European Economic Review 29 (1985) 137–155. North-Holland

# RELIABILITY OF POLICY ANNOUNCEMENTS AND THE EFFECTS OF MONETARY POLICY

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Received February 1984, final version received March 1985

Monetary authorities regularly announce targets for monetary growth, but the market may not completely trust these announcements because they may not always be truthful. Hence, the market does not have perfect knowledge about future monetary policy and must form its expectations on the basis of information it can extract from the announcements and its observations of the actual money supply. This paper asks how the macroeconomic effect of monetary policy might be altered by more reliable policy announcements, in the setting of a medium-sized open economy. It is found that, contrary to the full-information case, a reduction in monetary growth of 1% may lead on impact to a reduction in inflation of much less than 1%, if the announcements are not very credible. The output costs of lowering inflation are smaller both in the short run and the long run, the more reliable the announcements. However, the plausibility of announcements does not affect the output loss for a given appreciation of the currency. Fluctuations in the exchange rate that are attributable to monetary disturbances beyond the policy-makers' control can nonetheless be dampened by making announcements that are more highly correlated with the truth.

## 1. Introduction

Even though the market may pay close attention to changes in monetary policy it is impossible to ascertain exactly the course of the money supply in the future by observing only the actual level of the money stock from week to week. Even if the monetary authorities have a fairly tight control over high-powered money, disturbances in the banking system or in money demand lead to a fluctuating money stock. Thus, the change in the money supply from week to week is a noisy signal of the growth rate policy-makers intend.

The market can benefit from the revelation of the targets for the growth rate of money. They should help clarify how much of the weekly change in the money stock is due to factors beyond the policy-makers' control. However, it would be a rare monetary authority whose policy announcements are entirely reliable and completely trusted by the market. The usefulness of the announcements must depend upon how well they are correlated with the authorities' true goals.

*I would like to thank Ron Michener for helpful suggestions.

This paper seeks to gauge how varying degrees of reliability of policy announcements feed back onto the effectiveness of monetary policy. The setting is a 'medium-sized' open economy in which prices are slow to adjust to changes in demand. There are several issues which are addressed.

First, in many sticky-price open-economy models, a 1% increase in the money growth rate translates immediately into at least a 1% increase in inflation — this despite the fact that the price level is predetermined. This aspect of the models is considered unrealistic, and some authors [Buiter and Miller (1982)] have tried to make corrections by explicitly requiring stickiness not only in prices but also in the rate of change of prices. However, an intuitive explanation of why the inflation rate does not jump one-for-one with increases in the money growth rate is that the market does not fully perceive the change in the growth rate. If announcements are notoriously unreliable, then they are fairly useless in signalling a change. If, in addition, most of the period-to-period variation in the money supply comes from disturbances in the money markets, and not from intentional policy-dictated changes, changes in the money stock are not likely to be viewed as policy-induced changes in the growth rate of money.

This paper also examines the impact of increased reliability of announcements on the output cost of reducing inflation. It is shown that greater reliability reduces both the short-run output loss from a currently lower inflation rate, and the cumulative output loss from a move to lower steady-state inflation. (However, the short-run output loss from a change toward a lower long-run inflation — i.e., a lower money growth rate — is greater the higher the credibility of the announcements. The initially larger output loss is more than made up for in later periods.) Strikingly, the output loss required for a given appreciation of the currency does not depend upon the degree of reliability of the announcements.

Finally, it is shown that the exchange rate fluctuates less in response to random money market disturbances when the policy announcements are more trusted.

## 2. The model

This section presents a sticky-price flexible exchange rate model for a medium-sized open economy. It is small in the market for foreign produced goods and foreign assets, but large in the market for domestic money and domestically produced goods. The model is very similar to the one elaborated by Dornbusch (1976), Frankel (1979) and Mussa (1982), therefore the structure of the model will not be explained in great detail. Familiar results for the case of full information will be summarized briefly. Details are available in Engel (1983).

Output is demand determined in the short run. The aggregate demand function is given by

$$y_t = A - \alpha(i_t - (\mathrm{E}_t p_{t+1} - p_t)) - \beta(p_t - e_t). \tag{1}$$

(All variables are defined in table 1.) Money demand is

$$m_t - p_t = B - \lambda i_t. \tag{2}$$

Output has been left out of the money–demand relation because it allows massive simplifications in algebraic expressions without qualitatively affecting the conclusions.

Table 1

Definition of variables.

| | |
|---|---|
| $y$ | = log of output |
| $i$ | = nominal interest rate |
| $p$ | = log of price level |
| $e$ | = log of exchange rate |
| $m$ | = log of money supply |
| $\mu$ | = growth rate of money supply |
| $u, \varepsilon$ | = independent white-noice errors |
| * | = foreign variable |
| $\mathrm{E}_t$ | = expectation conditional on best information available at time $t$ |

The money supply is determined exogenously by the actions of policy-makers and the banking system. Monetary authorities set a desired growth rate of money each period, but they do not control the money stock exactly. It is assumed that the currency–deposit and the reserve–deposit ratios fluctuate randomly, so the log of the money multiplier follows a random walk. So, we have

$$m_t = m_{t-1} + \mu_t + u_t. \tag{3}$$

The authorities are assumed to allow $\mu_t$ to follow a random walk

$$\mu_t = \mu_{t-1} + \varepsilon_t. \tag{4}$$

(It is assumed the authorities do not know $u_t$ when $\mu_t$ is set, so $\mu_t$ is the policy-makers' desired growth rate.)

Uncovered interest parity holds

$$i_t = i^* + \mathrm{E}_t e_{t+1} - e_t. \tag{5}$$

Prices are predetermined, and adjust according to a Mussa (1981, 1982) specification

$$p_{t+1} = p_t - \theta(p_t - \bar{p}_t) + \mathrm{E}_t\bar{p}_{t+1} - \bar{p}_t. \tag{6}$$

$\bar{p}_t$ is defined to be the linear, rational expectations solution to

$$m_t - \bar{p}_t = B - \lambda(\mathrm{E}_t\bar{p}_{t+1} - \bar{p}_t) - \lambda i^*.$$

It can be shown

$$\bar{p}_t = m_t + \lambda i^* + \lambda \mathrm{E}_t\mu_t - B. \tag{7}$$

We can define a long-run equilibrium exchange rate using eq. (1):

$$\bar{e}_t = \bar{p}_t + (\bar{y} - A + \alpha i^*)/\beta, \tag{8}$$

where $\bar{y}$ is the long-run, steady-state level of output.

