Optimal Monetary Policy in an Economy with Sticky Nominal Wages

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While there is a consensus that monetary policy must be conducted within a framework in which people are confident of a low long-run inflation rate, there is little agreement on how the Federal Reserve ought to allow prices to respond to shocks over the near term. This article shows that the optimal monetary policy rule has the Federal Reserve target a geometric weighted average of output and the price level.

More than thirty-five years ago, Milton Friedman initiated an intense "rules versus discretion" debate by calling for the Federal Reserve to maintain constant growth of the money supply (Friedman 1959). The focus of this early debate was on whether an active monetary policy or a passive monetary policy is more successful at stabilizing output. Over the years, the debate has continued, but its terms have shifted.

First, large swings in the velocities of the monetary aggregates have led many economists to turn away from Friedman's constant-money-growth prescription, toward policy rules that are more directly concerned with output and prices.

Second, in a very real sense the debate is no longer over "rules *versus* discretion" but "*which* rule?" It's now taken for granted that the monetary authority follows a rule of *some* kind—albeit a rule that may not be clearly articulated and that may shift in response to changes in the composition of the authority's councils or changes in policymakers' understanding of how the economy operates. The behaviors of private agents are conditioned on how they expect the monetary authority to react to future shocks to the economy (Lucas 1976). Consequently, future policy choices cannot be treated as exogenous.

Finally, there is increased recognition that in monetary affairs—as in so many other areas of life—expedient policies are rarely the best policies. Moreover, to obtain a socially optimal outcome today may require that policymakers find a way to convince the private sector that shortsighted policies will not be pursued in the future (Barro and Gordon 1983, Kydland and Prescott 1977). In particular, the experience of the 1970s has led to a consensus that the private sector must never be given grounds for doubting the Federal Reserve's commitment to long-run price stability.

While there is a consensus that monetary policy must be conducted within a framework in which people are confident of a low long-run inflation rate, there is little agreement on how the Federal Reserve ought to allow prices to respond to shocks over the near term. This article attempts to shed light on the short-run stabilization issue within the context of an economy subject to productivity shocks, with sticky nominal wages. The article shows that the optimal monetary policy rule in such an economy has the Federal Reserve target a geometric weighted average of output and the price level. In a realistic special case, the monetary authority should target nominal spending.

The analysis is subject to a number of limitations. The model economy is not subject to any disturbances other than aggregate productivity shocks. There is no attempt to explicitly model the adverse effects of inflation. Nor does the article model how the Federal Reserve would actually go about implementing alternative policy rules. In the real world, some rules may have fewer informational requirements than others or may imply less extreme movements in policy instruments. Implementation errors are likely to be smaller for such rules, enhancing their performance.

This article has implications that extend beyond the short-run stabilization issue. Thus, this article illustrates that real-business-cycle models may accurately describe the historical behavior of an economy and yet be a poor guide to policy. That a large fraction of the business cycle can be attributed to supply shocks may mean not that monetary policy is ineffective but that the Federal Reserve has been doing its job. More generally, neither monetary policy nor private contracts should be analyzed in isolation. Policies optimal under one system of private contracts may perform poorly under a different system. Conversely, the performance of a given system of private contracts may be sensitive to the policy rule adopted by the monetary authority.

A simple model of aggregate supply

This section analyzes output determination and optimal monetary policy in a competitive economy subject to aggregate productivity shocks.[1] Initially, all prices are assumed to be perfectly flexible, so that markets clear instantaneously from period to period. In such an economy, monetary policy is irrelevant to short-run output determination. The monetary authority is, therefore, free to focus exclusively on maintaining price stability. Next, the money wage rate is assumed to be set one period in advance, introducing the possibility that output may deviate from its market-clearing level in response to unexpected shifts in the production function. Since the money wage rate fails to react to supply shocks in this economy, the burden of doing so falls on the monetary authority. The optimal policy rule has the monetary authority target a geometric weighted average of output and the price level. Insofar as the monetary authority is successful in implementing the optimal rule, the real economy will behave as if the money wage rate is perfectly flexible.

