

Commentary

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Woodford concludes his review of what the theoretical literature on optimal monetary policy has to say about the desirability of price stability with the following statement: “It is not a bad first approximation to say that the goal of monetary policy should be price stability.” It follows from this conclusion that the findings of the theoretical literature on optimal monetary policy can be interpreted as supportive of inflation targeting. However, it does not imply that there should be a single target variable—namely, inflation. Optimal policy, as Woodford explains, can only under quite special circumstances be described solely in terms of the behavior of inflation.

Woodford argues that even when full price stability fails to be optimal, near price stabilization is optimal in many cases. In particular, Woodford discusses that near stabilization of an appropriately defined price index continues to be optimal (i) in environments where negative real rates in combination with the zero bound on the nominal interest rate make a path of zero inflation impossible, (ii) in environments where asymmetric shocks require relative price changes, (iii) in sticky-wage models, and (iv) even in cases where the flexible-price equilibrium is not efficient, due to the presence of (possibly time-varying) market power or distorting taxes.

I would like to expand on this discussion and add to the list of environments in which near price stability is optimal. Also, I would like to give some more specific examples. Most of the theoretical work Woodford surveys uses dynamic, stochastic general equilibrium models that contain some specific simplifying assumption that make it possible to accurately characterize optimal policy using only linear approximations to the model and that allow for an analytical characterization of optimal policy. Absent those simplifying assumptions, one would have to use higher-order approximations to the equilibrium conditions for welfare calculations. Recent advances

in computational economics have delivered algorithms that make it feasible and simple to compute higher-order approximations to the equilibrium conditions of a general class of large stochastic dynamic general equilibrium models (see, for instance, Sims, 2000, and Schmitt-Grohé and Uribe, 2004a). Several authors have applied this toolkit to studying the welfare consequences of monetary policy in environments without the special assumption needed to make the linear approach work. And I will report findings on the desirability of price stability from this more numerically oriented branch of the literature.

Academic economists in the past have not always arrived at the conclusion that price stability should be a central objective of monetary policy. In particular, many of the theoretical environments that were used to study optimal policy in the 1980s assumed that there are no impediments to instantaneous adjustment of factor and product prices. In such environments, price stability in the sense of a constant price level over time does not in general represent the optimal monetary policy prescription. Rather, under optimal monetary policy, prices move over time in such a way as to eliminate the opportunity cost of holding money, that is, optimal policy follows the Friedman rule. The opportunity cost of holding money is the nominal interest rate, and, thus, optimal monetary policy calls for a constant and zero nominal interest rate. With nominal interest rates constant, prices move in response to changes in real interest rates, and fall on average at the real rate of interest.

In addition, Chari, Christiano, and Kehoe (1991) show that in a world in which the Friedman rule is optimal, optimal monetary policy is associated with high inflation volatility. In Chari, Christiano, and Kehoe, the reason why inflation is highly volatile under the optimal policy is that the government is using surprise inflation as a non-distorting fiscal

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Table 1**Desirability of Price Stability in an Optimal Monetary and Fiscal Policy Problem**

Variable	Mean	Standard deviation	Autocorrelation
Flexible-price economy			
π	-3.66	6.04	-0.04
R	0	0	—
Sticky-price economy			
π	-0.16	0.17	0.04
R	3.85	0.56	0.87

NOTE: Inflation, π , and the nominal interest rate, R , are expressed in percentage points.

SOURCE: Schmitt-Grohé and Uribe (2004b).

instrument. Specifically, it is assumed that the government can levy distortionary income taxes and can issue nominal non-state-contingent debt. In financing innovations to its budget, the government can therefore either adjust distortionary income taxes or adjust real public liabilities through an appropriate price level change. In the theoretical environment of Chari, Christiano, and Kehoe surprise changes in the price level are non-distorting, whereas changes in the tax rates are distorting. As a consequence, the optimal fiscal and monetary policy mix calls for stable tax rates and highly volatile inflation rates.