The system (1)–(8) can be solved by standard methods [see Blanchard and Kahn (1980)]. There is a unique stable saddle solution that requires

$$e_t - \bar{e}_t = -(1/\theta\lambda)(p_t - \bar{p}_t). \tag{9}$$

We can now easily derive the following results (where $z_t = u_t, \varepsilon_t$):

$$\mathrm{d}e_t/\mathrm{d}z_t = ((1+\theta\lambda)/\theta\lambda) + ((1+\theta\lambda)/\theta)\,\mathrm{dE}_t\mu_t/\mathrm{d}z_t, \tag{10}$$

$$\mathrm{d}\pi_t/\mathrm{d}z_t = \theta + (1+\theta\lambda)\,\mathrm{dE}_t\mu_t/\mathrm{d}z_t, \tag{11}$$

$$\mathrm{d}y_t/\mathrm{d}z_t = (\alpha\theta+\beta)((1+\theta\lambda)/\theta\lambda) + (\alpha\theta+\beta)((1+\theta\lambda)/\theta)\,\mathrm{dE}_t\mu_t/\mathrm{d}z_t. \tag{12}$$

Under full information about monetary policy $\mathrm{dE}_t\mu_t/\mathrm{d}u_t = 0$ and $\mathrm{dE}_t\mu_t/\mathrm{d}\varepsilon_t = 1$. Many of the results of this paper spring from the fact that under imperfect information about policy, both derivatives lie between 0 and 1.

It is probably unreasonable to assume that the market knows the policy-makers' goals exactly at any time. They can observe the current money stock but cannot distinguish how much of the change from last period is a result of a policy-induced growth in the money stock and how much follows from changes in the money multiplier.[1] People are helped out in forming their

[1]Errors could have been introduced into money demand instead of the money multiplier, with equivalent results. Many aspects of the imperfect information examined in this paper resemble the analysis in Mussa (1975). That paper, along with others such as Brunner, Cukierman and Meltzer (1980, 1983), discuss the effects of permanent and transitory shocks when they cannot be distinguished by agents. The present paper, by examining what happens if they can be partially distinguished, is a natural extension.

expectations of the current growth rate of money desired by policy-makers by the announcement of the intended growth rate. Actually, it is assumed that the authorities announce $a_t$, which is their claim about the value of $\varepsilon_t$ — the change in the desired growth rate.

Announcements of target growth rates do not yield full information to the market. People do not necessarily completely believe the announcement. In fact, the announcement is a random variable that may be imperfectly correlated with the true $\varepsilon_t$. The correlation coefficient $\rho$ is assumed to be known by the market. The closer $\rho$ is to 1, the more reliable are the announcements. By appropriate normalization, $a_t$ can have a zero mean and the same variance as $\varepsilon_t$.

It is obvious that the market's expectation of $\mu_t$ given the information it has access to at time $t$ is a critical variable in the system. Since people know $m_t - m_{t-1}$, from (3) they know $\mu_t + u_t$. Of course, they also know $a_t$. They do not know at time $t$, however, $\mu_t$, $u_t$ or $\mu_{t-1}$. For convenience, define

$$\gamma_t \equiv \mu_{t-1}.$$

It is useful to assume that at time $t$ the market has a prior distribution on $\gamma_t$ that is normal with mean $\hat{\gamma}_t$ and variance $\phi_{\gamma\gamma}$.

It follows from the discussion above that the vector $(u_t, a_t, \mu_t, \gamma_t)$ is distributed with a multivariate normal distribution that has a mean of $(0, 0, \hat{\gamma}_t, \hat{\gamma}_t)$ and a variance–covariance matrix of

$$\begin{bmatrix} \sigma_{uu} & 0 & 0 & 0 \\ 0 & \sigma_{\varepsilon\varepsilon} & \rho\sigma_{\varepsilon\varepsilon} & 0 \\ 0 & \rho\sigma_{\varepsilon\varepsilon} & \phi_{\gamma\gamma} + \sigma_{\varepsilon\varepsilon} & \phi_{\gamma\gamma} \\ 0 & 0 & \phi_{\gamma\gamma} & \phi_{\gamma\gamma} \end{bmatrix}.$$

The variance–covariance matrix represents the assumptions that $u_t$ is uncorrelated with $a_t$ and $\varepsilon_t$, while $a_t$ has a correlation of $\rho$ with $\varepsilon_t$. It also reflects the fact that $u_t$, $a_t$ and $\varepsilon_t$ are uncorrelated with $\gamma_t$.

We are interested in the expectation of $\mu_t$, conditional on $a_t$ and $\mu_t + u_t$. This is given by[2]

[2]This model can easily be recast in the terminology of Kalman filtering. The observation equation is $Y_t = F\xi_t + Z_t$ and the system equation is $\xi_t = G\xi_{t-1} + W_t$, where

$$Y_t = \begin{bmatrix} M_t - M_{t-1} \\ a_t \end{bmatrix}, \quad F = \begin{bmatrix} 1 & 0 \\ \rho & -\rho \end{bmatrix}, \quad \xi_t = \begin{bmatrix} \mu_t \\ \mu_{t-1} \end{bmatrix}, \quad Z_t = \begin{bmatrix} u_t \\ v_t \end{bmatrix}, \quad G = \begin{bmatrix} 1 & 0 \\ 1 & 0 \end{bmatrix}, \quad W_t = \begin{bmatrix} \xi_t \\ 0 \end{bmatrix},$$

$$\operatorname{var} Z_t = \begin{bmatrix} \sigma_{uu} & 0 \\ 0 & (1-\rho^2)\sigma_{\varepsilon\varepsilon} \end{bmatrix} \quad \text{and} \quad \operatorname{var} W_t = \begin{bmatrix} \sigma_{\varepsilon\varepsilon} & 0 \\ 0 & 0 \end{bmatrix}.$$

