11 Monetary Policy Operating Procedures

11.1 Introduction

Previous chapters treated the nominal money supply, the nominal interest rate, or even inflation as the variable directly controlled by the monetary policymaker. This approach ignores the actual problems surrounding policy implementation. Central banks do not directly control the nominal money supply, inflation, or long-term interest rates likely to be most relevant for aggregate spending. Instead, narrow reserve aggregates, such as the monetary base, or very short-term interest rates, such as the federal funds rate in the United States, are the variables over which the central bank can exercise close control. Yet previous chapters have not discussed the specific relationship between short-term interest rates, other reserve aggregates such as non-borrowed reserves or the monetary base, and the broader monetary aggregates such as $M1$ or $M2$. And there has been no discussion of the factors that might explain why many central banks choose to use a short-term interest rate rather than a monetary aggregate as their policy instrument. These issues are addressed in this chapter.

The actual implementation of monetary policy involves a variety of rules, traditions, and practices, and these collectively are called *operating procedures*. Operating procedures differ according to the actual instrument the central bank uses in its daily conduct of policy, the operating target whose control is achieved over short horizons (e.g., a short-term interest rate versus a reserve aggregate), the conditions under which the instruments and operating targets are automatically adjusted in light of economic developments, the information about policy and the types of announcements the monetary authority might make, its choice of variables for which it establishes targets (e.g., money supply growth or the inflation rate), and whether these targets are formal or informal.

The objective in examining monetary policy operating procedures is to understand what instruments are actually under the control of the monetary authority, the factors that determine the optimal instrument choice, and how the choice of instrument affects the manner in which short-term interest rates, reserve aggregates, or the money stock might reflect policy actions and nonpolicy disturbances. After discussing the role of instruments and goals, the chapter examines the factors that determine the optimal choice of an operating procedure and the relationship between the choice of operating procedure and the response of the market for bank reserves to various economic disturbances. Then, a model of a channel system for setting interest rates is presented. The chapter concludes with a brief history of the Fed's operating procedures.

11.2 From Instruments to Goals

Discussions of monetary policy implementation focus on *instruments*, *operating targets*, *intermediate targets*, and *policy goals*. Instruments are the variables directly controlled by the central bank. These typically include an interest rate charged on reserves borrowed from the central bank, the reserve requirement ratios that determine the level of reserves banks must hold against their deposit liabilities, and the composition of the central bank's own balance sheet (its holdings of government securities, for example). The instruments of policy are manipulated to achieve a prespecified value of an operating target, typically some measure of bank reserves (total reserves, borrowed reserves, or nonborrowed reserves—the difference between total and borrowed reserves), or a very short-term rate of interest, usually an overnight interbank rate (the federal funds rate in the case of the United States).

Goals such as inflation or deviations of unemployment from the natural rate are the ultimate variables of interest to policymakers; instruments are the actual variables under their direct control. Intermediate target variables fall between operating targets and goals in the sequence of links that run from policy instruments to real economic activity and inflation. Because observations on some or all of the goal variables are usually obtained less frequently than are data on interest rates, exchange rates, or monetary aggregates, the behavior of these latter variables can often provide the central bank with information about economic developments that will affect the goal variables. For example, faster than expected money growth may signal that real output is expanding more rapidly than was previously thought. The central bank might change its operating target (e.g., raise the interbank rate or contract reserves) to keep the money growth rate on a path believed to be consistent with achieving its policy goals. In this case, money growth serves as an intermediate target variable. Under inflation targeting policies, the inflation forecast plays the role of an intermediate target (Svensson and Woodford 2005).

Instruments, operating targets, intermediate targets, and goals have been described in a sequence running from the instruments directly controlled by the central bank to goals, the ultimate objectives of policy. Actually, policy design operates in the reverse fashion: from the goals of policy, to the values of the intermediate targets consistent with the goals, to the values of the operating targets needed to achieve the intermediate targets, and finally to the instrument settings that yield the desired values of the operating targets (Tinbergen 1956). In earlier chapters, inflation and the money supply were sometimes treated as policy instruments, ignoring the linkages from reserve markets to interest rates to banking sector behavior to aggregate demand. Similarly, it is often useful to ignore reserve market behavior and treat an operating target variable, such as the overnight interbank interest rate or a reserve aggregate, as the policy instrument. Since these two variables can be controlled closely over short time horizons, they are often also described as *policy instruments*.

11.3 The Instrument Choice Problem

If the monetary policy authority can choose between employing an interest rate or a monetary aggregate as its policy instrument, which should it choose? The classic analysis of this question is due to Poole (1970). He showed how the stochastic structure of the economy—the nature and relative importance of different types of disturbances—would determine the optimal choice of instrument.

11.3.1 Poole's Analysis

Suppose the central bank must set policy before observing the current disturbances to the goods and money markets, and assume that information on interest rates, but not output, is immediately available. This informational assumption reflects a situation in which the central bank can observe market interest rates essentially continuously, but data on inflation and output might be available only monthly or quarterly. In such an environment, the central bank will be unable to determine from a movement in market interest rates the exact nature of any economic disturbances. To make a simple parallel with a model of supply and demand, observing a rise in price does not indicate whether there has been a positive shock to the demand curve or a negative shock to the supply curve. Only by observing both price and quantity can these two alternatives be distinguished because a demand shift would be associated with a rise in both price and quantity, whereas a supply shift would be associated with a rise in price and a decline in quantity. At the macroeconomic level, an increase in the interest rate could be due to expanding aggregate demand (which might call for contractionary monetary policy to stabilize output) or an exogenous shift in money demand (which might call for letting the money supply expand). With imperfect information about economic developments, it will be impossible to determine the source of shocks that have caused interest rates to move.

Poole asked, in this environment, whether the central bank should try to hold market interest rates constant or hold a monetary quantity constant while allowing interest rates to move. And he assumed that the objective of policy was to stabilize real output, so he answered the question by comparing the variance of output implied by the two alternative policies.

