Feedback Rules for Inflation Control: An Overview of Recent Literature

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- *This article provides an overview of the considerable body of research done in recent years on policy rules. These are rules aimed at guiding central banks as they deal with the problem of how best to keep inflation close to a desired path without creating excess variability elsewhere in the economy.*
- *The authors describe the most popular types of feedback rules—the Taylor rule and the inflation-forecast-based rule—and review some simulation results.*

The success of industrial countries in reducing inflation, together with the adoption of formal inflation-control targets by a growing number of central banks, has generated considerable interest in "feedback rules" for inflation targeting. These rules link short-term interest rates controlled by the central bank to the rate of inflation and / or its deviation from the targeted rate. The last few years have seen a sizable amount of research devoted to assessing the performance of feedback rules.

Rules cannot and should not be followed mechanically by policy-makers.

One should note at the outset that most contributors to the literature on feedback rules seem to accept the notion that rules cannot and should not be followed mechanically by policy-makers. In this sense, policy rules are seen as a guide around which discretion should be used. Economists contributing to this research assume that central banks have a target for the inflation rate, whether explicit, as in Canada, or implicit. One challenge for inflation targeting is that while monetary policy affects the inflation rate with a lag, the economy is constantly subjected to shocks, the nature and duration of which are unknown when policy is implemented. In this context, the studies examine how feedback rules for the policy instrument may help keep inflation close to its target without creating undue variability in other economic variables, especially output and interest rates.

The main questions addressed in the studies reviewed relate to the kind of rule that a central bank should use to guide its decisions. Should the rule be simple or complex? Which variables, if any, should be included in addition to the inflation rate? Should the central bank act slowly or aggressively in response to these variables? Should it respond to current information only or to a forecast? One major issue is whether the central bank is better off using an "optimal" rule derived from its main model, or a "robust" rule that provides reasonable results across a variety of models or circumstances. Economists have attempted to answer these questions by conducting historical studies, developing theoretical models and, most often, by carrying out simulation studies using macroeconomic models.

This article provides an overview of the recent literature on feedback rules. It is not meant to be a comprehensive survey of the numerous articles written on the topic, but rather, the purpose is to give a general idea of the major issues and findings. We begin with a discussion of how the literature interprets the problems faced by central bankers and how policy rules are offered as a solution. This is followed by a description of the most popular types of feedback rules and a review of some simulation results.

Analytical Framework

Policy objectives

To assess what type of rule is best suited to guide the conduct of policy, one must develop criteria with which to evaluate the rule's performance. There is a fairly broad consensus in the literature that a policy rule should be judged on how close it keeps inflation around its target, and how effectively it dampens fluctuations in output (or unemployment). The models used in this literature assume that, in the long run, monetary policy affects only the price level so that it makes no sense for monetary policy to target the level or growth rate of output or the level of unemployment.[1] But in the short run, the assumption of market imperfections (typically, sticky prices) implies that monetary policy also affects real output. So, in the short run, it is assumed that monetary policy should aim at stabilizing inflation around its long-run target and output around its sustainable rate. This characterization of policy objectives appears consistent with the way inflation-targeting countries currently operate and with the view that the ultimate goal of monetary policy is an economy with stable paths for both inflation and output.

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Many studies also assume that interest rate stability is an additional criterion that should be used to evaluate the performance of alternative policy rules. Some researchers include this criterion in recognition of the fact that model relationships could break down if policy requires changes in interest rates that are outside the range of historical experience. Mishkin (1999) argues that interest rate smoothing should be considered for two reasons: (i) it helps maintain the central bank's reputation—reversing course frequently can reduce confidence in the central bank's competence and therefore reduce the credibility and effectiveness of policy; and (ii) it reduces the risks of financial instability since interest rate instability can be a source of financial fragility. Another argument, formalized by Woodford (1999), is that by adopting a policy of moving interest rates gradually, in a series of small steps in the same direction, the central bank provides clearer signals to the market than if it was reversing course frequently. By doing so, central bank actions have a greater effect on long-term interest rates and therefore on aggregate demand decisions.