The relation of Kalman filtering to the Bayesian formulation of the problem employed in this paper is expounded in Meinhold and Singpurwalla (1983).

$$\mathrm{E}_t\mu_t = \hat{\gamma}_t + \frac{[(\gamma_t - \hat{\gamma}_t) + \varepsilon_t + u_t][(1-\rho^2)\sigma_{\varepsilon\varepsilon} + \phi_{\gamma\gamma}] + \rho\sigma_{uu}a_t}{(\phi_{\gamma\gamma} + \sigma_{\varepsilon\varepsilon} + \sigma_{uu}) - \rho^2\sigma_{\varepsilon\varepsilon}}, \tag{13}$$

where $\mathrm{E}_t$ should now be interpreted as the appropriate conditional expectations operator. The conditional variance of $\mu_t$, $\psi_{\mu\mu}$, is given by

$$\psi_{\mu\mu} = \phi_{\gamma\gamma} + \sigma_{\varepsilon\varepsilon} - \left\{\frac{[(1-\rho^2)\sigma_{\varepsilon\varepsilon} + \phi_{\gamma\gamma}](\phi_{\gamma\gamma} + \sigma_{\varepsilon\varepsilon}) + \rho^2\sigma_{\varepsilon\varepsilon}\sigma_{uu}}{(\phi_{\gamma\gamma} + \sigma_{\varepsilon\varepsilon} + \sigma_{uu}) - \rho^2\sigma_{\varepsilon\varepsilon}}\right\}. \tag{14}$$

When period $t+1$ comes around, this mean and variance will serve as the mean and variance of the prior distribution of $\gamma_{t+1}$. A stationarity requirement is that $\psi_{\mu\mu} = \phi_{\gamma\gamma}$. From (14), this implies

$$\phi_{\gamma\gamma} = [-(1-\rho^2)\sigma_{\varepsilon\varepsilon} + [(1-\rho^2)^2\sigma_{\varepsilon\varepsilon}^2 + 4(1-\rho^2)\sigma_{\varepsilon\varepsilon}\sigma_{uu}]^{1/2}]2. \tag{15}$$

In order to make results comparable to those in the full information case, it will be assumed that changes in the growth rate of money are accompanied by equal changes in the announcement, i.e., $\mathrm{d}a_t = \mathrm{d}\varepsilon_t$.

## 3. The response of inflation to an increase in money growth

A fairly well-established stylized fact is that an increase in the money growth rate does not feed back into an increase in inflation immediately. Although there is wide agreement that an increase in monetary growth will eventually be passed through to increased inflation, at least one purpose for modelling slow-adjustment in prices is to allow the response in inflation to be less than instantaneous when money growth changes.

Nonetheless, as demonstrated in the previous section, when there is full information on monetary policy the model implies that inflation will respond immediately at least one-for-one to a policy-induced change in the growth rate of money. Intuitively, in a setting of overlapping contracts, every period there are some contracts that are expiring, so there can be increases in inflation in response to current shocks. If the price setters realize that money will be growing over the entire period of the contract, then they realize average prices will be rising over the entire contract period. In order to make sure they do not get cheated, they require a large jump in their prices for the contract period. Thus, even though only a fraction of contracts expire in each period, those new contracts that are signed require large price increases, to allow for the expected continuing growth of money over the length of the new contract. The average price level rises at the rate of the increase in the money growth rate.

This explanation requires that price-setters realize there has been a permanent change in the growth rate of money. In the absence of reliable announcements, there is no way to tell whether a given change in the money supply has occurred because policy-makers have changed their goals, or because there was a change in the money multiplier over which the monetary authorities have no control. If shocks to the money multiplier usually account for most of the short-term variation in the money supply, then the market is unlikely to attribute much of any observed change in the money supply to a policy-induced change. So, when policy is not too variable, but announcements are unreliable, price-setters are unlikely to think the permanent growth rate of money has changed.

This explanation for why inflation is unlikely to jump much when the growth rate of money jumps is appealing both because it is intuitive and it stays with the familiar price-adjustment mechanism for which Mussa (1981), McCallum (1980) and others have found microeconomic rationales. An alternative approach is taken by Buiter and Miller (1982), who simply make the assumption that the core rate of inflation $(\mathrm{E}_t\bar{p}_{t+1}-\bar{p}_t)$ adjusts sluggishly. Saddle-stability, however, still requires the core rate to jump when the growth rate of money changes. In contrast, in the approach taken here, as the variance in changes in the money growth rate relative to the variance of changes in the money multiplier, the degree of credibility of announcements, and the speed of adjustment of prices all go to zero, the response of inflation to changes in money growth approaches zero.

To see why this is true, first note from eq. (13) (and with the assumption that $\mathrm{d}a_t=\mathrm{d}\varepsilon_t$),

$$\frac{\mathrm{dE}_t\mu_t}{\mathrm{d}\varepsilon_t}=b\equiv\frac{(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+\rho\sigma_{uu}}{(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+\sigma_{uu}}. \tag{16}$$

From inspection of (16),

$$\lim_{\rho\to 1} b=1,$$

so that when announcements are perfectly correlated with the true $\varepsilon$'s, the market responds to changes in $\varepsilon_t$ exactly as if it had perfect information.