Poole treated the price level as fixed; to highlight his basic results, the same is done here. Since the instrument choice problem primarily relates to the decision to hold either a market rate or a monetary quantity constant over a fairly short period of time (say, the time between policy board meetings), ignoring price level effects is not unreasonable as a starting point for the analysis. Poole's result can be derived in a simple model given in log terms by

$$y_t = -\alpha i_t + u_t \tag{11.1}$$

$$m_t = y_t - c i_t + v_t. \tag{11.2}$$

Equation (11.1) represents an aggregate demand relationship in which output is a decreasing function of the interest rate; demand also depends on an exogenous disturbance u_t with variance σ_u^2. Equation (11.2) gives the demand for money as a decreasing function of the interest rate and an increasing function of output. Money demand is subject to a random shock v_t with variance σ_v^2. Equilibrium requires that the demand for money equal the supply of money m_t. For simplicity, u and v are treated as mean zero serially and mutually uncorrelated processes. These two equations represent a simple IS-LM model of output determination, given a fixed price level.[1]

The final aspect of the model is a specification of the policymaker's objective, assumed to be the minimization of the variance of output deviations:

$$\mathrm{E}[y_t]^2, \tag{11.3}$$

where all variables have been normalized so that the economy's equilibrium level of output in the absence of shocks is $y = 0$.

The timing is as follows: the central bank sets either i_t or m_t at the start of the period, then the stochastic shocks u_t and v_t occur, determining the values of the endogenous variables (either y_t and i_t if m_t is the policy instrument, or y_t and m_t if i_t is the policy instrument).

When the money stock is the policy instrument, (11.1) and (11.2) can be solved jointly for equilibrium output:

$$y_t = \frac{\alpha m_t + c u_t - \alpha v_t}{\alpha + c}.$$

1. Note that the price level has been normalized to equal 1 so that the log of the price level is zero; $p = 0$. The income elasticity of money demand has also been set equal to 1.

Then, setting m_t such that $\mathrm{E}[y_t] = 0$,[2] one obtains $y_t = (cu_t - \alpha v_t)/(\alpha + c)$. Hence, the value of the objective function under a money supply procedure is

$$\mathrm{E}_m[y_t]^2 = \frac{c^2\sigma_u^2 + \alpha^2\sigma_v^2}{(\alpha + c)^2}, \tag{11.4}$$

where it is assumed that u and v are uncorrelated.

Under the alternative policy, i_t is the policy instrument, and (11.1) can be solved directly for output. That is, the money market condition is no longer needed, although it will determine the level of m_t necessary to ensure money market equilibrium. By fixing the rate of interest, the central bank lets the money stock adjust endogenously to equal the level of money demand given by the interest rate and the level of income. Setting i_t such that $\mathrm{E}[y_t] = 0$, output will equal u_t and

$$\mathrm{E}_i[y_t]^2 = \sigma_u^2. \tag{11.5}$$

The two alternative policy choices can be evaluated by comparing the variance of output implied by each. The interest rate operating procedure is preferred to the money supply operating procedure if and only if

$$\mathrm{E}_i[y_t]^2 < \mathrm{E}_m[y_t]^2,$$

and, from (11.4) and (11.5), this condition is satisfied if and only if

$$\sigma_v^2 > \left(1 + \frac{2c}{\alpha}\right)\sigma_u^2. \tag{11.6}$$

Thus, an interest rate procedure is more likely to be preferred when the variance of money demand disturbances is larger, the LM curve is steeper (the slope of the LM curve is $1/c$), and the IS curve is flatter (the slope of the IS curve is $-1/\alpha$). A money supply procedure will be preferred if the variance of aggregate demand shocks (σ_u^2) is large, the LM curve is flat, or the IS curve is steep.[3]

If only aggregate demand shocks are present (i.e., $\sigma_v^2 = 0$), a money rule leads to a smaller variance for output. Under a money rule, a positive IS shock leads to an increase in the interest rate. This acts to reduce aggregate spending, thereby partially offsetting the original shock. Since the adjustment of i acts automatically to stabilize output, preventing this interest rate adjustment by fixing i leads to larger output

2. This just requires $m = 0$ because of the normalization.

3. In the context of an open economy in which the IS relationship is $y_t = -\alpha_1 i_t + \alpha_2 s_t + u_t$, where s_t is the exchange rate, Poole's conclusions go through without modification if the central bank's choice is expressed not in terms of i_t but in terms of the monetary conditions index $i_t - (\alpha_2/\alpha_1)s_t$.

fluctuations. If only money demand shocks are present, (i.e., $\sigma_u^2 = 0$), output can be stabilized perfectly under an interest rate rule. Under a money rule, money demand shocks cause the interest rate to move to maintain money market equilibrium; these interest rate movements then lead to output fluctuations. With both types of shocks occurring, the comparison of the two policy rules depends on the relative variances of u and v as well as on the slopes of the IS and the LM curves, as shown by (11.6).

This framework is quite simple and ignores many important factors. To take just one example, no central bank has direct control over the money supply. Instead, control can be exercised over a narrow monetary aggregate such as the monetary base, and variations in this aggregate are then associated with variations in broader measures of the money supply. To see how the basic framework can be modified to distinguish between the base as a policy instrument and the money supply, suppose the two are linked by

$$m_t = b_t + hi_t + \omega_t, \tag{11.7}$$

where b is the (log) monetary base, and the money multiplier ($m_t - b_t$ in log terms) is assumed to be an increasing function of the rate of interest (i.e., $h > 0$). In addition, ω_t is a random money multiplier disturbance. Equation (11.7) could arise under a fractional reserve system in which excess reserves are a decreasing function of the rate of interest.[4] Under an interest rate procedure, (11.7) is irrelevant for output determination, so $\mathrm{E}_i(y_t)^2 = \sigma_u^2$, as before. But now, under a monetary base operating procedure,

$$y_t = \frac{(c+h)u_t - \alpha v_t + \alpha\omega_t}{\alpha + c + h}$$

and

$$\mathrm{E}_b(y_t)^2 = \left(\frac{1}{\alpha + c + h}\right)^2 [(c+h)^2\sigma_u^2 + \alpha^2(\sigma_v^2 + \sigma_\omega^2)].$$