Given the foregoing arguments, the policy-maker's preferences are often formalized in terms of a loss function. The function identifies which targets are deemed important by the policy-makers and indicates the relative weights attached to those variables. For ease of solution, most studies specify a static loss function of the following type:

$$L = a \cdot (y_t - y_t^*)^2 + b \cdot (\Pi_t - \Pi^*)^2 + c \cdot (i_t - i_{t-1})^2 , \quad (1)$$

1. It is, nevertheless, increasingly recognized that, in the real world, low inflation improves the functioning of the economy over time.

where y_t is the level of output in period t, y^* is potential output, Π is the inflation rate, Π^* is the target inflation rate, and i is the nominal interest rate.[2] The relative weights assigned to the various objectives (the parameters a, b, and c) are positively related to the costliness of these factors. Unfortunately, there is very little theoretical analysis on this topic. For this reason, most researchers experiment with alternative values for the parameters in the loss function.[3] The loss function is a highly simplified representation of the central bank's objectives. Notice that the deviations of the variables from their "targets" are squared. This implies that larger deviations are relatively more costly than small deviations. The quadratic form also implies that the central bank is equally averse to misses on both sides of the targets under all circumstances.

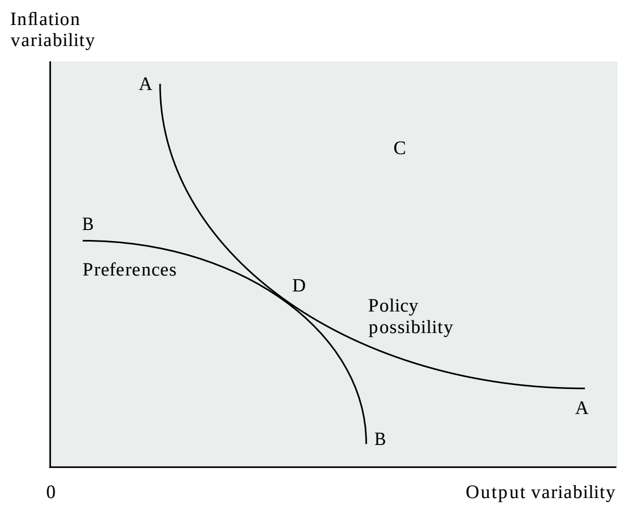
From policy objective to policy rule

A policy rule is a formula linking the policy instrument to specified economic conditions. In current central bank practice, the instrument is usually a short-term interest rate.[4] In linear models, once the loss function is specified, the optimal control problem can be solved analytically to determine the optimal policy rule. The optimal rule will be the rule that minimizes the loss function under constraints describing the structure of the economy, which are embodied in a model.

Models can vary greatly in level of complexity and detail but, typically, they reflect the following aspects of the transmission mechanism. A change in interest rates first causes a change in aggregate demand and then, later on, a change in inflation, since the latter depends on the discrepancy between actual and potential output (output gap). When the economy is hit by a demand shock, the monetary authority's response will help stabilize both the output gap and inflation, so that there is not really a trade-off between inflation and output variability arising from these shocks. Consider a reduction in consumption spending that causes output to fall below potential and therefore leads to inflation falling below target. In response to this negative demand shock, the central bank lowers interest rates, which helps return both inflation and output to their targeted levels. In contrast, if the economy gets hit by an inflation shock, the monetary authority faces a short-run trade-off between output and inflation variability. As an example, consider an energy shortage that pushes inflation above its target. To bring inflation back down, interest rates must be increased. This will not immediately lower inflation, however, but instead will first cause output to fall below potential. It is this negative output gap that will reduce inflation. Trying to push inflation back to its target rapidly may result in large variations in output around potential and, in extreme cases, may lead to instrument instability.[5] On the other hand, trying to prevent output from moving significantly could lead to continuous and excessive deviations of inflation from the target (Fuhrer 1997).