Aggregate supply with flexible prices. Profit maximization implies that the representative competitive firm will hire labor up to the point where the marginal product of labor equals the real wage:

$$MP_N = W/P, \tag{1}$$

where N denotes hours of work. Suppose, in particular, that output is produced according to the function

$$Y = \Theta N^{1-\beta}/(1-\beta), \tag{2}$$

where Y is output, $0 < \beta < 1$ is a fixed parameter, and Θ is a random productivity shock. Equation 1 is then equivalent to

$$\theta - \beta n = w - p, \tag{1'}$$

where lowercase letters represent logarithms of their uppercase counterparts. The demand for labor is an increasing function of the productivity shock and a decreasing function of the real wage. For any given level of hours, a doubling of Θ doubles the marginal product of labor and, so, doubles the real wage.

Utility maximization implies that the representative household will supply labor up to the point where the marginal rate of substitution between leisure and consumption equals the real wage. Equivalently, each household will supply labor up to the point where minus the marginal rate of substitution between *labor* and consumption equals the real wage:

$$-MRS_{N,C} = W/P. \tag{3}$$

If the representative household's utility function takes the form

$$U(C,N) = (C^{1-\alpha} - 1)/(1-\alpha) - N^{1+\lambda}/(1+\lambda),$$

where C is consumption and $\alpha > 0$ and $\lambda > 0$ are fixed parameters, then equation 3 is equivalent to

$$\lambda n + \alpha c = w - p. \tag{3'}$$

The supply of labor is increasing in the real wage and decreasing in consumption.

To close the model, take logarithms of equation 2:

$$y = (1-\beta)n + \theta - \ln(1-\beta), \tag{2'}$$

and assume that all output is consumed, so that y can be substituted for c in equation 3′.

The market-clearing values of output, the real wage, and labor are obtained by simultaneously solving equations 1′, 2′, and 3′:

$$(4)\qquad y^* = A\left[(1+\lambda)\theta - (\beta+\lambda)\ln(1-\beta)\right],$$

$$(5)\qquad (w-p)^* = A\left[(\alpha+\lambda)\theta - \alpha\beta\ln(1-\beta)\right],$$

and

$$(6)\qquad n^* = A\left[(1-\alpha)\theta + \alpha\ln(1-\beta)\right],$$

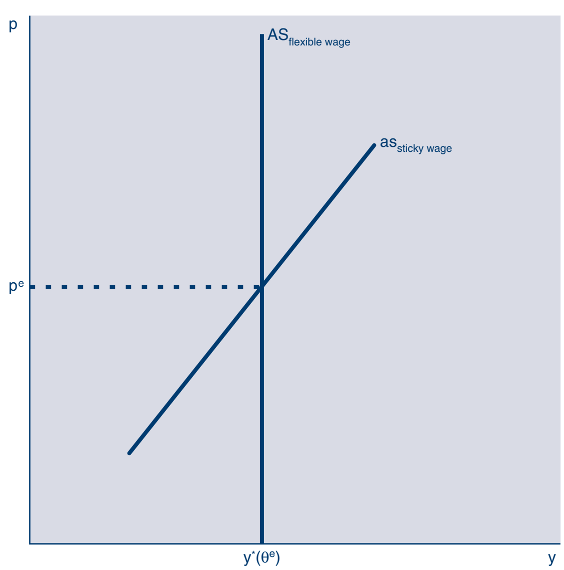
where $A \equiv [\alpha + \beta(1-\alpha) + \lambda]^{-1}$. Equations 4 and 5 say that a positive productivity shock (an increase in θ) raises equilibrium output and the equilibrium real wage. The impact on equilibrium hours of work is ambiguous. The higher real wage that accompanies an increase in productivity tends to increase the supply of labor. This substitution effect is opposed, however, by a negative wealth effect: as output becomes more readily available, people are less willing to work at any given wage. In the real world, hours of work per person have changed relatively little despite large productivity gains. This observation suggests that $\alpha \approx 1$. If $\alpha = 1$, the substitution and wealth effects of an increase in productivity cancel. Equilibrium output and the equilibrium real wage rise one-for-one with θ, while equilibrium hours are constant.