The interest rate procedure is preferred over the monetary base procedure if and only if

$$\sigma_v^2 + \sigma_\omega^2 > \left[1 + \frac{2(c+h)}{\alpha}\right]\sigma_u^2.$$

Because ω shocks do not affect output under an interest rate procedure, the presence of money multiplier disturbances makes a base rule less attractive and makes it more

4. See, for example, Modigliani, Rasche, and Cooper (1970) or McCallum and Hoehn (1983).

likely that an interest rate procedure will lead to a smaller output variance. This simple extension reinforces the basic message of Poole's analysis; increased financial sector volatility (money demand or money multiplier shocks in the model used here) increases the desirability of an interest rate policy procedure over a monetary aggregate procedure. If money demand is viewed as highly unstable and difficult to predict over short time horizons, greater output stability can be achieved by stabilizing interest rates, letting monetary aggregates fluctuate. If, however, the main source of short-run instability arises from aggregate spending, a policy that stabilizes a monetary aggregate will lead to greater output stability.

This analysis is based on the realistic assumption that policy is unable to identify and respond directly to underlying disturbances. Instead, policy is implemented by fixing, at least over some short time interval, the value of an operating target or policy instrument. As additional information about the economy is obtained, the appropriate level at which to fix the policy instrument changes. So the critical issue is not so much which variable is used as a policy instrument but how that instrument should be adjusted in light of new but imperfect information about economic developments.

Poole's basic model ignores such factors as inflation, expectations, and aggregate supply disturbances. These factors and many others have been incorporated into models examining the choice between operating procedures based on an interest rate or a monetary aggregate (e.g., see Canzoneri, Henderson, and Rogoff 1983). B. Friedman (1990) contains a useful and comprehensive survey. In addition, as Friedman stressed, the appropriate definition of the policymaker's objective function is unlikely to be simply the variance of output once inflation is included in the model. The choice of instrument is an endogenous decision of the policymaker and is therefore dependent on the objectives of monetary policy.

This dependence is highlighted in the analysis of Collard and Dellas (2005). They employed a new Keynesian model of the type studied in chapter 8 in which households optimally choose consumption and firms maximize profit subject to a restriction on the frequency with which they can change prices, as in the model of Calvo (1983).[5] Two policy rules are considered. One is a fixed growth rate for the nominal quantity of money. The second is an interest rate rule that is close to a nominal interest rate peg. The rule does allow a long-run response to inflation that slightly exceeds 1 to ensure determinacy of the rational-expectations equilibrium (see section 8.3.3). Unlike Poole's original analysis, in which an ad hoc loss function was used to evaluate policies, Collard and Dellas ranked each rule according to its effect on the welfare of the representative agent. In a calibrated version of their model, they found that the

5. Collard and Dellas included capital in their model and allowed firms to index prices to nominal growth.

relative ranking of the rules can differ from the ones obtained in Poole's analysis. For example, a fiscal policy shock acts to raise nominal interest rates, so the interest rate rule must allow the money supply to expand to prevent the nominal rate from rising. This represented a procyclical policy in Poole's framework, and made the interest rate rule less desirable than the money rule. However, in the new Keynesian and other neoclassical frameworks, a rise in government spending reduces consumption, so the interest rate rule turns out to be countercyclical with respect to consumption. By stabilizing consumption (which enters the welfare function), the interest rate rule could actually dominate the money rule for some values of the calibrated parameters. In response to a positive money demand shock, a money rule causes consumption and output to fall. However, this induces a negative correlation between consumption and leisure that can actually stabilize utility. Thus, depending on parameter values, a money rule may outperform an interest rate rule in the face of money demand shocks. Ireland (2000) evaluated a money rule and an interest rate rule estimated from post-1980 Federal Reserve behavior. He found that an estimated policy rule dominates a fixed money growth rule. The general lesson to be drawn is that the objectives used to evaluate alternative policy rules and the parameter values used to calibrate the model can be critical to the results.

11.3.2 Policy Rules and Information

The alternative policies considered in the previous section can be viewed as special cases of the following policy rule:[6]

$$b_t = \mu i_t. \tag{11.8}$$

According to (11.8), the monetary authority adjusts the base, its actual instrument, in response to interest rate movements. The parameter μ, both its sign and its magnitude, determine how the base is varied by the central bank as interest rates vary. If $\mu = 0$, then $b_t = 0$ and one has the case of a monetary base operating procedure in which b is fixed (at zero by normalization) and is not adjusted in response to interest rate movements. If $\mu = -h$, then (11.7) implies that $m_t = \omega_t$ and one has the case of a money supply operating procedure in which the base is automatically adjusted to keep m_t equal to zero on average; the actual value of m_t varies as a result of the control error ω_t. In this case, b_t is the policy instrument and m_t is the operating target. Equation (11.8) is called a *policy rule* or an *instrument rule* in that it provides a description of how the policy instrument is set.

6. Recall that constants are normalized in equations such as (11.8) to be zero. More generally, there might be a rule of the form $b_t = b_0 + \mu(i_t - \mathrm{E}i_t)$, where b_0 is a constant and $\mathrm{E}i_t$ is the expected value of i_t. Issues of price level indeterminacy can arise if the average value of b_t is not tied down (as it is in this case by b_0); see chapter 10.

Combining (11.8) with (11.1) and (11.2),

$$i_t = \frac{v_t - \omega_t + u_t}{\alpha + c + \mu + h}, \tag{11.9}$$

so that large values of μ reduce the variance of the interest rate. As $\mu \to \infty$, an interest rate operating procedure is approximated in which i_t is set equal to a fixed value (zero by normalization). By representing policy in terms of the policy rule and then characterizing policy in terms of the choice of a value for μ, one can consider intermediate cases to the extreme alternatives considered in section 11.3.1.