Clearly, this branch of the theoretical literature is at odds with the goal of price stability. In the mid-1990s, rigidities in product and factor price adjustment found renewed attention in monetary economics. Under sticky prices, both the predictions about the optimal level and the volatility of inflation may change. First, authors such as Goodfriend and King (1997) showed that in simple models with price stickiness but no money, the optimal inflation rate is zero at all times and under all circumstances. Khan, King, and Wolman (2003) show that if one is to introduce money into the sticky-price model, a tension arises between nominal interest rate stabilization at zero—to minimize the distortions associated with money—and the sticky-price friction, which calls for constant prices at all times and under all circumstances. Khan, King, and Wolman show that for realistic calibrations of their model, the optimal level of inflation is just -76 basis points.

(In their calibration, the Friedman rule would call for inflation of -293 basis points and, absent the monetary distortion, optimal policy is associated with zero inflation.) That is, the optimal long-run inflation rate is not that different from the one that is optimal in a sticky-price model without money.

Schmitt-Grohé and Uribe (2004b) study optimal monetary and fiscal policy in a model with (i) sticky prices, (ii) money demand, (iii) distortionary taxation, and (iv) a fiscal role for price level variations. In that economy, as in the work of Chari, Christiano, and Kehoe (1991), price level variations are desirable because they allow the fiscal authority to finance surprises in its budget by inflating or deflating the real value of government debt rather than via changes in distortionary income tax rates. Therefore, there exist additional reasons to deviate from price stability beyond those present in Khan, King, and Wolman.

Yet, for a model calibrated to the U.S. economy, Schmitt-Grohé and Uribe (2004b) find that under the Ramsey policy, the mean of inflation and its standard deviation is close to zero. As shown in Table 1, in the sticky-price economy, the Ramsey optimal mean rate of inflation is only -0.16 percent and the optimal inflation volatility 0.17 percent. By contrast, under fully flexible prices, the mean inflation rate is -3.66 percent and the standard deviation of inflation is 6.04 percentage points.

Furthermore, Schmitt-Grohé and Uribe (2004b) show that the inflation-volatility tax-rate-volatility trade-off is resolved in favor of inflation stability not only for degrees of price stickiness observed in the U.S. economy, but also for much lesser degrees of price stickiness. This point is illustrated in Figure 1, which shows on the horizontal axis the degree of price stickiness as measured by a parameter θ . When prices are perfectly flexible, then the parameter θ is equal to zero. As the parameter θ increases, prices become more sticky. The value of price stickiness estimated for the U.S. economy is 4.4. The graph shows that even for a degree of price stickiness ten times smaller than the value estimated for the post-war U.S. economy, the optimal inflation volatility is below 1 percent per year. These findings are further support for Woodford's conclusion that, in most existing work, price stability should be the central goal of optimal monetary policy.

This conclusion is based on evidence that relies exclusively on models without an accumulable factor of production. Next, I discuss some evidence on the desirability of price stability in models where

physical capital is a factor of production and can be accumulated. The basic elements of the model with capital accumulation are, as in the one discussed above, that money facilitates purchases of goods, product markets are monopolistically competitive, the government must finance a stochastic stream of public consumption either with lump-sum or income taxes, and prices are sticky à la Calvo (1983). The production technology is described by some homogenous-of-degree-one function and is subject to shocks to total factor productivity ($z_t F(K_t, H_t)$). The evolution of capital is given by $K_{t+1} = (1 - \delta) K_t + I_t$. In Schmitt-Grohé and Uribe (2003), we compute welfare in that economy under a number of alternative monetary and fiscal policy arrangements. One of the policies considered is one in which the inflation rate is held forever constant. We refer to that policy as inflation targeting. We compute the welfare consequences for the various rules under the assumption that business cycles are driven by government purchases and total factor productivity shocks. We calibrate the model to the U.S. economy.