Regardless of the value of α, in a market-clearing economy the evolution of output is independent of the evolution of the price level.

Figure 1

Aggregate Supply in Sticky-Wage and Flexible-Wage Economies

The aggregate supply curve is vertical when the money wage is flexible and upward sloping when the money wage is predetermined.



Since there is no short-run trade-off between output stability and price stability, the monetary authority can concentrate its efforts on achieving the latter.

Aggregate supply with a predetermined money wage. Predetermined nominal wages are an oft-studied source of monetary nonneutrality.[2] Moreover, the existence of meaningful nominal wage rigidities is consistent with several recent empirical studies (Card 1990, Cho 1993, Cho and Cooley 1992, McLaughlin 1994). Accordingly, the remainder of this article assumes that the money wage rate is set, one period in advance, at its expected market-clearing level and that firms have discretionary control over hours of work at the preset wage.[3] From equation 5, the money wage will equal

$$(7)\qquad w = p^e + A\left[(\alpha+\lambda)\theta^e - \alpha\beta\ln(1-\beta)\right],$$

where an e superscript indicates an expected value conditioned on information available in the immediately preceding period.

With the money wage set as above, the representative firm's profit maximization condition (equation 1′) implies that hours of work are given by

$$(8)\qquad n = n^* + \frac{1}{\beta}\left[\left(p-p^e\right) + \left(\alpha+\lambda\right)A\left(\theta-\theta^e\right)\right].$$

Substituting into the production function (equation 2′), one obtains a formula for output:

$$(9)\quad y = y^* + \left[\frac{1-\beta}{\beta}\right]\left[\left(p-p^e\right) + \left(\alpha+\lambda\right)A\left(\theta-\theta^e\right)\right].$$

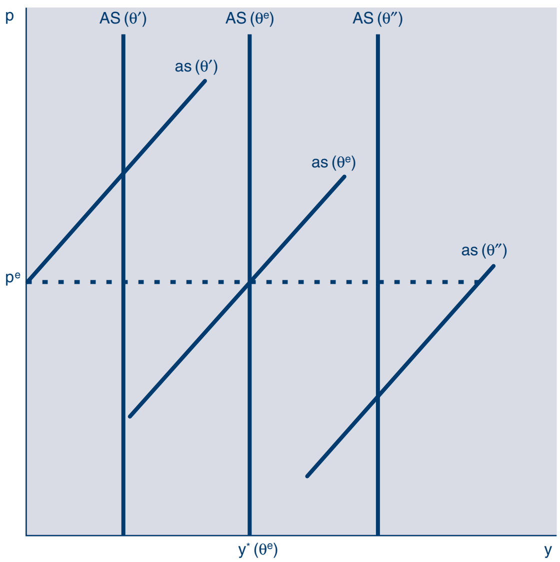
Output and employment deviate from their market-clearing levels to the extent that the output price or productivity deviates from values expected at the time the wage rate was set.

The intuition behind these results is straightforward. Consider, first, an unexpected increase in the price of output. For any given productivity realization, a surprise price increase lowers the real wage. Firms move down along their labor demand schedules, hiring more labor (and expanding production) as the real wage falls.[4]

Similarly, an increase in productivity causes firms' labor demand schedules to shift upward. In a market-clearing economy, the positive impact that this upward shift would otherwise have had on equilibrium hours is partially offset by an increase in the wage rate as households move out along their labor supply schedules. When the money wage is predetermined, this offset can occur only insofar as the productivity increase was expected. (Compare equation 5, which ap-

Figure 2
The Response of Aggregate Supply To Productivity Shocks

Holding the price level fixed at its expected value, the sticky-wage aggregate supply curve shifts farther in response to productivity shocks than does the flexible-wage aggregate supply curve.



plies to the market-clearing case, with equation 7.) Consequently, surprise increases in productivity have a larger positive impact on employment and output than do anticipated increases.