Substituting (11.9) into (11.1), output is given by

$$y_t = \frac{(c + \mu + h)u_t - \alpha(v_t - \omega_t)}{\alpha + c + \mu + h}.$$

From this expression, the variance of output can be calculated:

$$\sigma_y^2 = \frac{(c + \mu + h)^2\sigma_u^2 + \alpha^2(\sigma_v^2 + \sigma_\omega^2)}{(\alpha + c + \mu + h)^2}.$$

Minimizing with respect to μ, the optimal policy rule (in the sense of minimizing the variance of output) is given by

$$\mu^* = -\left[c + h - \frac{\alpha(\sigma_v^2 + \sigma_\omega^2)}{\sigma_u^2}\right]. \tag{11.10}$$

In general, neither the interest rate $(\mu \to \infty)$ nor the base $(\mu = 0)$ nor the money supply $(\mu = -h)$ operating procedures will be optimal. Instead, as Poole (1970) demonstrated, the way policy (in the form of the setting for b_t) should respond to interest rate movements will depend on the relative variances of the three underlying economic disturbances.

To understand the role these variances play, suppose first that $v \equiv \omega \equiv 0$ so that $\sigma_v^2 = \sigma_\omega^2 = 0$; there are no shifts in either money demand or money supply, given the base. In this environment, the basic Poole analysis concludes that a base rule dominates an interest rate rule. Equation (11.10) shows that the central bank should reduce b_t when the interest rate rises (i.e., $b_t = -(c + h)i_t$). With interest rate movements signaling aggregate demand shifts (since u_t is the only source of disturbance), a rise in the interest rate indicates that $u_t > 0$. A policy designed to stabilize output should reduce m_t; this decline in m_t can be achieved by reducing the base. Rather than "leaning against the wind" to offset the interest rate rise, the central bank should engage in a contractionary policy that pushes i_t up even further.

When σ_v^2 and σ_ω^2 are positive, interest rate increases may now be the result of an increase in money demand or a decrease in money supply. Since the appropriate response to a positive money demand shock or a negative money supply shock is to increase the monetary base and offset the interest rate rise (i.e., it *is* appropriate to lean against the wind), $\mu^* > -(c+h)$; it will become optimal to actually increase the base as $\sigma_v^2 + \sigma_\omega^2$ becomes sufficiently large.

The value for the policy rule parameter in (11.10) can also be interpreted in terms of a signal extraction problem faced by the policy authority. Recall that the basic assumption in the Poole analysis was that the policymaker could observe and react to the interest rate, but perhaps because of information lags, the current values of output and the underlying disturbances could not be observed. Suppose instead that the shocks u, v, and e are observed, and the central bank can respond to them. That is, suppose the policy rule could take the form $b_t = \mu_u u_t + \mu_v v_t + \mu_\omega \omega_t$ for some parameters μ_u, μ_v, and μ_ω. If this policy rule is substituted into (11.1) and (11.2), one obtains

$$y_t = \frac{(c+h+\alpha\mu_u)u_t - \alpha(1-\mu_v)v_t + \alpha(1+\mu_\omega)\omega_t}{\alpha+c+h}.$$

In this case, which corresponds to a situation of perfect information about the basic shocks, it is clear that the variance of output can be minimized if $\mu_u = -(c+h)/\alpha$, $\mu_v = 1$ and $\mu_\omega = -1$.

If the policymaker cannot observe the underlying shocks, then policy will need to be set on the basis of forecasts of these disturbances. Given the linear structure of the model and the quadratic form of the objective, the optimal policy can be written $b_t = \mu_u \hat{u}_t + \mu_v \hat{v}_t + \mu_\omega \hat{\omega}_t = -[(c+h)/\alpha]\hat{u}_t + \hat{v}_t - \hat{\omega}_t$, where $\hat{u}_t$, $\hat{v}_t$, and $\hat{\omega}_t$ are the forecasts of the shocks.[7] In the Poole framework, the central bank observes the interest rate and can set policy conditional on i_t. Thus, the forecasts of shocks will depend on i_t and will take the form $\hat{u}_t = \delta_u i_t$, $\hat{v}_t = \delta_v i_t$, and $\hat{\omega}_t = \delta_\omega i_t$. The policy rule can then be written as

$$b_t = -\left(\frac{c+h}{\alpha}\right)\hat{u}_t + \hat{v}_t - \hat{\omega}_t = \left(-\frac{c+h}{\alpha}\delta_u + \delta_v - \delta_\omega\right)i_t. \tag{11.11}$$

Using this policy rule to solve for the equilibrium interest rate, determining the $\delta_i' s$ from the assumption that forecasts are equal to the projections of the shocks on i_t, it is straightforward to verify that the coefficient on i_t in the policy rule (11.11) is equal to the value μ^* given in (11.10).[8] Thus, the optimal policy response to observed

7. The linear quadratic structure of the policy problem implies certainty equivalence holds. Under certainty equivalence, optimal policy depends only on the expected values of the disturbances.

8. See problem 5 at the end of this chapter.

interest rate movements represents an optimal response to the central bank's forecasts of the underlying economic disturbances.

11.3.3 Intermediate Targets

The previous section showed how the optimal response coefficients in the policy rule could be related to the central bank's forecast of the underlying disturbances. This interpretation of the policy rule parameter is important because it captures a very general way of thinking about policy. When the central bank faces imperfect information about the shocks to the economy, it should respond based on its best forecasts of these shocks.[9] In the present example, the only information variable available was the interest rate, so forecasts of the underlying shocks were based on i. In more general settings, information on other variables may be available on a frequent basis, and this should also be used in forecasting the sources of economic disturbances. Examples of such information variables include (besides market interest rates) exchange rates, commodity prices, and asset prices.[10]

Because the central bank must respond to partial and incomplete information about the true state of the economy, monetary policy is often formulated in practice in terms of intermediate targets. Intermediate targets are variables whose behavior provides information useful in forecasting the goal variables.[11] Deviations in the intermediate targets from their expected paths indicate a likely deviation of a goal variable from its target and signal the need for a policy adjustment. For example, if money growth, which is observed weekly, is closely related to subsequent inflation, which is observed only monthly, then faster than expected money growth signals the need to tighten policy. When action is taken to keep the intermediate target variable equal to its target, the hope is that policy will be adjusted automatically to keep the goal variables close to their targets as well.[12]

To see the role of intermediate targets in a very simple framework, consider the following aggregate supply, aggregate demand, and money demand system, expressed in terms of the rate of inflation:

9. Brainard (1967) showed that this statement is no longer true when there is uncertainty about the model parameters in additional to the additive uncertainty considered here. Parameter uncertainty may make it optimal to adjust less than completely. See section 8.4.7.