Consider what happens when information is not perfect. Suppose the variance of $\varepsilon$ gets very small relative to the variance of $u$. Then, first note from (15)

$$\lim_{\sigma_{\varepsilon\varepsilon}/\sigma_{uu}\to 0}\phi_{\gamma\gamma}=0.$$

It then follows immediately from (16)

$$\lim_{\sigma_{\varepsilon\varepsilon}/\sigma_{uu}\to 0} b=\rho.$$

So, when changes in policy-determined money growth are usually responsible for little of the change in the money stock, only the announcement can signal to the market that a perturbation to $\varepsilon$ has occurred. But when the announcements usually have little correlation with the truth, then any particular announcement is unlikely to be believed. So, it follows[3]

$$\lim_{\rho,\,\sigma_{\varepsilon\varepsilon}/\sigma_{uu}\to 0} b=0. \tag{17}$$

To see how the current inflation rate changes with $\varepsilon_t$, from (11)

$$d\pi_t/d\varepsilon_t=\theta+b(1+\theta\lambda).$$

Then, when announcements are not very reliable, and policy does not vary much:

$$\lim_{\rho,\,\sigma_{\varepsilon\varepsilon}/\sigma_{uu}\to 0} d\pi_t/d\varepsilon_t=\theta.$$

Thus, in the limiting case, inflation only changes by the speed of adjustment of prices. This is exactly the response of inflation when, under full information, there is a one-time shock to the level of the money supply. As $\theta$ goes to zero, the response of inflation goes to zero. This can be contrasted with the case where policy is known, in which as the speed of adjustment goes to zero, $d\pi_t/d\varepsilon_t$ goes to one.

Although initially the market may be fooled about the current growth rate of money, eventually it will catch on. If there is initially a jump in $\varepsilon_t$, some fraction of the increase will be attributed to changes in the level of the money stock. In the long run, as the money supply continues to grow in excess of expectations, the market changes its estimate of the growth rate chosen by policy. Ultimately, expectations fully adjust. The appendix shows

$$\lim_{\tau\to\infty} dE_{t+\tau}\mu_{t+\tau}/d\varepsilon_t=1. \tag{18}$$

Since $\varepsilon_t$ is essentially known in the long-run, it is not surprising that a 1% change in the money growth rate is fully reflected as a 1% increase in inflation in the long-run:

$$\lim_{\tau\to\infty} d\pi_{t+\tau}/d\varepsilon_t=1. \tag{19}$$

This result is also demonstrated in the appendix.

[3]The notation here is unambiguous, since the limits could have been taken in either order.

## 4. The short-run output cost of reducing inflation

In sticky-price Keynesian models there is a trade-off between current output and current inflation. In order to lower the inflation rate through monetary policy, some real output must be given up. The purpose of this section is to examine how the terms of that trade-off are affected by increased reliability of policy announcements. That is, if the announcements are more highly correlated with the truth, will there be less output loss if the authorities wish to lower inflation by, say, 1%?

The tool the policy makers have available is the growth rate of money. If the loss in output for a given reduction in the monetary growth rate was unaffected by the degree of usefulness of the announcements, then the answer to the question would be easy. More reliable announcements mean that any drop in money growth leads to a larger drop in inflation, because the expectations effects will be larger. Therefore there would be less output loss for a given reduction in inflation.

However, the full answer is not so simple. There is more output loss for any reduction in the growth rate of money, the *greater* the reliability of announcements. To see why this is true, remember that output is determined by demand and demand depends only on the real interest rate and the real exchange rate. The nominal interest rate is unaffected by the degree of announcement credibility — it is determined only by the actual money supply level. But since inflation falls more the greater the reliability of the announcements, then the real interest rate rises more. It is also true that the exchange rate appreciates more the more highly correlated are the announcements with the truth, and given the inflexibility of prices, this implies the real exchange rate appreciates more. Thus, both determinants of aggregate demand are more unfavorable for some change in money growth the higher is the reliability of the announcements.

To see that these conclusions hold, first, from eqs. (12) and (16)

$$D_1 \equiv \mathrm{d}y_t/\mathrm{d}\varepsilon_t = (1+b\lambda)(\alpha\theta+\beta)((1+\theta\lambda)/\theta\lambda).$$

This is the response of output to a change in money growth. Since $b<1$, output does not move as much as in the case where the market has full information about monetary policy. The appendix shows

$$\mathrm{d}b/\mathrm{d}\rho > 0. \tag{20}$$

This is simply the claim that people perceive more of the true change in the money growth rate the greater $\rho$ is. Since

$$\mathrm{d}D_1/\mathrm{d}b = \lambda(\alpha\theta+\beta)((1+\theta\lambda)/\theta\lambda) > 0, \quad \text{it follows that}$$

$$\mathrm{d}D_1/\mathrm{d}\rho = \mathrm{d}D_1/\mathrm{d}b \cdot \mathrm{d}b/\mathrm{d}\rho > 0. \tag{21}$$

This is the conclusion reached in the discussion above — the short-run output response to a change in the money growth rate is greater the larger is $\rho$.

Inflation responds more to changes in $\varepsilon_t$ the larger is $\rho$. From (11) and (16)

$$D_2 \equiv \mathrm{d}\pi_t/\mathrm{d}\varepsilon_t = \theta + b(1+\lambda\theta).$$

This is the change in inflation when money growth changes. Not surprisingly, when there is imperfect information about policy the inflation rate changes less [see eq. (11)]. Now

$$\mathrm{d}D_2/\mathrm{d}\rho = \mathrm{d}D_2/\mathrm{d}b \cdot \mathrm{d}b/\mathrm{d}\rho = (1+\lambda\theta)\,\mathrm{d}b/\mathrm{d}\rho > 0. \tag{22}$$

Ultimately what we are interested in here is how the output–inflation trade-off is affected by $\rho$. We have seen that there are effects that would work different directions on the trade-off. Greater announcement reliability means inflation would drop more for any decrease in money growth, but it also means output drops more. How is $\mathrm{d}y_t/\mathrm{d}\pi_t$ (for a given change in $\varepsilon_t$) affected by $\rho$?

$$D_3 \equiv \mathrm{d}y_t/\mathrm{d}\pi_t = D_1/D_2 = (1+\lambda b)(1+\lambda\theta)(\alpha\theta+\beta)/[\theta + b(1+\lambda\theta)],$$

$$\mathrm{d}D_3/\mathrm{d}b = -(1+\lambda\theta)(\alpha+\theta\beta)/[\theta+b(1+\lambda\theta)]^2 < 0,$$

$$\mathrm{d}D_3/\mathrm{d}\rho = \mathrm{d}D_3/\mathrm{d}b \cdot \mathrm{d}b/\mathrm{d}\rho < 0.$$

This tells us that the short-run (one-period) output cost of a short-run reduction in inflation (that comes from a reduction in money growth) is smaller the larger is $\rho$. The effect of greater reliability on inflation outweighs the effect on output. When announcements are better signals of policy, inflation can be reduced less painfully.

