these papers. Svensson (1998) evaluates optimal interest rate rules under different loss functions, treats inflation as predetermined, and does not consider the role of the time series processes of the error terms in affecting the desired preferences of the central banker. McCallum and Nelson employ a different specification of price adjustment than equation (2) and focus on nominal income targeting. The model of Haldane and Batini differs in that they use the Fuhrer-Moore specification for price and wage adjustments.[3] Ball (1998) employs a backward looking model to analyze inflation targeting in an open economy. McCallum (1996) has argued that the dynamics in backward-looking models are unlikely to capture the economy's behavior under alternative policy regimes.

3 Policy preferences and policy under discretion

Following the standard approach in the literature, assume the central bank desires to minimize the expected value of a loss function that depends on the variance of the output gap and inflation:

$$L = E\sum_{i=0}^{\infty}\beta^{i}\left[\lambda\left(y_{t+i}-y_{t+i}^{n}\right)^{2}+\pi_{t+i}^{2}\right] \tag{5}$$

Note that with this specification, the central bank's implicit target for output is equal to the economy's natural rate of output y_{t+i}^{n}. Thus, the standard inflation bias due to time inconsistency does not arise.

Let the output gap, $y_t - y_t^n$, be denoted by x_t. It will also be useful to define the change in the natural rate of output, $y_{t+1}^n - y_t^n$, as ψ_{t+1}.

In solving its decision problem, the central bank is assumed to use the nominal interest rate R_t as its instrument variable. It will be convenient initially, however, to treat the central bank as choosing the output gap variable x_t. In this case, the interest parity condition (3) can be used to eliminate the real rate of interest from (1), which can then be solved for the real exchange rate as a function of the output gap, expected future values

[3] Haldane and Batini also use the domestic and foreign consumer price indexes to define the real exchange rate. For a two country model of a common monetary policy that uses the Fuhrer-Moore specification, see Leichter and Walsh (1999).

of the output gap, the natural rate of output, the exchange rate, and the current aggregate demand and exchange rate disturbances:

$$e_t = \left(\frac{1}{\sigma+\phi}\right)(\sigma E_t e_{t+1} + x_t - E_t x_{t+1} - E_t \psi_{t+1} + \sigma\varphi_t - u_t) \tag{6}$$

Substituting this into the inflation adjustment equation (2) yields

$$\begin{aligned} \pi_t &= \beta E_t \pi_{t+1} + \theta\left(\gamma + \frac{\mu}{\sigma+\phi}\right)x_t \\ &\quad + \left(\frac{\theta\mu}{\sigma+\phi}\right)(\sigma E_t e_{t+1} - E_t x_{t+1} - E_t\psi_{t+1} + \sigma\varphi_t - u_t) + \varepsilon_t \end{aligned} \tag{7}$$

Under a discretionary policy regime in which the central bank optimizes each period and is unconstrained by previous choices, expectations about future outcomes are not affected by current policy choices. Thus, the trade-off between inflation and output that the central bank perceives it faces is determined by the impact of the current output gap x_t on inflation, treating expectations of future variables as fixed. From equation (7), this is given by $\theta\left(\gamma + \frac{\mu}{\sigma+\phi}\right)$; it depends on both the direct effect of output on inflation (given by $\theta\gamma$) and on the indirect effect on inflation operating through the impact of output on the real exchange rate. From (6), an output expansion requires a fall in the real rate of interest, leading to a real depreciation. This rise in e is inflationary. This indirect effect of a change in x_t on inflation via the exchange rate is given by $\theta\left(\frac{\mu}{\sigma+\phi}\right)$.

The first order condition for an optimal policy requires that

$$E^{cb}x_t = -\frac{\theta}{\lambda}\left(\gamma + \frac{\mu}{\sigma+\phi}\right)E^{cb}\pi_t \equiv -qE^{cb}\pi_t \tag{8}$$

where the expectations are with respect to the central bank's information set at the time it chooses policy. This is the open economy version of the first order condition for optimal discretionary policy in the closed economy that Clarida, Galí, and Gertler (1999) study, although they assume the central bank can observe current period disturbances when setting its policy instrument.[4]

To ease comparisons with results obtained in the closed economy context, it will be useful to follow Clarida, Galí, and Gertler (and most other papers

[4]For the special case of the closed economy (so $\mu = 0$), this reduces to the optimality condition derived by Clarida, Galí, and Gertler (1999). See also Haldane and Quah (1998).

in this area) and assume the central bank is able to observe current period disturbances without error. In this case, the optimal policy must satisfy[5]

$$x_t = -\frac{\theta}{\lambda}\left(\gamma + \frac{\mu}{\sigma + \phi}\right)\pi_t = -q\pi_t \tag{9}$$

The central bank's first order condition equates the marginal benefit of additional output (λx_t) to the marginal cost of the additional inflation that would result ($\theta\left(\gamma + \frac{\mu}{\sigma+\phi}\right)\pi_t$). This marginal cost is, for given values of the basic parameters, higher in the open economy because of the effect on inflation of the exchange rate movement that accompanies higher output.