10. As discussed in chapter 1, commodity prices eliminate the price puzzle in VAR estimates of monetary policy effects because of the informational role they appear to play.

11. See Kareken, Muench, and Wallace (1973) and B. Friedman (1975; 1977b; 1990) for early treatments of the informational role of intermediate targets. More recently, Svensson (1997a; 1999b) stressed the role of inflation forecasts as an intermediate target. Bernanke and Woodford (1997) showed, however, how multiple equilibria may arise if policy is based on private sector forecasts, which are, in turn, based on expectations of future policy.

12. B. Friedman (1990) and McCallum (1990b) provided discussions of the intermediate target problem.

$$y_t = a(\pi_t - \mathrm{E}_{t-1}\pi_t) + z_t \tag{11.12}$$

$$y_t = -\alpha(i_t - \mathrm{E}_t\pi_{t+1}) + u_t \tag{11.13}$$

$$m_t - p_t = m_t - \pi_t - p_{t-1} = y_t - ci_t + v_t. \tag{11.14}$$

Equation (11.12) is a standard Lucas supply curve; (11.13) gives aggregate demand as a decreasing function of the expected real interest rate; and (11.14) is a simple money demand relationship. Assume that each of the three disturbances z, u, and v follows a first-order autoregressive process:

$$z_t = \rho_z z_{t-1} + e_t$$

$$u_t = \rho_u u_{t-1} + \varphi_t$$

$$v_t = \rho_v v_{t-1} + \psi_t,$$

where $-1 < \rho_i < 1$ for $i = z, u, v$. The innovations e, φ, and ψ are assumed to be mean zero serially and mutually uncorrelated processes. The interest rate i is taken to be the policy instrument.

Suppose that the monetary authority's objective is to minimize the expected squared deviations of the inflation rate around a target level π^*. Hence, i_t is chosen to minimize[13]

$$V = \frac{1}{2}\mathrm{E}(\pi_t - \pi^*)^2. \tag{11.15}$$

To complete the model, one must specify the information structure. Suppose that i_t must be set before observing e_t, φ_t, or ψ_t but that y_{t-1}, π_{t-1}, and m_{t-1} (and therefore p_{t-1}, z_{t-1}, u_{t-1}, and v_{t-1}) are known when i_t is set. The optimal setting for the policy instrument can be found by solving for the equilibrium price level in terms of the policy instrument and then evaluating the loss function given by (11.15).

Solving the model is simplified by recognizing that i_t will always be set to ensure that the expected value of inflation equals the target value π^*.[14] Actual inflation will

13. Note that for this example the loss function in output deviations is replaced with one involving only inflation stabilization objectives. As is clear from (11.12), stabilizing inflation to minimize unexpected movements in π is consistent with minimizing output variability if there are no supply disturbances ($z \equiv 0$). If the loss function depends on output and inflation variability and there are supply shocks, the optimal policy will depend on the relative weight placed on these two objectives.

14. The first-order condition for the optimal choice of i_t is

$$\frac{\partial V}{\partial i_t} = \mathrm{E}(\pi_t - \pi^*)\frac{\partial \pi_t}{\partial i_t} = 0,$$

implying $\mathrm{E}\pi_t = \pi^*$.

differ from π^* because policy cannot respond to offset the effects of the shocks to aggregate supply, aggregate demand, or money demand, but policy will offset any expected effects of lagged disturbances to ensure that $E_{t-1}\pi_t = E_t\pi_{t+1} = \pi^*$. Using this result, (11.12) can be used to eliminate y_t from (11.13) to yield

$$\pi_t = \frac{(a+\alpha)\pi^* - \alpha i_t + u_t - z_t}{a}. \tag{11.16}$$

Equation (11.16) shows that, under an interest rate policy, π_t is independent of v_t and the parameters of the money demand function. If the policymaker had full information on u_t and z_t, the optimal policy would be to set the interest rate equal to $i_t^* = \pi^* + (1/\alpha)(u_t - z_t)$ since this would yield $\pi_t = \pi^*$. If policy must be set prior to observing the realization of the shocks at time t, the optimal policy can be obtained by taking expectations of (11.16), conditional on time $t-1$ information, yielding the optimal setting for i_t:

$$\hat{\imath} = \pi^* + \left(\frac{1}{\alpha}\right)(\rho_u u_{t-1} - \rho_z z_{t-1}). \tag{11.17}$$

Substituting (11.17) into (11.16) shows that the actual inflation rate under this policy is equal to[15]

$$\pi_t(\hat{\imath}) = \pi^* + \frac{\varphi_t - e_t}{a}, \tag{11.18}$$

and the value of the loss function is equal to

$$V(\hat{\imath}) = \frac{1}{2}\left(\frac{1}{a}\right)^2(\sigma_\varphi^2 + \sigma_e^2),$$

where σ_x^2 denotes the variance of a random variable x.