We consider monetary policy rules of the type

$$(1) \hat{R}_t = \alpha_R \hat{R}_{t-1} + \alpha_\pi \hat{\pi}_{t-j} + \alpha_y \hat{y}_{t-j}, \quad \text{for } j = -1, 0, +1,$$

where a hat over a variable indicates log-deviations from its non-stochastic steady-state value and

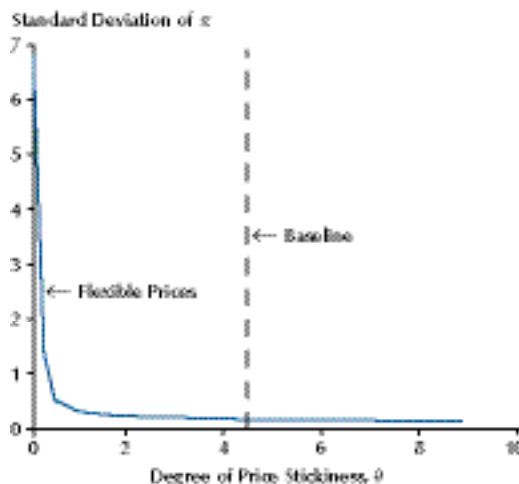
$$(2) \hat{R}_t = \hat{R}_{t-1} + \alpha_\pi \hat{\pi}_t + \alpha_y \ln y_t / y_{t-1}.$$

The variable measuring the output gap here is \hat{y}_t , which denotes the deviations of output from the non-stochastic steady state. Related studies typically use a different measure of the output gap—namely, one that measures the log-difference between the actual level of output and the one that would obtain in a model without price-adjustment frictions. (This is what Woodford refers to as the properly defined real stabilization objective.) Note that this is not simply the difference of output from a linear time trend, rather this is a highly sophisticated concept. To be able to estimate that output gap, one needs to know what the current realizations of the shocks are and one has to know exactly where the nominal frictions lie and how to compute the flexible-price equilibrium.

The advantage of the interest rate feedback rule given in equation (2) is that it puts even fewer informational requirements on the monetary authority. To implement this rule, all the central bank needs to know are the current values of output and inflation, the past value of the nominal interest rate and output,

Figure 1

Degree of Price Stickiness and Optimal Inflation Volatility



NOTE: The baseline value of θ is 4.4. The standard deviation is measured in percent per year.
SOURCE: Schmitt-Grohé and Uribe (2004b).

and the central bank's inflation target, π^* . The inflation target is needed to compute $\hat{\pi}_t$. Note that this rule does not require knowledge of the non-stochastic steady state; in particular, it is not necessary to know the non-stochastic steady-state value of output or the nominal interest rate.

For each case that we consider, we find that the highest level of welfare is attained under a policy of inflation targeting—that is, when the central bank conducts policy in such a way that in equilibrium the inflation rate is equal to its non-stochastic steady-state value at all times. This finding suggests that even in models with capital, money, and distorting taxes (but flexible wages), price stabilization should be the overriding goal of policy. Table 2 illustrates this point for the case that all taxes are lump-sum and the economy is cashless. Similar results hold for the monetary economy and in the presence of distorting taxes. Inflation targeting yields at least as much welfare as any of the optimized rules considered. Thus it provides further evidence that inflation stability is desirable.

The table suggests two other interesting results. One is that it is optimal not to respond to output. This is reflected in the fact that the optimal response coefficient on output is zero in almost all cases. The second is that the welfare differences