Chart 1

Trade-Off Between Inflation and Output Variability



For a given model of the economy, one can trace a curve like the AA curve shown in Chart 1, which can

2. In dynamic models, the monetary authority is viewed as minimizing the discounted present value of the current and expected future losses.

3. Svensson (1996) suggests that a central bank with limited experience with inflation targeting may want to place a high weight on inflation relative to other variables so that inflation targets are closely adhered to and credibility is enhanced. McCallum (1993) and Poole (1999) argue that the performance of rules should be judged primarily by the rate of inflation because the short-run impact of policy on the real economy is uncertain. McCallum also notes that the objective of actual policy appears to be dominated by a desire for output (or employment) to be high and inflation to be low. Output above normal is avoided not because it is itself considered undesirable, but because of the fear that it will lead to increased inflation in the future.

4. A notable exception is McCallum (1988) who proposed a simple rule linking the monetary base to developments in nominal income.

5. Because interest rates affect inflation with a lag, a change in interest rates calculated to bring inflation back to target very quickly can conceivably push inflation further off the other side of the target, requiring a larger change in interest rates in the other direction. This can set off a seesaw pattern in interest rates that becomes explosive.

be thought of as a menu of output-price variability choices for the authorities (a policy possibility frontier). The shape and location of this curve are a function of, among other things, the price-setting structure of the economy, with more flexible markets moving the curve closer to the origin. Clearly, the best outcome for the economy is at the origin, where inflation is always on target and output is at potential. But in an economy subject to shocks, this outcome is not feasible. The curve AA is the minimum attainable combination of inflation and output variability. A point like C is not optimal because there are many points closer to the origin with less variability in both output and inflation. However, once the curve AA is achieved, less inflation variability can be achieved only at the cost of higher output variability. The optimal policy is represented by the point of tangency (point D) between the preferences of the authorities (the indifference curve BB) and the possibility frontier.[6]

The variables in the optimal rule need not be the same as those in the loss function. Typically, the optimal rule will include more variables than appear in the loss function since, in most circumstances, the optimal rule depends on all the economic variables that affect the target variables. The more complicated the model, the more model-specific and complicated the optimal rule will be. For example, in an open economy, foreign variables or the exchange rate may enter the policy rule because they affect the outcome for output and inflation. The coefficients in the optimal policy rule are linked in a precise manner to the underlying structure of the economy and to the weights the central bank places on its various objectives.

As noted above, providing the model is not too complex, the optimal rule can be derived analytically (see the Box on page 48 for an example). Alternatively, researchers have made increasing use of stochastic simulations to find an approximation of the optimal rule. Stochastic simulations involve subjecting the model to an array of random shocks similar to those that have been observed over a historical period or representative of those that are likely to prevail in the future. This allows the distribution of target variables under various rules or other model assumptions to be calculated. The best rule is then determined as the one that provides the best economic performance under specific assumptions about the weights in the loss function.

Complications arising from uncertainty

The above analysis ignores the fact that when making decisions on interest rates, policy-makers are confronted with various sources of uncertainty. They are uncertain about the current state of the economy because information on many variables is available only with a lag and is subject to revision. In addition, some key concepts like potential output are measured very imprecisely. Policy-makers are uncertain about the nature and persistence of the shocks they currently face or will face in the future. They are also uncertain about the parameter values linking variables in their model, including the effect of their own policy actions ("long and variable" lags). More basically, they are uncertain about the specification of the economy (how best to characterize the overall model).