Equation (9) is a first order condition involving two endogenous variables. To complete the model description and obtain solutions for the endogenous variables requires assumptions about the processes followed by the disturbances. Assume each follows a first order autoregressive process with independent innovations:

$$u_t = \rho_u u_{t-1} + s_t$$
$$\varepsilon_t = \rho_\varepsilon \varepsilon_{t-1} + \omega_t$$
$$\varphi_t = \rho_\varphi \varphi_{t-1} + \psi_t$$

To solve the model, first reduce it to two expectational equations involving inflation and the real exchange rate. From (9) and (2),

$$\pi_t = \beta E_t \pi_{t+1} - \theta\gamma q \pi_t + \theta\mu e_t + \varepsilon_t$$

[5] The informational assumption has important implications for the correlation between inflation and output implied by the model. This is easiest to see in the closed economy version of the model ($\mu = 0$) if one lets $\hat{u}$ and $\hat{\varepsilon}$ be the central bank's forecasts for u and ε and, for simplicity, assumes the central bank and the public have the same information. In this case, (8), (2), and (1) imply

$$Cov(y_t, \pi_t) = -\left[\frac{\lambda\theta\gamma}{\left(\lambda + \theta^2\gamma^2\right)^2}\right]\sigma^2_{\hat{\varepsilon}} + \theta\gamma\sigma^2_{u-\hat{u}}$$

The sign of this covariance depends on the sign of

$$1 - \frac{\lambda}{\left(\lambda + \theta^2\gamma^2\right)^2}\left(\frac{\sigma^2_{\hat{\varepsilon}}}{\sigma^2_{u-\hat{u}}}\right)$$

This depends on λ, the weight the central bank places on its output stabilization objective. If output stabilization is important (λ is large), or if unforecastable demand shocks are important, output and inflation will display a positive correlation. Otherwise they will be negatively correlated. As stressed by Haldane and Quah (1998), simple scatterplots of inflation versus the output gap may reveal nothing about the presence (or absence) of the expectations augmented Phillips Curve equation (2).

$$= \left(\frac{1}{1+\theta\gamma q}\right)(\beta E_t \pi_{t+1} + \theta \mu e_t + \varepsilon_t) \tag{10}$$

while from (9), (1), and (3),

$$E_t e_{t+1} = \left(1 + \frac{\phi}{\sigma}\right) e_t + \left(\frac{1}{\sigma}\right)[q\pi_t - qE_t\pi_{t+1} + u_t] - \varphi_t \tag{11}$$

Equations (10) and (11) can be written in the form

$$E_t z_{t+1} = M z_t + \chi_t \tag{12}$$

where $z_t' = (\pi_t \quad e_t)$, $\chi_t' = (-\varepsilon_t/\beta \quad -\varphi_t + u_t/\sigma + q\varepsilon_t/\beta\sigma)$, and the matrix M is given by

$$M = \begin{bmatrix} \frac{1+\theta\gamma q}{\beta} & -\frac{\theta\mu}{\beta} \\ -\frac{q(1-\beta+\theta\gamma q)}{\beta\sigma} & 1 + \frac{\phi}{\sigma} + \frac{q\theta\mu}{\beta\sigma} \end{bmatrix}$$

Equation (12) has a unique stable equilibrium if both eigenvalues of M are greater than 1 (Blanchard and Kahn 1980). A grid search over a wide range of parameter values revealed no combinations for which either eigenvalue was less than one.

The equilibrium solutions for inflation and the real exchange rate under the optimal policy are derived in the Appendix. The solutions take the form

$$\pi_t = a_1\varepsilon_t + a_2 u_t + a_3\varphi_t$$

$$e_t = b_1\varepsilon_t + b_2 u_t + b_3\varphi_t$$

while from equation (9),

$$x_t = -q\left[a_1\varepsilon_t + a_2 u_t + a_3\varphi_t\right]$$

The Appendix shows that $a_2 = a_3 = 0$ when $\mu = 0$; thus, under the optimal policy in a closed economy, inflation and the output gap respond only to the cost push shock, ε_t. This is a familiar result and reflects the fact that demand disturbances can be neutralized completely so that neither output nor inflation are affected.

In contrast in the open economy, inflation (and output) are affected by demand shocks and exchange rate shocks ($a_2 \neq 0$, $a_3 \neq 0$) under the optimal policy. Inflation and output objectives must be traded off in the face of cost push shocks, as in the closed economy, but in the open economy they must also be traded-off when demand and exchange rate shocks are present. The reason lies in the fact that the exchange rate directly affects inflation. The effect of a demand shock on output, for example, cannot be offset by an adjustment in the interest rate without affecting the real exchange rate. This exchange rate movement then has a direct impact on the domestic rate of inflation through (2). A positive demand shock that leads to an increase in the real rate of interest also leads to an appreciation that lowers inflation. Stabilizing inflation then calls for a less then full offset of the output effects of the demand shock.

The equilibrium impact of an aggregate demand shock on the output gap under the optimal discretionary policy is shown in Figure 1.[6] For a closed economy, the impact of u_t on x_t would always be zero, regardless of the values of the policy weight λ or the serial correlation coefficient ρ_u. As would be expected, the impact of demand shocks on output is decreasing in the weight placed on output stabilization, although this effect is not large. Demand shocks are allowed to have a larger effect on the current output gap under the optimal policy if they are highly serially correlated. In addition to their direct impact, expected future output also rises in response to a positive realization of u_t, and from (1), this also affects current demand. This effect is larger if demand shocks are highly serially correlated. To offset a demand shock requires a stronger monetary tightening when ρ_u is large. This leads to a larger appreciation and fall in inflation. Because the central bank also cares about stabilizing inflation, the optimal policy offsets less of the output effect of a demand shock when it is highly serially correlated.