## 5. The output cost of reducing long-run inflation

If policy-makers have a planning horizon that goes beyond the very short run, then it is of interest to ask how the costs of moving to a lower steady-state inflation rate are affected by the degree of reliability of policy announcements.

Eq. (19) of section 3 demonstrates that a 1% reduction in the long-run inflation rate can be accomplished with a 1% decrease in $\varepsilon_t$. Thus, questions about the output for long-run inflation trade-off come down to asking how much output changes for a given reduction in the money growth rate.

There is not much sense in talking about the trade-off of long-run output for long-run inflation. The appendix demonstrates that

$$\lim_{\tau \to \infty} \mathrm{d}y_{t+\tau}/\mathrm{d}\varepsilon_t = 0. \tag{23}$$

Output approaches the full-employment level of output in the long run, irrespective of the steady-state inflation rate.

We have already seen in section 4 [eq. (21)] that the initial drop in output for any decrease in the growth rate of money is larger the more highly correlated are announcements with true policy. However, does this hold for every period into the future? How is the cumulative output loss along the path to the new steady-state affected by announcement reliability? We want to know how $D_4$ responds to changes in $\rho$, where $D_4$ is defined by

$$D_4 \equiv \sum_{\tau=0}^{\infty} \frac{\mathrm{d}y_{t+\tau}}{\mathrm{d}\varepsilon_t}.$$

The appendix shows

$$\mathrm{d}D_4/\mathrm{d}\rho < 0. \tag{24}$$

Even though the output loss is greater the first period for higher $\rho$, as output begins to return to its long-run level, it returns much faster for high values of $\rho$. The real interest rate goes up more and the real exchange rate appreciates more in the first period for higher $\rho$'s, causing aggregate demand to fall more at first. But when the announcement is a more useful indicator of policy, the system adjusts more quickly to the steady state in response to policy changes. Thus, the real interest rate and the real exchange rate return more quickly to their long-run levels, so demand picks up sooner.

## 6. The output cost of currency appreciation

If the monetary authorities wish to appreciate the exchange rate in the short run by reducing money growth, there will be costs in terms of lost output. As in the previous sections, the effect of increased announcement reliability on the output costs of achieving a given appreciation can be examined. It can be shown that the strength of the correlation of the announcements with true policy does not affect the trade-off between output and appreciation.

This surprising conclusion can be explained easily by noticing that in Dornbusch-type models of the exchange rate there is a fixed linear relationship between real interest rates and the real exchange rate. A higher real interest rate is associated with a real appreciation of the currency. Since aggregate demand depends only on the real interest rate and the real exchange rate, it follows that a 'reduced form' can be developed in which demand depends only on the real exchange rate. Since prices are fixed in the short run, there is a fixed relation between currency appreciation and changes in aggregate demand in the short run. The degree of reliability of announcements has no effect on this relation.

These conclusions can be derived easily.[4] First, lead eq. (9) forward one period and take expectations:

$$\mathrm{E}_t e_{t+1} - \mathrm{E}_t \bar{e}_{t+1} = -(1/\theta\lambda)(p_{t+1} - \mathrm{E}_t \bar{p}_{t+1}).$$

Substitute from eq. (6) to obtain

$$\mathrm{E}_t e_{t+1} - \mathrm{E}_t \bar{e}_{t+1} = -(1-\theta)(p_t - \bar{p}_t)/\theta\lambda. \tag{25}$$

Then use (9) to get

$$\mathrm{E}_t e_{t+1} - e_t = -\theta(e_t - \bar{e}_t) + \mathrm{E}_t \bar{e}_{t+1} - \bar{e}_t.$$

Thus, expectations take a regressive form [as in Dornbusch (1976)]. Subtract (6) from (25) to obtain

$$\mathrm{E}_t e_{t+1} - e_t - (p_{t+1} - p_t) = -\theta(e_t - p_t - (\bar{e}_t - \bar{p}_t)).$$

Using eqs. (5) and (8)

$$i_t - \pi_t = i^* + \theta(\bar{y} - A + \alpha i^*)/\beta - \theta(e_t - p_t).$$

This is the promised linear relation between the real interest rate and the real exchange rate. Substituting this into the aggregate demand eq. (1)

$$y_t = A - \alpha i^* - \alpha\theta(\bar{y} - A + \alpha i^*)/\beta + (\alpha\theta + \beta)(e_t - p_t). \tag{26}$$

It follows from (26) that

$$\mathrm{d}y_t/\mathrm{d}e_t = \alpha\theta + \beta$$

regardless of the exogenous force that changes $y_t$ and $e_t$. Since this trade-off does not depend on anything that is a function of $\rho$, the reliability of announcement has no effect.

[4]Because of the Obstfeld–Rogoff (1983) conclusion about observational equivalence of models with various price-adjustment mechanisms, this conclusion does not depend on using the Mussa equation.

## 7. The variability of the exchange rate

This section attempts to answer a question which is quite different from the ones addressed in previous sections. It is a well-known stylized fact that exchange rates have been quite volatile under the floating exchange rate regime since 1973. Dornbusch (1976) has provided a satisfying theoretical explanation of why exchange rates may overshoot their long-run values in response to a monetary shock — thus partly explaining the observed volatility. Not all monetary shocks are engineered by monetary authorities. The money multiplier may vary, thus causing the money stock to change even with constant monetary policy. Of course, fluctuations in the money multiplier contribute to fluctuations in the exchange rate. Can increased reliability of policy announcements reduce the overshooting of exchange rates in response to a money multiplier shock?