In linear models with quadratic preferences, uncertainty about the state of the economy and the shocks (additive uncertainty) does not change optimal policy. This result is referred to as "certainty-equivalence." Other sources of uncertainty, however, may lead to an optimal policy response that is more muted than it would be in a world of certainty. In a seminal article, Brainard (1967) explains that the presence of uncertainty about the interest sensitivity of the economy will cause the policy-maker to move the policy instrument by smaller magnitudes than would be the case with certainty. However, little can be said about the impact on optimal policy response if there is uncertainty about all, or most, parameters in the model. In general, Brainard-type parameter uncertainty induces the policy-maker to attempt to minimize the deviations in the variables to which the uncertain coefficient is attached.[7] For example, uncertainty about the effect of inflation surprises on future inflation would lead the policy-maker to respond to inflation shocks *more* sharply, not less, in order to minimize deviations of

6. The problem is more complex when the loss function includes more than two objectives. For example, if the central bank has a three-fold objective including interest rate stability, there will typically be a trade-off between the variability of inflation, the variability of output, and the variability of interest rates. Note also that the trade-off curves are not necessarily as smooth as represented in Chart 1.

7. This is because the larger the change in the variable concerned, the greater the uncertainty about the effect of that variable on the economy (in other words, the larger is the variance of outcomes). Parameter uncertainty introduces a trade-off between setting the instrument to get as near as possible to the desired value of the target variables and increasing the prospective variance of the target variables because of the uncertainty about the relationship between the instrument and the target. Some have argued that in an intertemporal framework, it may be optimal for a monetary authority to experiment because such experimentation reveals information about how the economy works and speeds up the learning process. Wieland (1998) finds that the optimal policy that balances the cautionary and activist motives is typically less aggressive than a policy that ignores parameter uncertainty. There are exceptions, however, when the degree of uncertainty is very high and inflation is close to target.

inflation from target.[8] So, in this example, the policy response would be more aggressive than in the certainty case.

To deal with model uncertainty, a number of economists, most notably McCallum (1988), have recommended that policy-makers search for policy rules that are robust, in the sense of yielding reasonably desirable outcomes in policy simulation experiments in a wide variety of models. At a recent conference on policy rules, Sargent (1999) and Stock (1999) discussed the results of some ongoing work on approaches to robustness vis-à-vis model uncertainty. One approach would be to use a linear combination of the optimal policy rules (each one accounting for parameter uncertainty) derived from competing models. However, Stock argues that these calculations require an unrealistic amount of information. An alternative that both promote is to evaluate policies by their worst-case performance across the various models considered. The rationale here is that by planning against the worst, the policy-maker assures acceptable performance under a range of specification errors. From this perspective, the best policy is the policy that has the lowest maximum risk across models. A main conclusion of their work is that caution induced by a preference for robustness does not necessarily translate into "doing less."

Model uncertainty greatly complicates the problem of finding a good monetary policy rule. Robustness across models has generated considerable interest in "simple" rules, that is, rules that include only a few variables. The intuition here is that simple rules are less likely to be model-specific than complicated rules. It is also often argued that simple rules are more advantageous for policy-makers because they are more easily understood and therefore more conducive to building and maintaining policy credibility. Obviously, this last argument does not carry as much weight if policy-makers do not follow the rules very closely.

The Most Popular Rules

Two types of rules have attracted a good deal of attention in recent empirical work: the Taylor rule, which is by far the more popular, and the inflation-forecast-based rule. This section briefly describes these rules and the rationale behind their construction.

8. See Srour (1999) for a more detailed discussion of the various sources of uncertainty and their effect on optimal policy.