Table 1

Desirability of Price Stability in a Model with Capital Accumulation

	α_π	α_y	α_R	Welfare	Welfare cost
I. Monetary policy: $\hat{R}_t = \alpha_\pi \hat{\pi}_{t-i} + \alpha_y \hat{y}_{t-i} + \alpha_R \hat{R}_{t-1}$					
Smoothing					
Current-looking ($i = 0$)	3	0	0.9	-628.2180	0
Backward-looking ($i = 1$)	3	0	2.8	-628.2207	0.0004
Forward-looking ($i = -1$)	3	0	-2.3	-628.8657	0.0886
No smoothing					
Current-looking ($i = 0$)	3	0	—	-628.2193	0.0002
Backward-looking ($i = 1$)	3	-1.2	—	-629.2988	0.1477
Forward-looking ($i = -1$)	The equilibrium is indeterminate				
II. Monetary policy: $\hat{R}_t - \hat{R}_{t-1} = \alpha_\pi \hat{\pi}_t + \alpha_y [\hat{y}_t - \hat{y}_{t-1}]$					
	3	0	—	-628.2180	≈0
III. Monetary policy: inflation targeting $\hat{\pi}_t = 0$					
				-628.2175	-0.00007

NOTE: (i) R_t denotes the gross nominal interest rate, π_t denotes the gross inflation rate, and y_t denotes output. (ii) For any variable x_t , its non-stochastic steady-state value is denoted by x , and its log-deviation from steady state by $\hat{x}_t \equiv \ln(x_t/x)$. (iii) In all cases, the parameters α_π , α_y , and α_R are restricted to lie in the interval $[-3, 3]$. (iv) Welfare is defined as follows: Let $V(s_t)$ denote the equilibrium level of lifetime utility of the representative household in period t given that period's state s_t . Then welfare is defined as $V(s)$. (v) The welfare cost is relative to the optimal current-looking rule with smoothing and is defined as the percentage decrease in the consumption process associated with the optimal rule necessary to make the level of welfare under the optimized rule identical to that under the alternative policy considered. Thus, a positive figure indicates that welfare is higher under the optimized rule than under the alternative policy considered. (vi) Computations are based on a second-order approximation.

SOURCE: Schmitt-Grohé and Uribe (2003).

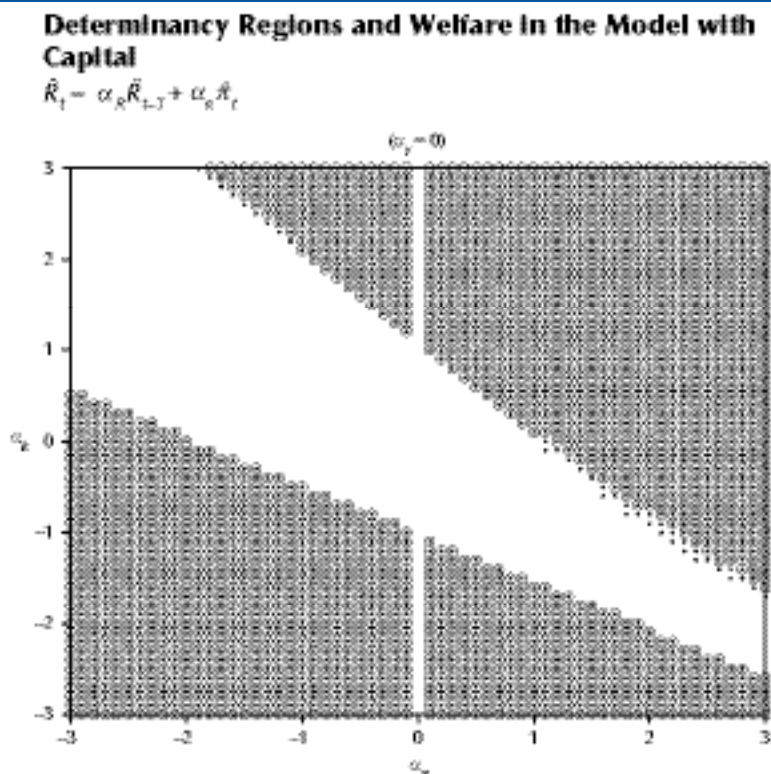
between the various optimized rules and inflation targeting are negligible from a welfare point of view as long as the central bank has the option to smooth interest rates over time.