The contrast between the open and closed economies can be see in the behavior of a monetary conditions index MCI, defined from equation (1) as $r_t - \left(\frac{\phi}{\sigma}\right) e_t$. The equilibrium expression for the monetary conditions index under the optimal policy is obtained by first using the equilibrium solution for the exchange rate, together with equation (3), to find the real interest rate:

$$\begin{aligned} r_t &= E_t\left[b_1\varepsilon_{t+1} + b_2 u_{t+1} + b_3\varphi_{t+1}\right] - \left[b_1\varepsilon_t + b_2 u_t + b_3\varphi_t\right] + \varphi_t \\ &= -b_1(1-\rho_\varepsilon)\varepsilon_t - b_2(1-\rho_u)u_t + \left[1 - b_3(1-\rho_\varphi)\right]\varphi_t \end{aligned}$$

Combining this with the equilibrium expression for the real exchange rate, the monetary conditions index under the optimal discretionary policy is equal to

$$MCI_t = r_t - \left(\frac{\phi}{\sigma}\right) e_t$$

[6] The figure is based on the following values for the model parameters: $\beta = 0.99$, $\sigma = 1$, $\phi = 0.2$, $\theta\gamma = \theta\mu = 0.3$. The .3 value for $\theta\gamma$ is the value adopted by Clarida, Galí, and Gertler (1999).

$$
\begin{aligned}
&= -b_1\left[1-\rho_\varepsilon+\frac{\phi}{\sigma}\right]\varepsilon_t - b_2\left[1-\rho_u+\frac{\phi}{\sigma}\right]u_t \\
&\quad +\left[1-b_3\left(1-\rho_\varphi+\frac{\phi}{\sigma}\right)\right]\varphi_t \qquad (13)
\end{aligned}
$$

Aggregate output would be full insulated from demand shocks if the coefficent on u_t were equal to $\frac{1}{\sigma}$. Using the solution for b_2 given in the Appendix, $0 < -b_2\left[1-\rho_u+\frac{\phi}{\sigma}\right] < \frac{1}{\sigma}$. A positive demand shock still leads to a monetary tightening (a rise in MCI), but the output gap is not fully insulated from the shock. As a consequence, output rises. The output effect acts to raise inflation, but the associated real appreciation offsets that and inflation actually declines ($a_2 \leq 0$). A positive exchange rate shock ($\varphi > 0$) also produces a monetary tightening, as $1-b_3\left(1-\rho_\varphi+\frac{\phi}{\sigma}\right) > 0$ when $\mu > 0$. In this case, an exchange rate shock reduces the output gap and increases inflation.

Figure 2 shows how the monetary conditions index response to aggregate demand shocks (the coefficient on u_t in 13) varies with the preference parameter λ and the impact of the exchange rate on inflation ($\theta\mu$). The serial correlation coefficient ρ_u is set equal to zero. Since $\sigma = 1$ in the baseline calibration, the output effect of a demand shock is completely offset when the response of MCI^s to u is 1; this occurs for large value of λ (the weight on output stabilization) and small values of $\theta\mu$. In this case, stabilizing output is important, and the resulting exchange rate movement has little impact on inflation. It becomes optimal, therefore, to offset the demand shock completely.

Figure 3 illustrates how the response of the monetary conditions index to exchange rate shocks varies with the weight placed on output stabilization in the central bank's objective function (λ) and the impact of the real exchange rate on inflation ($\theta\mu$). As output objectives become less important, the MCI responses more to exchange rate shocks. As the impact of the exchange rate on inflation increases, so too does the optimal response to exchange rate shocks.

Figures 2 and 3 reveal how the response of the central bank's policy instrument (in this case, expressed in terms of the monetary conditions index) depends on the policy preferences of the central bank (the parameter λ). As a result, the variance of output and inflation in equilibrium is also dependent on λ. This raises the issue first addressed by Rogoff (1985); what type of central bank would the public wish to have conduct monetary policy?

4 The role of a Rogoff central banker

One of the results from the time-inconsistency literature on monetary policy that has had wide appeal for both its positive and normative implications is Rogoff's argument that social loss can be reduced if a conservative central banker is appointed (Rogoff 1985). This result has been used to rationalize the observed negative correlation between central bank independence and average inflation, and it has been used to argue for central bank reforms that provide increased political independence in the conduct of monetary policy.

In the present model, the standard source of an inflation bias is absent. The policy objectives of the central bank are defined in terms of stabilizing output fluctuations around the (stochastic) natural rate y_t^n. Even in this context, however, discretionary policy can be improved upon when expectations of future inflation and output affect the equilibrium (Woodford 1999). Clarida, Galí, and Gertler (1999) make this point in a closed economy version of the model of Section 2. If the central bank were able to commit to a policy rule, loss could be reduced. Under commitment, the central bank is able to affect both current inflation and the public's expectations of future inflation. This improves the short-run output-inflation trade-off faced by the central bank. A policy contraction that reduces the current output gap will have a greater impact on current inflation if the public believes future inflation will be reduced as well; as a consequence, any given reduction in inflation can be achieved with a smaller reduction in the output gap.