Graphically, the aggregate supply curve in a flexible-wage economy is vertical at y^*. In contrast, the aggregate supply curve in an economy with predetermined wages is upward sloping. Figure 1 depicts the case where $\theta = \theta^e$.

Although both aggregate supply curves shift to the right in response to a positive unanticipated productivity shock, the sticky-wage aggregate supply schedule shifts more. Similarly, a negative unanticipated productivity shock causes a larger leftward shift in the sticky-wage aggregate supply curve than in the flexible-wage aggregate supply curve (*Figure 2*).

Optimal policy. Competitive allocations are efficient. Consequently, policymakers will want to keep the sticky-wage economy as close to the market-clearing allocation as possible. However, the market-clearing levels of output and hours are not, in general, directly observable. Fortunately, this problem can be circumvented.

Consider a graphical representation of the monetary authority's problem. Figure 3, like Figure 2, plots three aggregate supply curves, one for the case in which $\theta = \theta' < \theta^e$, one for the case in which $\theta = \theta^e$, and one for the case in which $\theta = \theta'' > \theta^e$. The corresponding market-clearing output levels are denoted $y^*(\theta')$, $y^*(\theta^e)$, and $y^*(\theta'')$, respectively. The monetary authority would like the economy to end up at point A $\equiv [y^*(\theta'), p']$ in the first case, point B $\equiv [y^*(\theta^e), p^e]$ in the second case, and point C $\equiv [y^*(\theta''), p'']$ in the third case. More generally, the monetary authority would like to restrict the economy to the line passing through points A, B, and C. Everywhere along this line, $y = y^*$.

From equation 4, as θ rises from θ^e to θ'', the market-clearing output level rises by

$$y^*(\theta'') - y^*(\theta^e) = (1+\lambda)A(\theta'' - \theta^e).$$

From equation 9, the price level changes by

$$p'' - p^e = -(\alpha+\lambda)A(\theta'' - \theta^e).$$

Therefore, the line connecting points B and C has a slope of $-(\alpha + \lambda)/(1 + \lambda)$, and the equation of the line passing through points A, B, and C can be written

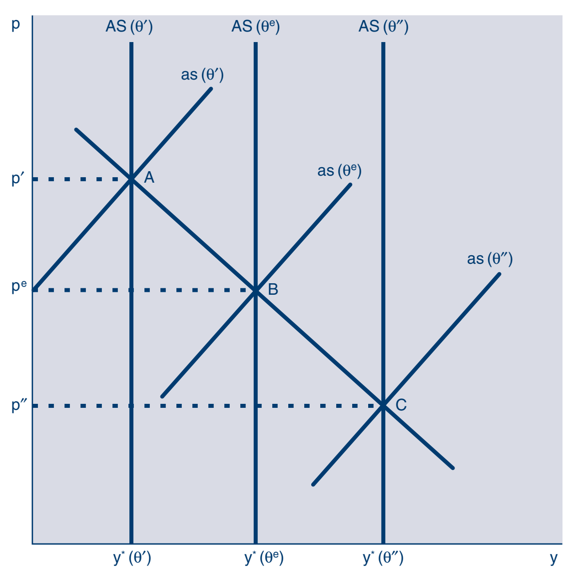
$$(p - p^e) = -\left[\frac{\alpha+\lambda}{1+\lambda}\right](y - y^e)$$

or, equivalently,

$$p + \left[\frac{\alpha+\lambda}{1+\lambda}\right]y = p^e + \left[\frac{\alpha+\lambda}{1+\lambda}\right]y^e. \tag{10}$$

Figure 3
Optimal Monetary Policy

In a sticky-wage economy, optimal monetary policy calls for the price level to fall as output rises.