Every period the new money supply is announced, and a new piece of information is available to the market on monetary policy. People are likely to think some of the change is from a policy-induced change in the growth rate, and some from a shock to the money multiplier which changes the level of the money supply. A shock to the growth rate of money causes the exchange rate to jump more than when there is a shock to the level of the money supply. When the money multiplier does fluctuate, the exchange rate will fluctuate less the better the information that is available on monetary policy. This is because with better information, people know with more confidence that the shock came from the money multiplier rather than the growth rate of money. In this case, when $\rho$ is higher, the exchange rate will overshoot to a lesser extent in response to a surprise in the level of the money stock.

From eqs. (10) and (13) it can be seen that

$$D_5 \equiv \mathrm{d}e_t/\mathrm{d}u_t = ((1+\lambda\theta)/\lambda\theta) + ((1+\lambda\theta)/\theta)f, \quad \text{where} \tag{27}$$

$$f \equiv 1 - \sigma_{uu}/(1-\rho^2+\theta_{\gamma\gamma}+\sigma_{uu}) < 1.$$

A useful way of viewing the response of the exchange rate to a change in $u_t$ under imperfect information is to notice that eq. (27) can be rewritten as

$$\mathrm{d}e_t/\mathrm{d}u_t = (1-f)(\mathrm{d}e_t/\mathrm{d}u_t)' + f(\mathrm{d}e_t/\mathrm{d}\varepsilon_t)',$$

where the $'$ represents the derivatives when information is complete. The fraction $f$ represents how much of an observed change in the money supply is attributed to a change in the growth rate. The smaller $f$ is, the smaller $\mathrm{d}e_t/\mathrm{d}u_t$ will be. The appendix shows

$$\mathrm{d}f/\mathrm{d}\rho < 0. \tag{28}$$

Thus, increased reliability of announcements leads to more stability of the exchange rate when the money supply changes from factors that are beyond the monetary authority's control. That is, from (27) and (28)

$$\mathrm{d}D_5/\mathrm{d}\rho<0.$$

## 8. Conclusions

Generally announcements about monetary policy are a useful, but not perfectly reliable, source of information about the policy-makers' intended policy goals. This paper explores the consequences of announcements that are not perfectly correlated with true policy. The degree of correlation is taken as exogenous to the model. Clearly it would be of interest to model the influences that lead announcements to be imperfect signals.

The paper suggests that imperfect information about policy might explain slow response of inflation to changes in monetary growth. Improved information, through more reliable announcements, lowers the short-run output cost of an immediate reduction in inflation, and the cumulative long-run output loss of a reduced steady-state inflation rate. However, it has no effect on the short-run output loss from appreciation of the currency. More reliable announcements do reduce the degree of overshooting of the exchange rate when there are shocks to the money supply that arise from the banking system, rather than from policy-makers.

## Appendix

Eq. (18) must be demonstrated. First note that eq. (13) may be rewritten as

$$\mathrm{E}_t\mu_t=(1-f)\mathrm{E}_{t-1}\mu_{t-1}+f\mu_{t-1}+f\varepsilon_t+fu_t+ga_t,\quad \text{where}$$

$$f\equiv\frac{(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}}{(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+\sigma_{uu}}<1\quad\text{and}\quad g\equiv\frac{\rho\sigma_{uu}}{(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+\sigma_{uu}}<1.$$

Notice that

$$f+g=b<1,$$

where $b$ is defined by eq. (16). More generally,

$$\mathrm{E}_{t+\tau}\mu_{t+\tau}=(1-f)\mathrm{E}_{t+\tau-1}\mu_{t+\tau-1}+f\mu_{t+\tau-1}+f\varepsilon_{t+\tau}+fu_{t+\tau}+ga_{t+\tau},$$

because of the stationarity assumption. It follows that

$$\frac{\mathrm{dE}_{t+\tau}\mu_{t+\tau}}{\mathrm{d}\varepsilon_t}=(1-f)\frac{\mathrm{dE}_{t+\tau-1}\mu_{t+\tau-1}}{\mathrm{d}\varepsilon_t}+f. \tag{A.1}$$

We need to show that

$$\frac{\mathrm{dE}_{t+\tau}\mu_{t+\tau}}{\mathrm{d}\varepsilon_t}=1-(1-b)(1-f)^{\tau}. \tag{A.2}$$

This will be shown by induction. From (16) it clearly is true for $\tau=0$. Assume that

$$\frac{\mathrm{dE}_{t+\tau-1}\mu_{t+\tau-1}}{\mathrm{d}\varepsilon_t}=1-(1-b)(1-f)^{\tau-1}.$$

Then from (A.1)

$$\frac{\mathrm{dE}_{t+\tau}\mu_{t+\tau}}{\mathrm{d}\varepsilon_t}=(1-f)[1-(1-b)(1-f)^{\tau-1}]+f=1-(1-b)(1-f)^{\tau},$$

which is what was to be demonstrated. Eq. (18) follows from (A.2).

Next, (19) must be demonstrated. From the price-adjustment eq. (6)

$$p_{t+1}=(1-\theta)p_t+\theta \mathrm{E}_t\bar{p}_t+\mathrm{E}_t\mu_t.$$

Using the definition of $\bar{p}_t$ from (7)

$$p_{t+1}=(1-\theta)p_t+\theta m_t+(1+\theta\lambda)\,\mathrm{E}_t\mu_t+\lambda\theta i^*.$$

In general

$$p_{t+\tau}=(1-\theta)p_{t+\tau-1}+\theta m_{t+\tau-1}+(1+\theta\lambda)\,\mathrm{E}_{t+\tau-1}\mu_{t+\tau-1}+\lambda\theta i^*.$$

We have

$$\frac{\mathrm{d}p_{t+\tau}}{\mathrm{d}\varepsilon_t}=(1-\theta)\frac{\mathrm{d}p_{t+\tau-1}}{\mathrm{d}\varepsilon_t}+\theta\frac{\mathrm{d}m_{t+\tau-1}}{\mathrm{d}\varepsilon_t}+(1+\theta\lambda)\frac{\mathrm{dE}_{t+\tau-1}\mu_{t+\tau-1}}{\mathrm{d}\varepsilon_t}. \tag{A.3}$$