Clarida, Galí, and Gertler (1999) argue that the gains from commitment can be achieved under discretion by appointing a Rogoff conservative central banker, one who places less weight on output stabilization than society does. Their argument can be illustrated in the closed economy version of the model by setting $\mu = \phi = 0$. In this case, demand shocks are completely offset through policy actions, and inflation and the output gap are only affected by the cost push shock ε_t. To derive the optimal policy under commitment, assume the central bank adjusts policy to ensure that $x_t = b\varepsilon_t$ for some constant parameter b. Inflation will also be of the form $\pi_t = k\varepsilon_t$ so that equation (2) becomes

$$k\varepsilon_t = \beta k \rho_\varepsilon \varepsilon_t + \theta\gamma b \varepsilon_t + \varepsilon_t$$

which holds for all realizations of ε_t if and only if

$$k = \frac{1 + \theta\gamma b}{1 - \beta\rho_\varepsilon}$$

The value of b is then chosen to minimize the expectation of the loss function (5). Carrying out this minimization yields

$$b = \frac{-\theta\gamma}{\lambda\left(1-\beta\rho_\varepsilon\right)^2+\theta^2\gamma^2}$$

and

$$k = \frac{\lambda\left(1-\beta\rho_\varepsilon\right)}{\lambda\left(1-\beta\rho_\varepsilon\right)^2+\theta^2\gamma^2}$$

Under this commitment policy, output and inflation respond to the aggregate cost push disturbance such that

$$x_t = \left(\frac{b}{k}\right)\pi_t = -\left[\frac{\theta\gamma}{\lambda\left(1-\beta\rho_\varepsilon\right)}\right]\pi_t \tag{14}$$

As Clarida, Galí, and Gertler note, this is equivalent to the outcome under discretion given by equation (9) if the central bank places a weight $\hat{\lambda}_c$ on output objectives, where

$$\hat{\lambda}_c = \lambda\left(1-\beta\rho_\varepsilon\right) < \lambda$$

Thus, the optimal commitment policy can be achieved by appointing a Rogoff conservative central banker, defined as one who places less weight on output objectives that the society does.

This is an important generalization of Rogoff's, since the gain arises solely from the role played by forward looking expectations and not from the presence of the standard inflation bias story. This result is easiest to understand by considering the response to a positive cost push shock. This raises current inflation, and output must be reduced to offset some of the inflationary impact of the shock. If the central bank is perceived to place more weight on inflation objectives, expected future inflation will rise less than it would with a less conservative central bank. And because $E_t\pi_{t+1}$ rises less, current inflation can be kept lower with less of a real output contraction.

The situation is more complex in the open economy, both because output and inflation are affected by more than just the cost push shock and because the real exchange rate has a direct impact on aggregate demand.[7] To derive

[7] I follow Clarida, Galí, and Gertler in only considering policies that involve a commitment to a non-inertial rule. Woodford (1999) shows how outcomes can be improved under an optimal commitment policy that includes inertial behavior in setting policy.

the optimal commitment policy, note that equations (1) and (2) can be written, after using the interest parity condition (3) to eliminate r_t, as

$$x_t = E_t x_{t+1} + (\sigma + \phi) e_t - \sigma E_t e_{t+1} + z_t \tag{15}$$

and

$$\pi_t = \beta E_t \pi_{t+1} + \theta \gamma x_t + \theta \mu e_t + \varepsilon_t \tag{16}$$

where

$$z_t = u_t - \sigma \varphi_t + E_t \psi_{t+1}$$

Now consider first the case in which only cost push shocks are present ($z \equiv 0$). Suppose the central bank can commitment to a rule in which the output gap is a function of the cost push disturbance:

$$y_t - y_t^n = d_\varepsilon \varepsilon_t \tag{17}$$

Combining (17) with (15) yields a solution for the real exchange rate as

$$e_t = \left[\frac{d_\varepsilon (1 - \rho_\varepsilon)}{\sigma(1 - \rho_\varepsilon) + \phi} \right] \varepsilon_t$$

Using this, together with (17) in (16) implies a solution for the rate of inflation given by

$$\pi_t = \left[\frac{1 + A d_\varepsilon}{1 - \beta \rho_\varepsilon} \right] \varepsilon_t \tag{18}$$

where $A = \theta\gamma + \frac{\theta\mu(1-\rho_\varepsilon)}{\sigma(1-\rho_\varepsilon)+\phi}$. Equations (17) and (18) can be substituted into the loss function and minimized with respect to d_ε. When this is done, one obtains the following relationship between the output gap and inflation:

$$x_t = - \left[\frac{\theta}{\lambda (1 - \beta \rho_\varepsilon)} \right] \left[\gamma + \frac{\mu(1 - \rho_\varepsilon)}{\sigma(1 - \rho_\varepsilon) + \phi} \right] \pi_t$$

Comparing this to the relationship that arises under pure discretion (given in equation 9) reveals that when $\mu \neq 0$ the commitment equilibrium cannot be sustained simply by appointing a central banker with output weight $\lambda (1 - \beta \rho_\varepsilon)$ unless $\phi = 0$ (the exchange rate does not affect demand) or $\rho_\varepsilon = 0$ (in which case there is no gain from commitment). The reason is that, in the open economy case, such a conservative central banker correctly compensates for the persistence arising through the impact of future expected inflation on current inflation (the $1 - \beta\rho_\varepsilon$ term) but does not correct for the impact that the expected future exchange rate has on the current equilibrium (and that shows up in the $\frac{\mu(1-\rho_\varepsilon)}{\sigma(1-\rho_\varepsilon)+\phi}$ term).