The Taylor rule

Taylor (1993) proposed that the central bank should adjust its real interest rate in response to three variables: the current value of the output gap, the current deviation of inflation from its target (with inflation being measured as a four-quarter rate of increase), and a measure of the equilibrium (or "neutral") real interest rate (equation 2). Inflation and output are given equal weights of 0.5:

$$r_t = r^* + 0.5 \cdot (\Pi_t - \Pi^*) + 0.5 \cdot (y_t - y^*) . \qquad (2)$$

This rule indicates that when the economy is in equilibrium, that is, when the inflation rate is equal to its target rate and output is equal to potential, the real interest rate is also at its equilibrium or "neutral" value. If inflation is above target or output is above potential, then real interest rates have to increase above their neutral value to bring these variables back to target. If, on the contrary, inflation or output are below their targeted or equilibrium values, interest rates have to decline to restore equilibrium.[9]

Taylor developed this rule after examining the results of a major model-comparison project (Bryant et al. 1993).[10] His objective was to find a simple, easily understandable rule that would capture the key results from simulations of many different models. The equation was not estimated, but the values of the parameters and the equilibrium levels were chosen such that the equation roughly described the actual behaviour of the Federal Reserve during the (successful) Greenspan period: 1987–92. The fit of the equation could have been improved by using a regression to estimate the parameters of the rule, especially if one included lagged variables and additional terms.[11] However, Taylor notes that the equation was meant to be a normative recommendation of what interest rates should be, not a description of actual Fed behaviour. It is, nevertheless, clear that enormous interest was generated by the close correlation between the Fed behaviour and the Taylor rule during a period where monetary policy was judged to be very successful. The rule also helps to explain why policy was not so successful in other years because real interest rates did not move appropriately. In particular, the research

9. This rule can also be written with the nominal interest rate on the left-hand side as follows: $i_t = i^* + 1.5 \cdot (\Pi_t - \Pi^*) + 0.5 \cdot (y_t - y^*)$, where $i^* = r^* + \Pi^*$.

10. This discussion is based on Taylor (1998).

11. This has been demonstrated in a number of papers. Good examples of this work include Judd and Rudebusch (1998) and Clarida, Gali, and Gertler (1998).

Deriving an Optimal Rule: A Simple Example

Following Svensson (1997), Ball (1997), and Srour (1999), let us assume that the economy can be represented by a simple two-equation closed-economy model:

$$\Pi_{t+1} = \Pi_t + \lambda \cdot (y_t - y^*) + \varepsilon_{t+1}, \qquad (1)$$

$$y_{t+1} - y^* = \mu \cdot (y_t - y^*) - \varsigma \cdot (r_t - r^*) + \eta_{t+1}, \qquad (2)$$

where y_{t+j} is the level of output j periods in the future, y^* is potential output, Π is the inflation rate, r is the real interest rate. ε_t and η_t are independently and identically distributed random shocks (and therefore expected to be zero on average), which are known to the monetary authority only after the interest rate has been set in period t. Equation (1) is a standard Phillips curve, and equation (2) is an IS curve. Notice that the interest rate affects output only after one period and inflation only after two periods (through the output gap). Let us assume further that the monetary authority tries to minimize a loss function, such as equation (1) in the main text. To simplify the problem, set a and c to 0, which implies that the monetary authority is concerned only about deviations of inflation from target.[1] Therefore, the optimal policy is to choose the interest rate such that expected inflation two periods ahead is on target and, therefore, $E_t(\Pi_{t+2}) = \Pi^*$, the target inflation rate. (Remember that this is the earliest period over which monetary policy has control over inflation.)

Substituting equation (2) into equation (1) results in

$$E_t(\Pi_{t+2}) = E_t(\Pi_{t+1}) + \lambda\mu \cdot (y_t - y^*) - \lambda\varsigma \cdot (r_t - r^*). \qquad (3)$$

Substituting equation (1) into equation (3) and setting $E_t(\Pi_{t+2}) = \Pi^*$ gives

$$\Pi^* = \Pi_t + \lambda \cdot (y_t - y^*) + \lambda\mu \cdot (y_t - y^*) - \lambda\varsigma \cdot (r_t - r^*). \qquad (4)$$

Rearranging and combining terms generates an equation for r_t:

$$r_t = r^* + \varphi \cdot (\Pi_t - \Pi^*) + \gamma \cdot (y_t + y^*). \qquad (5)$$

In this simple case, the optimal control rule has the form of a Taylor rule, with the coefficients φ and γ being a function of the model parameters λ, μ, and ς.