The second point raises an interesting issue. Clearly, one would like to know what the optimal monetary policy is. But, at the same time, it is also important to gauge how costly it would be to pursue a policy that is not the optimal one but something that one could realistically implement in practice. For example, the optimal policy prescription presented by Woodford in the appendix (drawing on Giannoni and Woodford, forthcoming) is based on an estimated model with wage and price stickiness. Consequently, one would expect the optimal policy to be quite complex, and indeed so it is. Its characterization involves not only current values but also infinite-lead polynomials of wages, prices, and a sophisticated output gap measure. So it is natural to ask how much of a quantitative difference it would make in terms

of welfare to follow this optimal policy prescription as opposed to a much simpler one. In addition, it would be useful to know whether it is important to get the response coefficients exactly right or whether there exists a large family of rules that are associated with welfare levels that are very close to the level of welfare associated with the optimum. These are quantitative questions that are necessarily model specific.

As a first pass on this question, I will present some numerical results from the economy studied in Schmitt-Grohé and Uribe (2003) described above. In that particular framework there may be very little difference between a large number of monetary policies that the central bank can follow. The economy of Schmitt-Grohé and Uribe (2003) differs from the Giannoni and Woodford economy in several dimensions. Our model features capital accumulation, whereas the Giannoni and Woodford economy does not. On the other hand, the Giannoni and

Figure 2



NOTE: A dot represents a parameter combination for which the equilibrium is determinate. A circle denotes that the welfare cost of the policy relative to the optimized rule (i.e., $\alpha_\pi = 3$, $\alpha_R = 0$, and $\alpha_R = 0.9$) is less than 0.05 percent.
SOURCE: Schmitt-Grohé and Uribe (2003).

Woodford framework features habit formation, sticky wages (which is an important difference, as it makes price stabilization less desirable), and some decision lags that make that framework match estimated empirical impulse responses. Ours is not an estimated model.

Figure 2 shows regions of the interest rate feedback rule coefficients α_R and α_π introduced in equation (1) for which the welfare cost of following that policy (as opposed to the optimized rule) is at most 5 one-hundredths of 1 percent of the consumption stream associated with the optimized rule. In these computations the output response coefficient is held constant at zero ($\alpha_y = 0$). The graph shows that the region of parameters for which the equilibrium is unique is virtually the same as the region for which the welfare costs are below 5 basis points. This suggests that from a welfare point of view, it does not really matter to which values the central banks sets

the response coefficients in the interest rate feedback rule as long as they render the equilibrium determinate. Similar results hold for the feedback rule given in equation (2), with α_y equal to its optimized value of zero (see Schmitt-Grohé and Uribe, 2003).

My last comment concerns the implementation of inflation targeting. In particular, one interesting issue is whether the emphasis on price stability that comes out of the theoretical literature on optimal monetary policy implies that interest rates should respond little to output measures. Suppose the central bank chooses to implement its policy objectives by following a feedback rule for the short-term nominal interest rate that it controls. The results presented in Table 2 indicate that the optimal response coefficient on the output gap should be zero, where the output gap is defined as the log-deviation of output from steady state. As we show in Schmitt-Grohé and Uribe (2003), the welfare losses

from choosing a non-zero coefficient on output can be large. We find values in excess of one-tenth of 1 percent of the stream of consumption associated with the optimized rule.¹ The argument that responding to output can lead to relatively sizeable welfare losses has been criticized on the grounds that the output measure used in the monetary policy rule is “not the right one.” The argument goes that, were one instead to use an output gap measure based on the difference between actual output and the output that would arise in a world without nominal frictions, then the welfare losses from responding to output in the feedback rule would be much smaller.

In practice the central bank may not be able to construct this sophisticated output gap measure and will instead use a simple measure that is much more akin to log deviations from a constant trend. Furthermore, one can show that if the output gap is interpreted as the difference of the quarterly output growth rate from some constant, then welfare losses associated with responding to that measure of output are small as well. Under such a rule it is still optimal not to respond to output (see the second panel of Table 2). However, Schmitt-Grohé and Uribe (2003) show that the welfare differences between a zero output coefficient and an output coefficient between -3 and 3 is at most 0.03 percentage points of the consumption stream associated with the best feedback rule. This welfare loss is relatively small.