The "optimal" central bank to appoint can still be characterized in terms of a preference parameter $\hat{\lambda}$ which satisfies

$$\hat{\lambda}_o = \lambda\left(1-\beta\rho_\varepsilon\right)\left[\frac{\gamma+\frac{\mu}{\sigma+\phi}}{\gamma+\frac{\mu(1-\rho_\varepsilon)}{\sigma(1-\rho_\varepsilon)+\phi}}\right] = \hat{\lambda}_c\left[\frac{\gamma+\frac{\mu}{\sigma+\phi}}{\gamma+\frac{\mu(1-\rho_\varepsilon)}{\sigma(1-\rho_\varepsilon)+\phi}}\right] \geq \hat{\lambda}_c$$

When $\mu = 0$, the term in brackets is equal to 1 and $\hat{\lambda}_o = \hat{\lambda}_c < \lambda$ since $1-\beta\rho_\varepsilon < 1$; this is Clarida, et al's result seen earlier. When $\mu > 0$ and $\rho_\varepsilon > 0$, however, the term in brackets will be greater than 1. In principle, then, it will not always be possible to achieve the optimal commitment policy through the appointment of a conservative central banker. For the baseline parameter values, $\hat{\lambda}_o$ is always less than λ. Because the term in brackets is greater than 1, we can conclude that the optimal central banker in the open economy is less conservative than in the open economy ($\hat{\lambda}_o \geq \hat{\lambda}_c$). The desired weight on output objectives ($\hat{\lambda}_o$) will depend not just on β and ρ_ε as in the closed economy, but on all the structural parameters in the model.

When aggregate demand and exchange rate shocks, as well as a time varying natural rate of output, are reintroduced (so z can differ from zero and be serially correlated), the situation becomes more complicated. In order to avoid undue complication, assume the composite disturbance z follows an AR(1) process with serial correlation coefficient ρ_z. The optimal response will depend on the underlying source of the disturbance, so assume the output gap under the commitment to a simple rule follows

$$x_t = d_\varepsilon \varepsilon_t + d_z z_t$$

Using this in (15) to solve for the exchange rate process in terms of the d_i coefficients, and then substituting the results into (16), one can find the equilibrium solution for the rate of inflation. Finally, the expected present discounted value of the loss function can be minimized with respect to d_ε and d_z. Doing so yields the optimal values

$$d_\varepsilon = -\left(\frac{A}{\lambda(1-\beta\rho_\varepsilon)^2 + A^2}\right), \qquad A = \theta\left[\gamma + \frac{\mu(1-\rho_\varepsilon)}{\sigma(1-\rho_\varepsilon)+\phi}\right]$$

$$d_z = \left(\frac{1}{\sigma(1-\rho_z)+\phi}\right)\left(\frac{B}{\lambda(1-\beta\rho_z)^2 + B^2}\right), \qquad B = \theta\left[\gamma + \frac{\mu(1-\rho_z)}{\sigma(1-\rho_z)+\phi}\right]$$

If ρ_ε and ρ_z differ but are both nonzero, then the responses under discretion to the two different disturbances could be improved upon through the appointment of a conservative central banker, but the "optimal" preferences of the appointed central banker would depend on the relative importance of the two sources of shocks. Figure 4 shows the gain (or loss if negative) if a society with preference λ appoints a central banker with preference λ^{cb} to conduct discretionary monetary policy when only the cost push shock is serially correlated.[8] Notice that while society can gain by appointing a central banker with $\lambda^{cb} < \lambda$, the gain is small, and appointing a central banker with a weight on output objectives that is too small can lead to large losses.[9]

In a closed economy model, the serially correlation properties of the aggregate demand shock play no role in determining the optimal preferences of the central banker. This is no longer true in an open economy. If the aggregate demand displays high serial correlation, the gain from appointing a central banker with a low λ^{cb} becomes much more significant. This is illustrated by Figure 5 which differs from Figure 4 only in setting $\rho_z = 0.8$.[10] The gain to appointing a central banker with a small λ^{cb} is now much larger. Since demand and exchange rate disturbances both affect the equilibrium only through the composite error z, similar results would follow if φ were assumed to be highly serially correlated.

5 Utility-Based Measures of Loss

Policy trade-offs in the open economy depend on all disturbances in the model except shocks to the natural rate of output. This focus on inflation-output variability trade-offs contrasts with the conclusions of King and Wolman (1999) and Woodford (1999), who argue that the optimal policy is always to maintain price stability. In their models, there is no trade-off between output and inflation variability; stabilizing the price level is consistent with stabilizing the output gap. They reach this conclusion by using the utility of the representative agent to evaluate alternative policies. Since the loss function given by (5) was not derived from an underlying model of individual utility, it must be viewed as ad hoc, even if it is familiar and commonly used in the monetary policy literature.

Woodford (1999) provides a detailed discussion of the connection between utility based measures of loss and the standard quadratic loss functions such as (5). If we ignore the cost push shocks assumed in (2), a closed

[8] The value of ρ_ε is set equal to 0.5.

[9] As the figure shows, it is never optimal to appoint a central bank such that $\lambda^{cb} > \lambda$ for the parameter values used. Extremely low values of the discount rate β (on the order of 0.2) do lead to values for λ^{cb} that are greater then λ.