An alternative approach to setting policy in this example would be to derive the money supply consistent with achieving the target inflation rate π^* and then to set the interest rate to achieve this level of m_t. Using (11.14) to eliminate i_t from (11.13),

$$y_t = \left(\frac{\alpha}{\alpha+c}\right)(m_t - \pi_t - p_{t-1} - v_t) + \left(\frac{c}{\alpha+c}\right)(u_t + \alpha\pi^*).$$

Using the aggregate supply relationship (11.12), the equilibrium inflation rate is

15. Note that under this policy, $E_{t-1}\pi_t = \pi^*$, as assumed.

$$\pi_t = \pi^* + \frac{1}{a}\left[\left(\frac{\alpha}{\alpha+c}\right)(m_t - \pi_t - p_{t-1} - v_t) + \left(\frac{c}{\alpha+c}\right)(u_t + \alpha\pi^*) - z_t\right]$$

$$= \frac{[a(\alpha+c)+\alpha c]\pi^* + \alpha(m_t - p_{t-1} - v_t) + cu_t - (\alpha+c)z_t}{a(\alpha+c)+\alpha}.$$

The value of m_t consistent with $\pi_t = \pi^*$ is therefore

$$m_t^* = (1-c)\pi^* + p_{t-1} - \left(\frac{c}{\alpha}\right)u_t + \left(1+\frac{c}{\alpha}\right)z_t + v_t.$$

If the money supply must be set before observing the time t shocks, the optimal target for m is

$$\hat{m}_t \equiv (1-c)\pi^* + p_{t-1} - \left(\frac{c}{\alpha}\right)\rho_u u_{t-1} + \left(1+\frac{c}{\alpha}\right)\rho_z z_{t-1} + \rho_v v_{t-1}. \tag{11.19}$$

As can be easily verified, the interest rate consistent with achieving the targeted money supply $\hat{m}_t$ is just $\hat{\imath}_t$, given by (11.17). Thus, an equivalent procedure for deriving the policy that minimizes the loss function is to first calculate the value of the money supply consistent with the target for π and then to set i equal to the value that achieves the targeted money supply.

Now suppose the policymaker can observe m_t and respond to it. Under the policy that sets i_t equal to $\hat{\imath}$, (11.14) implies that the actual money supply will equal $m_t = \pi_t(\hat{\imath}) + p_{t-1} + y_t(\hat{\imath}) - c\hat{\imath}_t + v_t$, which can be written as[16]

$$m_t(\hat{\imath}) = \hat{m}_t - \left(\frac{1}{a}\right)e_t + \left(1+\frac{1}{a}\right)\varphi_t + \psi_t. \tag{11.20}$$

Observing how m_t deviates from $\hat{m}_t$ reveals information about the shocks, and this information can be used to adjust the interest rate to keep inflation closer to target. For example, suppose aggregate demand shocks (φ) are the only source of uncertainty (i.e., $e \equiv \psi \equiv 0$). A positive aggregate demand shock ($\varphi > 0$) will, for a given nominal interest rate, increase output and inflation, both of which contribute to an increase in nominal money demand. Under a policy of keeping i fixed, the policy-

16. Substitute the solution (11.18) into the aggregate supply function to yield $y(\hat{\imath}_t) = \varphi_t - e_t + z_t = \varphi_t + \rho_z z_{t-1}$. Using this result in (11.17) and (11.18) in (11.14),

$$m(\hat{\imath}_t) = \pi^* + \frac{\varphi_t - e_t}{a} + p_{t-1} + \varphi_t + \rho_z z_{t-1} - c\hat{\imath}_t + v_t$$

$$= \pi^* + \left(\frac{\varphi_t - e_t}{a}\right) + p_{t-1} + \varphi_t + \rho_z z_{t-1} - c\left[\pi^* + \frac{\rho_u u_{t-1} - \rho_z z_{t-1}}{\alpha}\right] + v_t.$$

Collecting terms and using (11.18) yields (11.20).

maker automatically allows reserves to increase, letting m rise in response to the increased demand for money. Thus, an increase in m_t above $\hat{m}_t$ would signal that the nominal interest rate should be increased to offset the demand shock. Responding to the money supply to keep m_t equal to the targeted value $\hat{m}_t$ would achieve the ultimate goal of keeping the inflation rate equal to π^*. This is an example of an intermediate targeting policy; the nominal money supply serves as an intermediate target, and by adjusting policy to achieve the intermediate target, policy is also better able to achieve the target for the goal variable π_t.

Problems arise, however, when there are several potential sources of economic disturbances. Then it can be the case that the impact on the goal variable of a disturbance would be exacerbated by attempts to keep the intermediate target variable on target. For example, a positive realization of the money demand shock ψ_t does not require a change in i_t to maintain inflation on target.[17] But (11.20) shows that a positive money demand shock causes m_t to rise above the target value $m_t(\hat{\imath})$. Under a policy of adjusting i to keep m close to its target, the nominal interest rate would be raised, causing π to deviate from π^*. Responding to keep m on target will not produce the appropriate policy for keeping π on target.

Automatically adjusting the nominal interest rate to ensure that m_t always equals its target $\hat{m}_t$ requires that the nominal interest rate equal[18]

$$i_t^T = \hat{\imath}_t + \frac{(1+a)\varphi_t - e_t + a\psi_t}{ac + \alpha(1+a)}. \tag{11.21}$$

In this case, inflation is equal to

$$\begin{aligned}\pi_t(i_t^T) &= \pi^* + \left(\frac{1}{a}\right)[-\alpha(i_t^T - \hat{\imath}) + \varphi_t - e_t] \\ &= \pi^* + \frac{c\varphi_t - (\alpha + c)e_t - \alpha\psi_t}{ac + \alpha(1+a)}.\end{aligned}$$

Comparing this expression for inflation to $\pi_t(\hat{\imath}_t)$ from (11.18), the value obtained when information on the money supply is not used, one can see that the impact of an aggregate demand shock, φ, on the price level is reduced to $(c/[ac + \alpha(1+a)] < 1/a)$; because a positive φ shock tends to raise money demand, the interest rate must be increased to offset the effects on the money supply to keep m on target. This inter-

17. Equation (11.18) shows that inflation is independent of v_t.

18. Note that this discussion does not assume that the realizations of the individual disturbances can be observed by the policymaker; as long as m_t is observed, i_t can be adjusted to ensure that $m_t = \hat{m}_t$, and this results in i being given by (11.21). Equation (11.21) is obtained by solving (11.12)–(11.14) for m_t as a function of i_t and the various disturbances. Setting this expression equal to $\hat{m}_t$ yields the required value of i_t^T.

est rate increase acts to offset partially the impact of a demand shock on inflation. The impact of an aggregate supply shock (e) under an intermediate money targeting policy is also decreased. However, money demand shocks, ψ, now affect inflation, something they did not do under a policy of keeping i equal to $\hat{\imath}$; a positive ψ tends to increase m above target. If i is increased to offset this shock, inflation will fall below target.