Thus, for the monetary authority to guarantee that period-t output is optimal regardless of the value of θ_t, it is necessary and sufficient that the authority adjust its policy instruments so as to set

$$p_t + \left[\frac{\alpha+\lambda}{1+\lambda}\right] y_t = s_t, \tag{11}$$

where s_t is an arbitrary preannounced target. In the special case where the market-clearing level of employment is invariant with respect to productivity shocks ($\alpha = 1$), equation 11 reduces to a nominal spending target:[5]

$$p_t + y_t = s_t. \tag{11'}$$

Imperfect Implementation of Optimal Policy

There is only a loose connection between variables that are directly affected by Federal Reserve actions (bank reserves and the federal funds rate) and the variables that enter the optimal policy rule: aggregate output and the aggregate price level. Consequently, the Federal Reserve cannot be expected to maintain the relationship displayed in equation 11 exactly. The unanticipated component of the error that the Federal Reserve makes in trying to implement equation 11 plays the role of an aggregate demand shock in the model economy.

To see this, let δ denote the current-period policy implementation error. That is, suppose that equation 11 is replaced by

$$p + \left[\frac{\alpha+\lambda}{1+\lambda}\right] y = s + \delta,$$

where, as before, s is a preannounced target. This equation can be solved for p and substituted back into equations 8 and 9, yielding (after a little manipulation)

$$n - n^e = \left[\frac{1}{\alpha+\beta(1-\alpha)+\lambda}\right]\left[(1+\lambda)\,(\delta-\delta^e) + (1-\alpha)\,(\theta-\theta^e)\right]$$

$$y - y^e = \left[\frac{1+\lambda}{\alpha+\beta(1-\alpha)+\lambda}\right]\left[(1-\beta)\,(\delta-\delta^e) + (\theta-\theta^e)\right].$$

Hours respond positively to unanticipated policy implementation errors and ambiguously to productivity shocks.[1] Output responds positively to both unanticipated implementation errors and productivity surprises. Hence, the presence of implementation errors increases the chances that hours of work will vary procyclically. This effect is most obvious in the case where $\alpha = 1$ and is especially likely in the case where unanticipated implementation errors ($\delta - \delta^e$) are positively correlated with aggregate productivity shocks ($\theta - \theta^e$).

Substitute from the output equation back into the policy rule to obtain

$$p - p^e = \left[\frac{1}{\alpha+\beta(1-\alpha)+\lambda}\right]\left[\beta(1+\lambda)\,(\delta-\delta^e) - (\alpha+\lambda)\,(\theta-\theta^e)\right].$$

Thus, the price level responds responds positively to unanticipated implementation errors and negatively to aggregate productivity shocks. The real wage, of course, moves exactly opposite to the price level.

[1] As a technical matter, the anticipated component of the implementation error can always be folded into the preannounced target, s. That is, one can—without loss of generality—assume $\delta^e \equiv 0$.

Note that the optimal policy rule does not require that the monetary authority observe the realized values of productivity disturbances.

Insofar as the monetary authority is successful in implementing a policy rule of the form given in equation 11, it will appear that business-cycle fluctuations can be entirely attributed to aggregate productivity shocks—and this will, indeed, be the case.[6] However, it would be incorrect to use this observation as a basis for concluding that monetary policy is ineffective or unimportant.

The analysis presented above also illustrates a more general point: monetary policy and private contracting arrangements should be analyzed as a package. Clearly, optimal monetary policy depends upon private contracting arrangements. In the example above, the policy rule given in equation 11 would not be optimal (or even feasible) in an economy where it was the price level rather than the wage rate that was sticky.[7] Perhaps less obviously, private agents may rely upon the monetary authority to pursue policies that make complicated contingent contracts unnecessary.

Alternative versions of the optimal policy rule

We have seen that the optimal policy rule in a sticky-wage economy has the general form $p_t + ay_t = s_t$ (compare equation 11). No restrictions are placed on the price–output target, s_t, except for the requirement that it be announced one period in advance.[8] This section shows that a number of prominent proposed policy rules also have this general form. Some of these rules are nevertheless suboptimal, because they put too little weight on output. Other rules are optimal only under certain conditions.