These findings suggest that when implementing inflation targeting through interest rate feedback rules it may suffice to respond to variations in inflation alone. Second, a reason for policymakers to abstain from responding to output variations is that such behavior may have significant welfare consequences if the policymaker does not have the proper output gap measure. It is important to keep in mind that the optimal policy behavior advocated here does not have stabilization of inflation as its ultimate objective, but instead the maximization of welfare. Thus, even though the implementation of the optimal policy takes the form of a rule that responds little

to variations in the level of aggregate activity, this does not imply that the reasons for adopting this policy are that the policymaker does not fully internalize the welfare consequences of output fluctuations. One caveat is that these recommendations stem from an analysis in which factor prices are assumed to be fully flexible. It remains to be shown in future work how large the welfare costs or benefits of responding to output are in a world with sluggish factor price adjustments.

REFERENCES

- Calvo, Guillermo A. “Staggered Prices in a Utility-Maximizing Framework.” *Journal of Monetary Economics*, 1983, 12(3), pp. 383-98.
- Chari, Varadarajan V.; Christiano, Lawrence and Kehoe, Patrick J. “Optimal Fiscal and Monetary Policy: Some Recent Results.” *Journal of Money, Credit, and Banking*, August 1991, 23(3, Part 2), pp. 519-39.
- Giannoni, Marc P. and Woodford, Michael. “Optimal Inflation Targeting Rules,” in Ben S. Bernanke and Michael Woodford, eds., *The Inflation Targeting Debate*. Chicago: University of Chicago Press (forthcoming).
- Goodfriend, Marvin and King, Robert G. The New Neoclassical Synthesis and the Role of Monetary Policy,” in Ben S. Bernanke and Julio J. Rotemberg, eds., *NBER Macroeconomics Annual 1997*. Cambridge, MA: MIT Press, 1997, pp. 231-83.
- Khan, Aubhik; King, Robert G. and Wolman, Alexander. “Optimal Monetary Policy.” *Review of Economic Studies*, October 2003, 70, pp. 825-60.
- Rotemberg, Julio J. and Woodford, Michael. “An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy,” in Ben S. Bernanke and Julio J. Rotemberg, eds., *NBER Macroeconomics Annual 1997*. Cambridge, MA: MIT Press, 1997, pp. 297-346.
- Schmitt-Grohé, Stephanie and Uribe, Martín. “Simple Optimal Implementable Monetary and Fiscal Policy.” Unpublished manuscript, Duke University, October 2003.
- Schmitt-Grohé, Stephanie and Uribe, Martín. “Solving Dynamic General Equilibrium Models Using a Second-Order Approximation to the Policy Function.” *Journal of Economic Dynamics and Control*, January 2004a, 28(4), pp. 755-75.

¹ In a simple model in which complete inflation stabilization is optimal, Rotemberg and Woodford (1997, Table 2) report the value of a loss function that is a linear transformation of the unconditional expectation of the utility function for various values of the feedback rule coefficients α_x and α_y . For example, for values of $\alpha_x = 1.5$ and $\alpha_y = 0.5$, the loss function is 8.72, whereas for $\alpha_x = 10$ and $\alpha_y = 0$, it is only 0.93. These numbers suggest that not responding to output is desirable and that higher output response coefficients are associated with lower unconditional welfare. However, from those numbers one cannot tell whether the welfare losses would be large or small in terms of units of consumption.

Schmitt-Grohé, Stephanie and Uribe, Martín. "Optimal Fiscal and Monetary Policy Under Sticky Prices." *Journal of Economic Theory*, February 2004b, 114(2), pp. 198-230.

Sims, Christopher A. "Notes on the GYNSYS2 Packet."
Unpublished manuscript, Princeton University, 2000.