1. If a is different than zero, one can still show that the optimal rule for this model is a Taylor rule; however, the derivation becomes more complicated.

shows that it is crucial that the response of nominal interest rates to an inflation shock be large enough to ensure that real interest rates move in the right direction, preventing inflation from spinning out of control following an inflation shock.[12]

The Taylor rule has sometimes been criticized on the grounds that, despite its apparent simplicity, the rule is not all that easy to apply, because of uncertainty regarding the estimates of potential output and the equilibrium real interest rate. The results are also susceptible to data revisions.[13] These are valid concerns, but they would also apply to other policy approaches. Another difficulty with the Taylor rule is that, since monetary policy affects the economy with a lag, it may not be appropriate to move interest rates only in reaction to current values of inflation and output. Nevertheless, under some very specific and simple

12. This conclusion is supported by historical studies that find that the estimated coefficients on inflation are higher in countries that have had more stable inflation over time (Wright 1997). Furthermore, estimates for the United States show that the coefficient on inflation seems to have increased in the 1980s and 1990s compared with the previous two decades. This may account for the improved economic performance in the latter period (see, for example, Judd and Rudebusch 1998). Canada's experience under monetary targeting provides another example. Given that M1 has a high interest rate elasticity, the increases in short-term interest rates that were sufficient to keep M1 inside target in the face of increased inflationary pressures were not large enough to offset the impact of these price shocks (Thiessen 1983).

13. For instance, Orphanides (1998) and Evans (1998) have found that the performance of the Taylor rule in replicating history deteriorates when data that were actually available to policy-makers are used, as opposed to the final revised data used by Taylor.

model assumptions, Ball (1997) and Svensson (1997) have shown that rules with the Taylor form can be equivalent to a forward-looking inflation rule and can correspond to the optimal rule.[14] This is because in their simple model, the current output gap and current inflation are the optimal predictors of future inflation. The response to contemporaneous variables is not aimed at stabilizing current output and inflation, which would, in any case, be impossible, given the lags in the model. See the Box on page 48 for details.

Ball (1999) and Svensson (1998a) show that the Taylor rule may need to be modified for small open economies like Canada. Using an open-economy model with adaptive expectations (that is, expectations formed on the basis of past experience), Ball argues that the exchange rate should be included in two ways: first, the monetary conditions index (MCI) should replace the interest rate as the policy instrument, and second, the inflation term should abstract from temporary (i.e., price-level) exchange rate effects.[15] Ball's argument is that exchange rate changes tend to have temporary effects on inflation, and attempts to offset these effects could cause undue variability in output. Svensson (1998a), using a model with forward-looking, model-consistent expectations (that is, expectations that respond to information contained in the model), also finds support for a similar MCI rule.

Inflation-forecast-based rule

Rules based on inflation forecasts make the change in the policy instrument a function of the deviation of a conditional forecast of inflation in some future period from the target rate of inflation, as follows:

$$r_t = \alpha \cdot r_{t-1} + \gamma \cdot (E_t(\Pi_{t+k}) - \Pi^*) . \qquad (3)$$

Haldane (1997) refers to the above rule as the generic form of feedback rule under an inflation-targeting regime since it captures the operational practice of some inflation targeters. The conditional inflation forecast serves as a feedback variable, and the deviation between the feedback variable and the inflation target dictates the necessary degree of instrument adjustment.[16] For several years, the Bank of Canada has used a rule of this type in QPM, its projection model of the economy. But in QPM, the left-hand-side variable is the difference between the short- and long-term interest rate (the term spread) instead of just the short-term interest rate.