The value of the loss function under the money targeting procedure is

$$V(i_t^T) = \frac{1}{2}\left(\frac{1}{ac + \alpha(1+a)}\right)^2 [c^2\sigma_\varphi^2 + (\alpha + c)^2\sigma_e^2 + \alpha^2\sigma_\psi^2].$$

Comparing this to $V(\hat{\imath})$, the improvement from employing an intermediate targeting procedure in which the policy instrument is adjusted to keep the money supply on target will be decreasing in the variance of money demand shocks, σ_ψ^2. As long as this variance is not too large, the intermediate targeting procedure will do better than a policy of simply keeping the nominal rate equal to $\hat{\imath}$. If this variance is too large, the intermediate targeting procedure will do worse.

An intermediate targeting procedure represents a rule for adjusting the policy instrument to a specific linear combination of the new information contained in movements of the intermediate target. Using (11.20) and (11.21), the policy adjustment can be written as

$$\begin{aligned} i_t^T - \hat{\imath} &= \left[\frac{a}{ac + \alpha(1+a)}\right][m_t(\hat{\imath}) - \hat{m}] \\ &= \mu^T[m_t(\hat{\imath}) - \hat{m}]. \end{aligned}$$

In other words, if the money supply realized under the initial policy setting $(m_t(\hat{\imath}))$ deviates from its expected level $(\hat{m})$, the policy instrument is adjusted. Because the money supply will deviate from target due to φ and e shocks, which do call for a policy adjustment, as well as ψ shocks, which do not call for any change in policy, an *optimal* adjustment to the new information in money supply movements would depend on the relative likelihood that movements in m are caused by the various possible shocks. An intermediate targeting rule, by adjusting to deviations of money from target in a manner that does not take into account whether fluctuations in m are more likely to be due to φ or e or ψ shocks, represents an inefficient use of the information in m.

To derive the optimal policy response to fluctuations in the nominal money supply, let

$$\begin{aligned} i_t - \hat{\imath} &= \mu(m_t - \hat{m}) \\ &= \mu x_t, \end{aligned} \tag{11.22}$$

where $x_t = (1 + a^{-1})\varphi_t - a^{-1}e_t + \psi_t$ is the new information obtained from observing m_t.[19] Under an intermediate targeting rule, the monetary authority would adjust its policy instrument to minimize deviations of the intermediate target from the value consistent with achieving the ultimate policy target, in this case an inflation rate of π^*. But under a policy that optimally uses the information in the intermediate target variable, μ will be chosen to minimize $\mathrm{E}(\pi_t - \pi^*)^2$, not $\mathrm{E}(m_t - \hat{m})^2$. Using (11.22) in (11.16), one finds that the value of μ that minimizes the loss function is

$$\mu^* = \frac{1}{\alpha}\left[\frac{a(1+a)\sigma_\varphi^2 + a\sigma_e^2}{(1+a)^2\sigma_\varphi^2 + \sigma_e^2 + a^2\sigma_\psi^2}\right].$$

This is a messy expression, but some intuition for it can be gained by recognizing that if the policymaker could observe the underlying shocks, (11.16) implies that the optimal policy would set the nominal interest rate i equal to $\hat{\imath} + (1/\alpha)(\varphi_t - e_t)$. The policymaker cannot observe φ_t or e_t, but information that can be used to estimate them is available from observing the deviation of money from its target. As already shown, observing m_t provides information on the linear combination of the underlying shocks given by x_t. Letting $\mathrm{E}^x[\ ]$ denote expectations conditional on x, the policy instrument should be adjusted according to

$$i(x_t) = \hat{\imath} + \frac{1}{\alpha}(\mathrm{E}^x\varphi_t - \mathrm{E}^x e_t). \tag{11.23}$$

Evaluating these expectations gives

$$\mathrm{E}^x\varphi_t = \left[\frac{a(1+a)\sigma_\varphi^2}{(1+a)^2\sigma_\varphi^2 + \sigma_e^2 + a^2\sigma_\psi^2}\right]x_t$$

19. The expression for x_t is obtained by solving (11.12)–(11.14) for m_t as a function of the interest rate, yielding

$$m_t = \pi_t + p_{t-1} + y_t - ci_t + v_t = \left[\pi^* + \frac{y_t - z_t}{a}\right] + p_{t-1} + y_t - ci_t + v_t,$$

or

$$m_t = \left[\pi^* + \frac{-\alpha i_t + \alpha\pi^* + u_t - z_t}{a}\right] + p_{t-1} + [-\alpha i_t + \alpha\pi^* + u_t] - ci_t + v_t$$

$$= (1 + \alpha(1 + a^{-1}))\pi^* + p_{t-1} - (c + \alpha(1 + a^{-1}))i_t - a^{-1}z_t + (1 + a^{-1})u_t + v_t,$$

so that, conditional on i_t,

$$m_t - \mathrm{E}_{t-1}m_t = -a^{-1}e_t + (1 + a^{-1})\varphi_t + \psi_t \equiv x_t.$$

and

$$\mathrm{E}^x e_t = \left[\frac{-a\sigma_e^2}{(1+a)^2\sigma_\varphi^2 + \sigma_e^2 + a^2\sigma_\psi^2}\right] x_t.$$

Substituting these expressions into (11.23) yields

$$\begin{aligned} i(z_t) &= \hat{\imath} + \left(\frac{1}{\alpha}\right)\left[\frac{a(1+a)\sigma_\varphi^2 + a\sigma_e^2}{(1+a)^2\sigma_\varphi^2 + \sigma_e^2 + a^2\sigma_\psi^2}\right] x_t \\ &= \hat{\imath} + \mu^* x_t. \end{aligned}$$

Under this policy, the information in the intermediate target is used optimally. As a result, the loss function is reduced relative to a policy that adjusts i to keep the money supply always equal to its target:

$$V^* \leq V(i^T),$$

where V^* is the loss function under the policy that adjusts i according to $\mu^* z_t$.