[10] Svensson (1998) assumes the disturbance to aggregate demand in his open economy model has this degree of persistence.

economy version of the basic model used here implies that optimal policy always stabilizes the price level, keeping the inflation rate equal to zero. It does so by offsetting any impact of demand shocks. However, as Woodford notes, stabilizing the price level will no longer be optimal if relative price adjustments are necessary and/or goods vary in their degree of price stickiness.

This is the case in the open economy. The real exchange rate affects the relative price of foreign and domestic goods. If domestic goods prices are sticky while the nominal exchange rate is flexible (as assumed in equation 2), the degree of price stickiness between foreign and domestic goods differs. Thus, the general conclusions reached above–that the effects of the real exchange rate on both aggregate demand and inflation will force policy makers to trade-off output and inflation stability even in the absence of cost-push shocks–will extend to utility-based measures of loss.

6 Conclusions

A variety of very useful lessons about monetary policy have been derived recently using simple macro frameworks that incorporate forward looking behavior. Most of this work has been done within the context of a closed economy model. Expanding the framework to include open economy considerations leads to some new insights. First, policy trade offs are more complex in the open economy. In the closed economy, only cost push disturbances pose serious policy trade-offs. Demand shocks can be completely neutralized so that neither inflation nor real output is affected, and shocks to the economy's potential GDP should simply be accommodated. In the open economy, a policy that moves the short-term real interest rate to offset the impacts of a demand shock will also affect the real exchange rate. This, in turn, affects the rate of inflation. Both output and inflation objectives cannot be achieved simultaneously, just as is the case in the face of a cost push shock. Disturbances to the interest parity condition pose similar problems.

Because demand and exchange rate shocks in an open economy generate policy trade-offs, the time series properties displayed by these disturbances become important in affecting the optimal preferences of the central banker. When disturbances are highly serially correlated, discretionary policy no longer produces an optimal response to shocks. A central bank that can commit to a simple rule gains from being able to affect future expectations. Some of these gains can be achieved under discretion if policy is conducted by a Rogoff conservative central banker. In the closed economy, the gain from having the central bank place less weight on output objectives depends critically on the time series properties of the cost push shock. In an open economy, it also depends on the behavior of both aggregate demand and exchange rate disturbances.

7 Appendix

7.1 The inflation adjustment equation

This appendix provides details of the derivation of equation (2) of the text based on the Calvo (1983) model of staggered, overlapping price setting behavior. In this model, each firm faces a probability δ of being able to adjust its price. When it does change its price, it sets price to minimize the expected present discounted value of a loss function that depends on the deviation between the price it sets and nominal unit costs, as in Rotemberg (1987). Because workers are concerned with the wage relative to a consumer price index, the real exchange rate will affect wages and unit costs by affect the consumer price index.

Let z_t denote the price set by a firm adjusting its price in period t. With a continuum of firms, the fraction of firms adjusting in period t will be δ. Since all firms are assumed to be identical, the log aggregate price index is given by

$$p_t = \delta z_t + (1 - \delta)p_{t-1} \tag{19}$$

The optimal value of z_t that minimizes the expected present discounted value of deviations between price and nominal unit costs can be shown (see Walsh, 1998, Chapter 5) to equal

$$z_t = [1 - \beta(1 - \delta)]\, c_t + \beta(1 - \delta)E_t z_{t+1} \tag{20}$$

where c_t is nominal log unit costs. These are assumed to be given by

$$c_t = \gamma(y_t - y_t^n) + p_t^c \tag{21}$$

where p^c is the consumer price index:

$$p_t^c = p_t + \mu e_t \tag{22}$$

In (22), e_t is the real exchange rate and μ is the share of import goods in the representative household's composite consumption good.

Substituting (21) and (22) into (20) yields

$$z_t = [1 - \beta(1 - \delta)]\, [\gamma(y_t - y_t^n) + p_t + \mu e_t] + \beta(1 - \delta)E_t z_{t+1}$$

Combining this with equation (19),

$$\begin{aligned} p_t &= \delta \left\{ [1 - \beta(1-\delta)] \left[\gamma(y_t - y_t^n) + p_t + \mu e_t \right] + \beta(1-\delta) E_t z_{t+1} \right\} \\ &\quad + (1-\delta) p_{t-1} \end{aligned} \tag{23}$$

Moving the time subscript in (19) forward one period and taking expectations as of time t, one can obtain

$$E_t z_{t+1} = \left(\frac{1}{\delta} \right) [E_t p_{t+1} - (1-\delta) p_t]$$

Using this expression, the expectation of z_{t+1} can be eliminated from equation (23). Rearranging then yields equation (2) of the text.[11]

7.2 The model solution under optimal policy

The solutions for inflation and the real exchange rate consistent with equation (10) and (11) of the text are derived in this section.