The claim is that

$$\frac{\mathrm{d}p_{t+\tau}}{\mathrm{d}\varepsilon_t}=(1+\lambda)(1-(1-\theta)^{\tau})+\tau-(1+\theta\lambda)(1-b)\frac{(1-f)^{\tau}-(1-\theta)^{\tau}}{\theta-f}. \tag{A.4}$$

This will be shown by induction. For $\tau=0$ this expression vanishes, which is correct since prices are predetermined. Assume that

$$\frac{\mathrm{d}p_{t+\tau-1}}{\mathrm{d}\varepsilon_t}=(1+\lambda)(1-(1-\theta)^{\tau-1})$$
$$+\tau-1-(1+\theta\lambda)(1-b)\frac{(1-f)^{\tau-1}-(1-\theta)^{\tau-1}}{\theta-f}.$$

Then,

$$\frac{\mathrm{d}p_{t+\tau}}{\mathrm{d}\varepsilon_t}=(1-\theta)\bigg[(1+\lambda)(1-(1-\theta)^{\tau-1})$$
$$+\tau-1-(1+\theta\lambda)(1-b)\frac{(1-f)^{\tau-1}-(1-\theta)^{\tau-1}}{\theta-f}\bigg]$$
$$+\theta\tau+(1+\theta\lambda)[1-(1-b)(1-f)^{\tau-1}].$$

Straightforward algebra shows this is equivalent to (A.4). Now, using (A.4) we have

$$\frac{\mathrm{d}\pi_{t+\tau}}{\mathrm{d}\varepsilon_t}=\frac{\mathrm{d}(p_{t+\tau-1}-p_{t+\tau})}{\mathrm{d}\varepsilon_t}=\theta(1+\lambda)(1-\theta)^{\tau}$$
$$+1-(1+\theta\lambda)(1-b)\frac{\theta(1-\theta)^{\tau}-f(1-f)^{\tau}}{\theta-f}.$$

Letting $\tau\to\infty$ in this expression yields eq. (19).

To show (20),

$$\frac{\mathrm{d}b}{\mathrm{d}\rho}=\frac{\sigma_{uu}[(1-\rho)^2\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+(1-\rho)(\mathrm{d}\phi_{\gamma\gamma}/\mathrm{d}\rho)+\sigma_{uu}]}{[(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+\sigma_{uu}]^2}. \tag{A.5}$$

It follows that

$\mathrm{d}b/\mathrm{d}\rho>0$ if and only if

$$(1-\rho)^2\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+(1-\rho)\,\mathrm{d}\phi_{\gamma\gamma}/\mathrm{d}\rho+\sigma_{uu}>0. \tag{A.6}$$

Now

$$\mathrm{d}\phi_{\gamma\gamma}/\mathrm{d}\rho=\rho\sigma_{\varepsilon\varepsilon}-\frac{(\rho(1-\rho^2)\sigma_{\varepsilon\varepsilon}^2+2\rho\sigma_{\varepsilon\varepsilon}\sigma_{uu})}{((1-\rho^2)^2\sigma_{\varepsilon\varepsilon}^2+4(1-\rho^2)\sigma_{\varepsilon\varepsilon}\sigma_{uu})^{1/2}}.$$

Then, we have

$$(1-\rho)\frac{d\phi_{\gamma\gamma}}{d\rho}+\phi_{\gamma\gamma}+(1-\rho)^2\sigma_{\varepsilon\varepsilon}=\frac{(1-\rho^2)(1-\rho)^2\sigma_{\varepsilon\varepsilon}^2+4(1-\rho)\sigma_{\varepsilon\varepsilon}\sigma_{uu}}{2((1-\rho^2)^2\sigma_{\varepsilon\varepsilon}^2+4(1-\rho^2)\sigma_{\varepsilon\varepsilon}\sigma_{uu})^{1/2}}>0. \tag{A.7}$$

It follows from (A.6) and (A.7) that (20) holds.

To derive eq. (23) requires some work. Extending eq. (9) to period $t+\tau$:

$$e_{t+\tau}-\bar{e}_{t+\tau}=-(1/\theta\lambda)(p_{t+\tau}-\bar{p}_{t+\tau}).\quad \text{Since}$$

$$\bar{p}_{t+\tau}=m_{t+\tau}+\lambda i^*+\lambda \mathrm{E}_{t+\tau}\mu_{t+\tau}-B,\quad \text{and} \tag{A.8}$$

$$\bar{e}_{t+\tau}=\bar{p}_{t+\tau}+(1/\beta)(\bar{y}-A+\alpha i^*),\quad \text{it follows that}$$

$$\begin{aligned}e_{t+\tau}=&(1/\beta)(\bar{y}-A-\alpha i^*)+(\lambda+1/\theta)i^*-(1+1/\theta\lambda)B\\&+(1+1/\theta\lambda)m_{t+\tau}+(\lambda+1/\theta)\mathrm{E}_{t+\tau}\mu_{t+\tau}-(1/\theta\lambda)p_{t+\tau}.\end{aligned} \tag{A.9}$$

Next, from (6) extended to period $t+\tau$

$$\pi_{t+\tau}=-\theta p_{t+\tau}+\theta\bar{p}_{t+\tau}+\mathrm{E}_{t+\tau}\mu_{t+\tau}.$$

From (A.8),

$$\pi_{t+\tau}=-\theta p_{t+\tau}+\theta m_{t+\tau}+(1+\theta\lambda)\mathrm{E}_{t+\tau}\mu_{t+\tau}+\lambda\theta i^*-\theta B. \tag{A.10}$$

From the money demand eq. (2) for period $t+\tau$

$$i_{t+\tau}=-(1/\lambda)(m_{t+\tau}-p_{t+\tau}-B). \tag{A.11}$$

Aggregate demand for period $t+\tau$, from (1) is

$$y_{t+\tau}=A-\alpha(i_{t+\tau}-\pi_{t+\tau})-\beta(p_{t+\tau}-e_{t+\tau}). \tag{A.12}$$

Using (A.9), (A.10), (A.11), and (A.12) yields

$$\begin{aligned}y_{t+\tau}=&\bar{y}+(\alpha\theta+\beta)(1+1/\theta\lambda)(m_{t+\tau}-p_{t+\tau}-B)\\&+\lambda(\alpha\theta+\beta)(1+1/\theta\lambda)(\mathrm{E}_{t+\tau}\mu_{t+\tau}+i^*).\end{aligned}$$