Price-level and inflation targeting. Under a price-level target, s_t is a constant (or, more generally, a deterministic function of time), and a is set equal to 0. Under an inflation target, a is again set equal to 0, but s_t is defined to equal p_{t-1} (or p_{t-1} plus a constant).

Although the price-level and inflation targeting rules have the same *general* form as the optimal policy rule, they are not themselves optimal because they put zero weight on short-run output stabilization. In Figure 3, the price-level and inflation targeting rules would confine the economy to a horizontal line through point B, rather than the downward sloping line through points A and C. Consequently, output fluctuates too much in response to productivity shocks under these rules.

More formally, if strictly adhered to, the price-level and inflation targeting rules imply that there are no price surprises: $p_t = p_t^e$. But equation 9 tells us that in a sticky-wage economy, price surprises must partially offset productivity surprises if the economy is to achieve the market-clearing allocation.

The Hall and Taylor output-gap rules. Robert Hall (1984) and John Taylor (1985) have proposed that the Federal Reserve adopt a policy rule of the form

$$(p_t - p_t^T) + a(y_t - y_t^T) = 0,$$

where p_t^T and y_t^T are a target price level and target output level, respectively, and where $a > 0$. Rearranging terms to obtain

$$p_t + ay_t = p_t^T + ay_t^T, \tag{12}$$

we see that the Hall and Taylor rules will have the same form as the optimal rule derived here provided that p_t^T and y_t^T are known one period in advance. Full optimality also requires that $a = (\alpha + \lambda)/(1 + \lambda)$.

In Hall's analysis, the price target is a constant. In Taylor's analysis, $p_t^T = p_{t-1}$. In either case, the price target is known as of period $t - 1$. Both analyses assume that the output gap, $(y_t - y_t^T)$, is stationary. Therefore, target output and actual output must have a common permanent component. If y_t is stationary about a deterministic trend, it is natural to set target output equal to trend output. The right-hand side of equation 12 will be known as of period $t - 1$. Consequently, the Hall and Taylor rules will have the optimal form. If output's permanent component is a random walk with drift, the situation is a little more complicated. It will not do to set y_t^T equal to current-period permanent income, because period-t permanent income is stochastic from the perspective of period $t-1$. However, it would be consistent with optimality to set y_t^T equal to the *previous* period's permanent income plus a constant equal to the drift in permanent income.

Nominal income level and nominal income growth rules. The simplest versions of the optimal policy rule set s_t equal to a deterministic function of time or equal to $(p_{t-1} + ay_{t-1})$ plus a constant. In particular, if output growth varies about a well-defined long-run mean, $E(\Delta y)$, then setting s_t equal to $aE(\Delta y)t + s_0$ or equal to $aE(\Delta y) + (p_{t-1} + ay_{t-1})$—where $a = (\alpha + \lambda)/(1 + \lambda)$—will yield a policy rule that is optimal and that yields a zero long-run average rate of inflation. In the special case where $\alpha = 1$ (so that also $a = 1$), these definitions yield a nominal GDP level rule and a nominal GDP growth rule, respectively.

Discussion. How is it that so many seemingly very different rules can all be optimal? What matters for short-run stabilization purposes is only the relationship between *unexpected* price and output changes. Equation 11, which defines the optimal policy rule, leaves entirely open how this period's *expected* price level should depend upon past realizations of output and prices. Differences between rules along this dimension may have important implications for the distribution of wealth, particularly if debt contracts are specified in nominal terms. Additionally, some versions of the optimal rule may be easier than others for the monetary authority to implement. Such considerations are outside the scope of this article.