Rewriting (10) and (11), we have

$$(1 + \theta\gamma q)\, \pi_t = \beta E_t \pi_{t+1} + \theta \mu e_t + \varepsilon_t \tag{24}$$

and

$$\sigma E_t e_{t+1} = (\sigma + \phi)\, e_t + q\, [\pi_t - E_t \pi_{t+1}] + u_t - \sigma \varphi_t \tag{25}$$

the current state variables are ε_t, u_t, and φ_t, so let the proposed solutions for π_t and e_t be

$$\pi_t = a_1 \varepsilon_t + a_2 u_t + a_3 \varphi_t$$

and

$$e_t = b_1 \varepsilon_t + b_2 u_t + b_3 \varphi_t$$

Using the assumed processes for the disturbances,

$$E_t \pi_{t+1} = a_1 \rho_\varepsilon \varepsilon_t + a_2 \rho_u u_t + a_3 \rho_\varphi \varphi_t$$

$$E_t e_{t+1} = b_1 \rho_\varepsilon \varepsilon_t + b_2 \rho_u u_t + b_3 \rho_\varphi \varphi_t$$

If these are substituted into equations (24) and (25), one obtains

$$(1 + \theta\gamma q)\,(a_1 \varepsilon_t + a_2 u_t + a_3 \varphi_t) = \beta \left(a_1 \rho_\varepsilon \varepsilon_t + a_2 \rho_u u_t + a_3 \rho_\varphi \varphi_t \right) + \theta\mu\,(b_1 \varepsilon_t + b_2 u_t + b_3 \varphi_t) + \varepsilon_t$$

[11] Further details of the derivation can be found in Walsh (1998, Chapter 5).

$$
\begin{aligned}
\sigma\left(b_1\rho_\varepsilon\varepsilon_t + b_2\rho_u u_t + b_3\rho_\varphi\varphi_t\right) &= (\sigma+\phi)\left(b_1\varepsilon_t + b_2 u_t + b_3\varphi_t\right) \\
&\quad + q\left[a_1(1-\rho_\varepsilon)\varepsilon_t + a_2(1-\rho_u)u_t + a_3(1-\rho_\varphi)\varphi_t\right] \\
&\quad + u_t - \sigma\varphi_t
\end{aligned}
$$

For these to hold for all realizations of the stochastic disturbances, the unknown a_i and b_i coefficients must satisfy the following restrictions:

$$
\begin{bmatrix} 1+\theta\gamma q-\beta\rho_\varepsilon & -\theta\mu \\ q(1-\rho_\varepsilon) & \sigma(1-\rho_\varepsilon)+\phi \end{bmatrix}\begin{bmatrix} a_1 \\ b_1 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \end{bmatrix}
$$

$$
\begin{bmatrix} 1+\theta\gamma q-\beta\rho_u & -\theta\mu \\ q(1-\rho_u) & \sigma(1-\rho_u)+\phi \end{bmatrix}\begin{bmatrix} a_2 \\ b_2 \end{bmatrix} = \begin{bmatrix} 0 \\ -1 \end{bmatrix}
$$

$$
\begin{bmatrix} 1+\theta\gamma q-\beta\rho_\varphi & -\theta\mu \\ q(1-\rho_\varphi) & \sigma(1-\rho_\varphi)+\phi \end{bmatrix}\begin{bmatrix} a_1 \\ b_1 \end{bmatrix} = \begin{bmatrix} 0 \\ \sigma \end{bmatrix}
$$

Let

$$
\Delta_s = (1+\theta\gamma q-\beta\rho_s)\left[\sigma(1-\rho_s)+\phi\right] + \theta\mu q(1-\rho_s)
$$

for $s=\varepsilon,u,\varphi$. Then

$$
\begin{aligned}
\begin{bmatrix} a_1 \\ b_1 \end{bmatrix} &= \frac{1}{\Delta_\varepsilon}\begin{bmatrix} \sigma(1-\rho_\varepsilon)+\phi & \theta\mu \\ -q(1-\rho_\varepsilon) & 1+\theta\gamma q-\beta\rho_\varepsilon \end{bmatrix}\begin{bmatrix} 1 \\ 0 \end{bmatrix} \\
&= \frac{1}{\Delta_\varepsilon}\begin{bmatrix} \sigma(1-\rho_\varepsilon)+\phi \\ -q(1-\rho_\varepsilon) \end{bmatrix} \quad \Rightarrow a_1>0; b_1<0.
\end{aligned}
$$

$$
\begin{aligned}
\begin{bmatrix} a_2 \\ b_2 \end{bmatrix} &= \frac{1}{\Delta_u}\begin{bmatrix} \sigma(1-\rho_u)+\phi & \theta\mu \\ -q(1-\rho_u) & 1+\theta\gamma q-\beta\rho_u \end{bmatrix}\begin{bmatrix} 0 \\ -1 \end{bmatrix} \\
&= \frac{1}{\Delta_u}\begin{bmatrix} -\theta\mu \\ -(1+\theta\gamma q-\beta\rho_u) \end{bmatrix} \quad \Rightarrow a_2\le 0; b_2<0.
\end{aligned}
$$

$$
\begin{aligned}
\begin{bmatrix} a_3 \\ b_3 \end{bmatrix} &= \frac{1}{\Delta_\varphi}\begin{bmatrix} \sigma(1-\rho_\varphi)+\phi & \theta\mu \\ -q(1-\rho_\varphi) & 1+\theta\gamma q-\beta\rho_\varphi \end{bmatrix}\begin{bmatrix} 0 \\ \sigma \end{bmatrix} \\
&= \frac{1}{\Delta_\varphi}\begin{bmatrix} \sigma\theta\mu \\ \sigma\left(1+\theta\gamma q-\beta\rho_\varphi\right) \end{bmatrix} \quad \Rightarrow a_3\ge 0; b_3>0.
\end{aligned}
$$

The signs for b_2 and b_3 follow from $1+\theta\gamma q-\beta\rho_s>0$ since both β and ρ_s are less than 1.