As long as money demand shocks are not too large, an intermediate targeting procedure does better than following a policy rule that fails to respond at all to new information. The intermediate targeting rule does worse, however, than a rule that optimally responds to the new information. This point was first made by Kareken, Muench, and Wallace (1973) and B. Friedman (1975).

Despite the general inefficiency of intermediate targeting procedures, central banks often implement policy as if they were following an intermediate targeting procedure. During the 1970s, there was strong support in the United States for using money growth as an intermediate target. Support faded in the 1980s, when money demand because significantly more difficult to predict.[20] The Bundesbank (prior to being superseded by the European Central Bank) and the Swiss National Bank continued to formulate policy in terms of money growth rates that can be interpreted as intermediate targets, and money formed one of the pillars in the two-pillar strategy of the European Central Bank.[21] Other central banks seem to use the nominal exchange rate as an intermediate target. Today, many central banks have shifted to using inflation itself as an intermediate target.

20. B. Friedman and Kuttner (1996) examined the behavior of the Fed during the era of monetary targeting.

21. Laubach and Posen (1997) argued that the targets were used to signal policy intentions rather than serving as strict intermediate targets. See Beck and Wieland (2007) on the role of money in the ECB's strategy.

Intermediate targets provide a simple framework for responding automatically to economic disturbances. The model of this section can be used to evaluate desirable properties that characterize good intermediate targets. The critical condition is that σ_ψ^2 be small. Since ψ_t represents the innovation or shock to the money demand equation, intermediate monetary targeting will work best if money demand is relatively predictable. Often this has not been the case. The unpredictability of money demand is an important reason that most central banks moved away from using monetary targeting during the 1980s. The shock ψ can also be interpreted as arising from control errors. For example, assuming that the monetary base was the policy instrument, unpredictable fluctuations in the link between the base and the monetary aggregate being targeted (corresponding to the ω disturbance in 11.7) would reduce the value of an intermediate targeting procedure. Controllability is therefore a desirable property of an intermediate target.

Lags in the relationship between the policy instrument, the intermediate target, and the final goal variable represent an additional important consideration. The presence of lags introduces no new fundamental issues; as the simple framework shows, targeting an intermediate variable allows policy to respond to new information, either because the intermediate target variable is observed contemporaneously (as in the example) or because it helps to forecast future values of the goal variable. In either case, adjusting policy to achieve the intermediate target forces policy to respond to new information is a manner that is generally suboptimal. But this inefficiency will be smaller if the intermediate target is relatively easily controllable (i.e., σ_ψ^2 is small) yet is highly correlated with the variable of ultimate interest (i.e., σ_φ^2 and σ_e^2 are large), so that a deviation of the intermediate variable from its target provides a clear signal that the goal variable has deviated from its target. For central banks that target inflation, the inflation forecast serves as an intermediate target. An efficient forecast is based on all available information and should be highly correlated with the variable of ultimate interest (future inflation). Svensson and Woodford (2005) discussed the implementation of optimal policies through the use of inflation forecasts.

11.3.4 Real Effects of Operating Procedures

The traditional analysis of operating procedures focuses on volatility; the operating procedure adopted by the central bank affects the way disturbances influence the variability of output, prices, real interest rates, and monetary aggregates. The average values of these variables, however, is treated as independent of the choice of operating procedure. Canzoneri and Dellas (1998) showed that the choice of procedure can have a sizable effect on the average level of the real rate of interest by affecting the variability of aggregate consumption.

The standard Euler condition relates the current marginal utility of consumption to the expected real return and the future marginal utility of consumption:

$$u_c(c_t) = \beta R_{ft} \mathrm{E}_t u_c(c_{t+1}),$$

where β is the discount factor, R_{ft} is the gross risk-free real rate of return, and $u_c(c_t)$ is the marginal utility of consumption at time t. The right side of this expression can be written as

$$\beta R_{ft} \mathrm{E}_t u_c(c_{t+1}) \approx \beta R_{ft} u_c(\mathrm{E}_t c_{t+1}) + \frac{1}{2} \beta R_{ft} u_{ccc}(\mathrm{E}_t c_{t+1}) \ \mathrm{Var}_t(c_{t+1}),$$

where u_{ccc} is the third derivative of the utility function and $\mathrm{Var}_t(c_{t+1})$ is the conditional variance of c_{t+1}. If the variance of consumption differs under alternative monetary policy operating procedures, then either the marginal utility of consumption must adjust (i.e., consumption will change) or the risk-free real return must change. Because the expected real interest rate can be expressed as the sum of the risk-free rate and a risk premium, average real interest rates will be affected if the central bank's operating procedure affects R_{ft} or the risk premium.

Canzoneri and Dellas developed a general equilibrium model with nominal wage rigidity and simulated the model under alternative operating procedures (interest rate targeting, money targeting, and nominal income targeting). They found that real interest rates, on average, are highest under a nominal interest rate targeting procedure. To understand why, suppose the economy is subject to money demand shocks. Under a procedure that fixes the nominal money supply, such shocks induce a positive correlation between consumption (output) and inflation. This generates a negative risk premium (when consumption is lower than expected, the ex post real return is high because inflation is lower than expected). A nominal interest rate procedure accommodates money demand shocks and so results in a higher average risk premium. By calibrating their model and conducting simulations, Canzoneri and Dellas concluded that the choice of operating procedure can have a significant effect on average real interest rates.

11.4 Operating Procedures and Policy Measures

Understanding a central bank's operating procedures is important for two reasons. First, it is important in empirical work to distinguish between endogenous responses to developments in the economy and exogenous shifts in policy. Whether movements in a monetary aggregate or a short-term interest rate are predominantly endogenous responses to disturbances unrelated to policy shifts or are exogenous shifts in policy will depend on the nature of the procedures used to implement policy. Thus, some understanding of operating procedures is required for empirical investigations of the impact of monetary policy.