Summary and concluding remarks

Output and employment tend to be too responsive to aggregate productivity shocks in sticky-wage economies. Monetary policy can offset this tendency by allowing the price level to fall when output is high and allowing the price level to rise when output is low. Under optimal monetary policy, the economy responds to productivity shocks exactly as it would in a flexible-wage economy. Thus, despite a preset money wage, there are no $20 bills lying on the sidewalk: there is no loss of economic efficiency.

The optimal policy is sufficiently general in form to encompass several well-known policy proposals, including those of Robert Hall and John Taylor. In the realistic special case in which the market-clearing level of employment is independent of productivity, it is optimal for the monetary authority to target nominal spending.

It is, of course, possible that private contracts would adapt if the monetary authority insisted upon pursuing some policy other than that optimal in a sticky-wage economy.[9] The process of adaptation would likely take some time, however, and might never be complete. To minimize transition costs, a monetary authority choosing to implement some policy other than that optimal under current contracting arrangements would need to announce its intentions well in advance.

The particular modeling framework used in this article is unrealistic in its simplicity, and the details of the optimal policy rule derived here are sensitive to changes in model specification. However, minor changes in the model are unlikely to affect the article's principal conclusions:

1. In a sticky-wage economy, the Federal Reserve has a short-run output stabilization role to play.
2. Several variants of a given rule may have identical short-term stabilization properties. Consequently, in choosing between variants, distributional considerations and differences in ease of implementation will likely prove decisive.
3. The fraction of output variation that can be attributed to aggregate productivity shocks conveys little useful information about the importance or effectiveness of monetary policy.
4. The performance of a given system of private contracts is sensitive to the policy rule adopted by the monetary authority. Conversely, policies optimal under one system of private contracts may perform poorly under a different system. Thus, neither monetary policy nor private contracts should be analyzed in isolation.

Notes

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[1] The analysis extends Bean (1983) to the case where labor supply is derived explicitly from utility maximization—an extension that has important implications for the circumstances under which targeting nominal spending is optimal.

[2] See, for example, Fischer (1977), Gray (1978), and Taylor (1980).

[3] Perhaps relocation costs are negligible if workers switch jobs one period in advance and prohibitive otherwise. Then the labor market will be competitive ex ante and monopsonistic ex post. Workers will insist that some of the terms of their employment be spelled out in advance. Presetting the nominal wage, while giving firms control of hours, is an approach that is often observed in practice (Card 1990). The assumption that the wage is set equal to its expected market-clearing level is standard in the literature. In the model developed here, this assumption implies no loss of efficiency.

[4] If monetary-policy-induced price surprises were the primary driving force behind macroeconomic fluctuations, it would follow that the real wage ought to be countercyclical. Since the real wage is not, in fact, countercyclical, economists with strong priors that monetary policy drives the macroeconomy have in recent years tended to favor models of price stickiness over models of wage stickiness. See, for example, Ball and Mankiw (1994).

[5] In contrast, Bean (1983) finds that a nominal spending target is optimal only if labor is inelastically supplied—a problematic assumption when firms are given short-run control of hours. In general, a nominal spending target is optimal only if n^* is independent of productivity shocks. Because Bean uses an ad hoc labor supply function that lacks a wealth effect, the only way that he can make n^* independent of θ is by making the supply of labor independent of the real wage. In the model developed here, in contrast, n^* is independent of θ whenever $\alpha = 1$ (compare equation 6).

[6] The box entitled "Imperfect Implementation of Optimal Policy" discusses the behavior of the economy when the optimal policy is implemented with error.

[7] For discussion of optimal policy in an economy with sticky output prices, see Ireland (1994).

[8] More precisely, the target must be announced early enough that all labor contracts will be renegotiated before the target becomes binding. The real-world counterpart to "one period" is, thus, probably one to three years.

[9] This point is not new. According to Fischer (1977, 204), "An attempt by the monetary authority to exploit the existing structure of contracts to produce behavior far different from that envisaged when contracts were signed would likely lead to the reopening of the contracts and, if the new behavior of the monetary authority were persisted in, a new structure of contracts."

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