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Figure 1: Impact of Demand Shock on the Output Gap

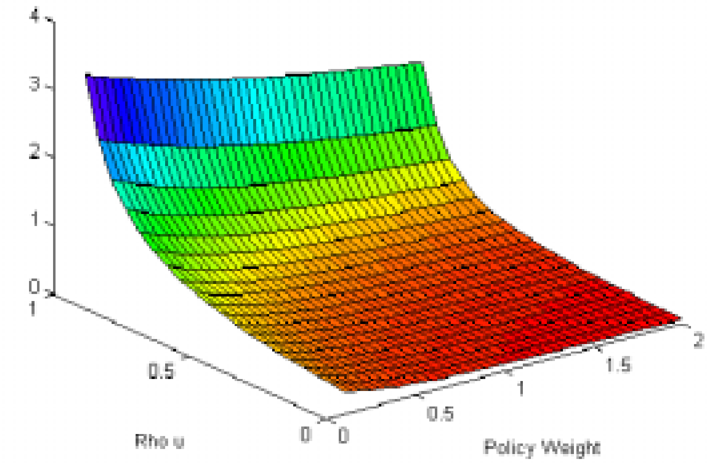

Figure 2: Response of MCI to a Demand Shock

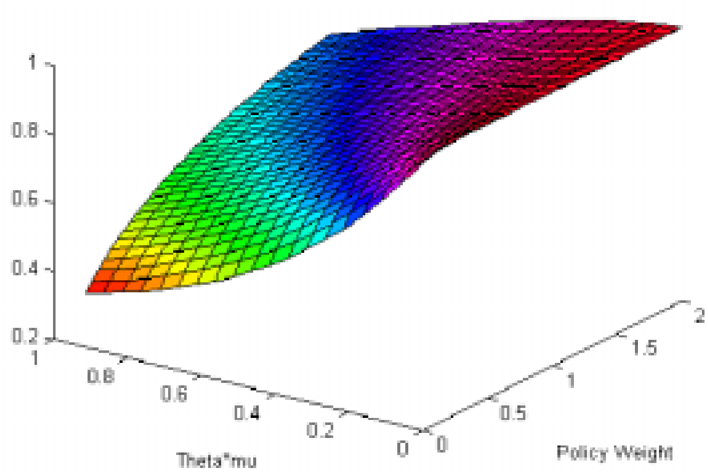

Figure 3: Response of MCI to Exchange Rate Shock

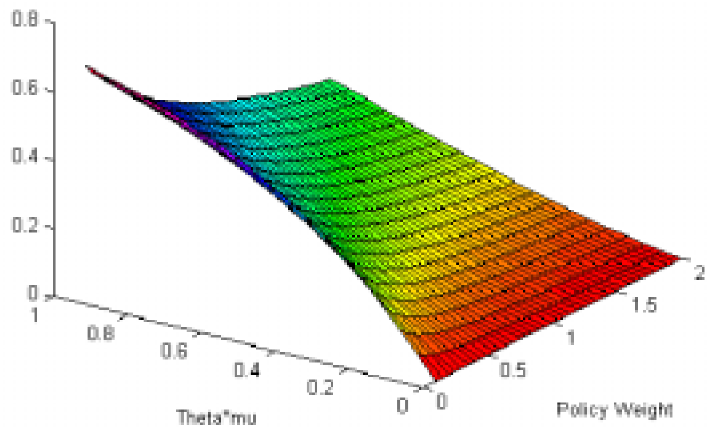

Figure 4: Gain from appointing a conservative central banker ($\rho_\varepsilon = 0.5$, $\rho_u = \rho_\varphi = 0$)

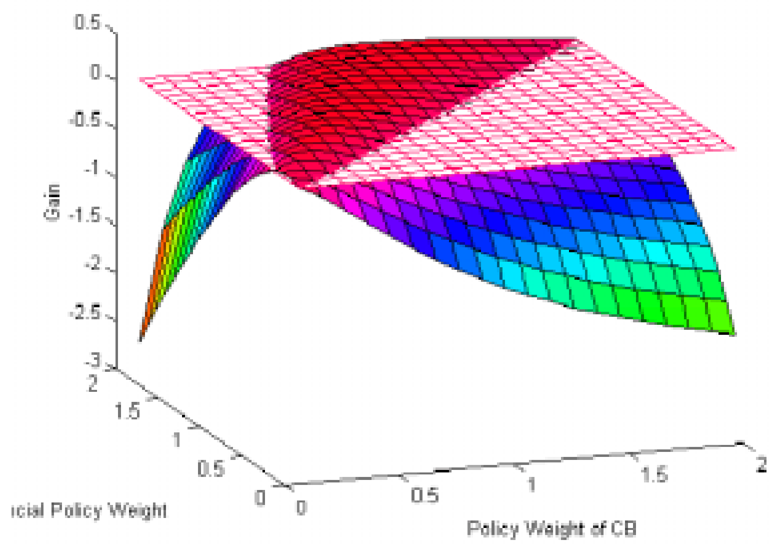

Figure 5: Gain from appointing a conservative central banker ($\rho_\varepsilon = 0.5$, $\rho_u = 0.8$, $\rho_\varphi = 0$)