It follows that

$$\frac{dy_{t+\tau}}{d\varepsilon_t}=(\alpha\theta+\beta)\left(1+\frac{1}{\theta\lambda}\right)\left[\frac{dm_{t+\tau}}{d\varepsilon_t}-\frac{dp_{t+\tau}}{d\varepsilon_t}+\lambda\frac{d\mathrm{E}_{t+\tau}\mu_{t+\tau}}{d\varepsilon_t}\right].$$

From (A.2) and (A.4)

$$\frac{\mathrm{d}y_{t+\tau}}{\mathrm{d}\varepsilon_t}=(\alpha\theta+\beta)\left(1+\frac{1}{\theta\lambda}\right)\left[\tau+1-(1+\lambda)(1-(1-\theta)^\tau)-\tau\right.$$

$$\left.+(1+\theta\lambda)(1-b)\frac{(1-f)^\tau-(1-\theta)^\tau}{\theta-f}+\lambda-\lambda(1-b)(1-f)^\tau\right]$$

$$=\frac{\alpha\theta+\beta}{\theta-f}\left(1+\frac{1}{\theta\lambda}\right)[(1+\lambda f)(1-b)(1-f)^\tau$$

$$+(b(1+\theta\lambda)-(1-\theta)-f(1+\lambda))(1-\theta)^\tau].$$

Letting $\tau\to\infty$, the derivative vanishes which yields (23).

From the above, it follows that

$$D_4\equiv\sum_{\tau=0}^{\infty}\frac{\mathrm{d}y_{t+\tau}}{\mathrm{d}\varepsilon_t}=\frac{\alpha\theta+\beta}{\theta f(\theta-f)}\left(1+\frac{1}{\theta\lambda}\right)[\theta(1+\lambda f)(1-b)+f(b(1+\lambda\theta)$$

$$+(1-\theta)-f(1+\lambda))]$$

$$=\frac{\alpha\theta+\beta}{\theta f}\left(1+\frac{1}{\theta\lambda}\right)[1-b+(1+\lambda)f]$$

$$=\left(\alpha+\frac{\beta}{\theta}\right)\left(1+\frac{1}{\theta\lambda}\right)\left[1+\lambda+\frac{(1-\rho)\sigma_{uu}}{(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}}\right].$$

Then

$$\frac{\mathrm{d}D_4}{\mathrm{d}\rho}=\frac{-\sigma_{uu}}{[(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}]^2}\left(\alpha+\frac{\beta}{\theta}\right)\left(1+\frac{1}{\theta\lambda}\right)$$

$$\times\left[(1-\rho)^2\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+(1-\rho)\frac{\mathrm{d}\phi_{\gamma\gamma}}{\mathrm{d}\rho}\right]$$

which is less than zero by (A.7).

To see that (28) holds

$$\frac{\mathrm{d}f}{\mathrm{d}\rho}=\frac{\sigma_{uu}[-2\rho\sigma_{\varepsilon\varepsilon}+\mathrm{d}\phi_{\gamma\gamma}/\mathrm{d}\rho]}{[(1-\rho^2)\sigma_{\varepsilon\varepsilon}+\phi_{\gamma\gamma}+\sigma_{uu}]}. \qquad \text{(A.13)}$$

But

$$-2\rho\sigma_{\varepsilon\varepsilon}+\frac{\mathrm{d}\phi_{\gamma\gamma}}{\mathrm{d}\rho}=-\rho\sigma_{\varepsilon\varepsilon}-\frac{(\rho(1-\rho^2)\sigma_{\varepsilon\varepsilon}^2+2\rho\sigma_{\varepsilon\varepsilon}\sigma_{uu})}{((1-\rho^2)^2\sigma_{\varepsilon\varepsilon}^2+4(1-\rho^2)\sigma_{\varepsilon\varepsilon}\sigma_{uu})^{1/2}}<0.$$

Substituting this into (A.13), (28) follows.

## References


Blanchard, O. and C. Kahn, 1980, The solution of linear difference models under rational expectations, Econometrica 48, July, 1305–1311.

Brunner, K., A. Cukierman and A. Meltzer, 1980, Stagflation, persistent unemployment and the permanence of economic shocks, Journal of Monetary Economics 6, Oct., 467–492.

Brunner, K., A. Cukierman and A. Meltzer, 1983, Money and economic activity, inventories and business cycles, Journal of Monetary Economics 11, May, 281–319.

Buiter, W. and M. Miller, 1982, Real exchange rate overshooting and the output cost of bringing down inflation, European Economic Review 18, May/June, 85–123.

Dornbusch, R., 1976, Expectations and exchange rate dynamics, Journal of Political Economy 84, Dec., 1161–1176.

Engel, C., 1983, Reliability of policy announcements and the effects of monetary policy, Discussion paper no. 140, June (The Thomas Jefferson Center for Political Economy, University of Virginia, Charlottesville, VA).

Frankel, J., 1979, On the mark: A theory of floating exchange rates based on real interest differentials, American Economic Review 69, Sept., 610–622.

McCallum, B.T., 1980, Rational expectations and macroeconomic stabilization policy: An overview, Journal of Money, Credit and Banking 12, Nov., 716–746.

Meinhold, R. and N. Singpurwalla, 1983, Understanding the Kalman filter, The American Statistician 37, May, 123–127.

Mussa, M., 1975, Adaptive and regressive expectations in a rational model of the inflationary process, Journal of Monetary Economics 1, Oct., 423–442.

Mussa, M., 1981, Sticky prices and disequilibrium adjustment in a rational model of the inflationary process, American Economic Review 71, Dec., 1020–1027.

Mussa, M., 1982, A model of exchange rate dynamics, Journal of Political Economy 90, Feb., 74–104.

Obstfeld, M. and K. Rogoff, 1983, Exchange rate dynamics with sluggish prices under alternative price-adjustment rules, International Economic Review, forthcoming.