Batini and Haldane (1999) argue that Taylor-type rules underplay the forward-looking aspect of policy. In principle, there may not be much to choose between the two types of rules, since forecasts are formed on the basis of information available in the current period. In practice, however, they see several advantages in having interest rates respond directly and explicitly to the inflation forecasts. First, it allows policy-makers to adjust the horizon of the inflation forecast, depending on the length of the transmission lag for monetary policy. Second, a judicious choice of the forecast horizon for inflation can ensure proper output stabilization. Finally, forecast-based rules may be more efficient than simple backward-looking rules since the inflation forecast can use all relevant information for predicting inflation.

There are potential difficulties with the inflation-forecast-based rule. Although it appears to be as simple as the Taylor rule because it includes only a few arguments, it is implicitly more complex and more model-specific. Furthermore, Carlstrom and Fuerst (1999) show that there is a risk of indeterminacy if a forecast-based rule, rather than a rule based on actual inflation, is used. Also, inflation-forecast-based rules do not attempt to distinguish between demand shocks and inflation shocks. The interest rate response depends only on the forecasted deviation of inflation from its target. Putting some weight on output, as in the Taylor rule, allows the responses to differ.

Stabilization Properties of Simple Rules: Some Simulation Results

A number of recent studies have examined how simple rules like those described above—or their variants—perform relative to the fully optimal rules

14. Note, however, that optimal rules typically have higher coefficients than Taylor's setting of 0.5, 0.5.

15. The MCI is a weighted sum of interest rates and the exchange rate with the weights based on the relative importance of the effect of the two variables on aggregate demand.

16. The inflation-forecast-based rule described in this section should not be confused with Svensson's inflation-targeting rule (Svensson 1998b). Svensson argues that the central bank should use an inflation forecast as an explicit intermediate policy target. While the Taylor rule and the inflation-forecast-based rule are simple feedback rules for the policy instrument, Svensson's approach requires that the central bank solve an optimal-control problem in which it tries to minimize the deviations of its inflation forecast from target some n periods in the future.

within a given model of the economy. Others have compared the performance of alternative rules across different models. Still others have examined how the optimal calibration of the rule varies with the model characteristics or with the presence of uncertainty. The following is a brief overview of what the research to date suggests.

Simple rules work well for closed economies

Several studies that use data from large countries conclude that once the coefficients have been judiciously chosen, simple Taylor-type rules, perhaps augmented with a lagged dependent variable, do remarkably well—their performance at stabilizing the economy almost matches the optimal rule in a given model.[17] This suggests that there is no need to use a rule that is too complicated. For instance, Levin, Wieland, and Williams (1999) compare the performance of alternative rules in four large-scale, rational-expectations models for the United States and find that a Taylor rule with a lagged interest rate provides very good results. Increasing the rule complexity, by adding lags and other variables in the model, yields very small gains. Rudebusch and Svensson (1999) find that a simple Taylor rule that includes only the current value of inflation and the output gap performs nearly as well as the optimal rule in a small adaptive-expectations model of the U.S. economy.[18]

In their model, Rudebusch and Svensson also find that model-consistent, inflation-forecast-based rules perform poorly compared with Taylor-type rules. In contrast, studies that examine smaller, more open economies find that inflation-forecast rules tend to perform better than simple Taylor rules. Using a modified version of the Bank of Canada's QPM model, Black, Macklem, and Rose (1998) conclude that the inflation-forecast rule does better than Taylor-type rules, especially with respect to minimizing interest rate volatility. They find that an eight-quarter lead on annual inflation provides the best outcome if the policy-maker is concerned about both output and inflation. Using a calibrated model of the U.K. economy, Batini and Haldane (1999) also find that an inflation-forecast rule outperforms a Taylor-type rule. In their model, a forecast horizon of four to six quarters for quarterly inflation appears to do best.[19] Furthermore, they find that an inflation-forecast rule comes close to matching the optimal rule.

As noted by Levin, the fundamental mechanism seems to be that forward-looking rules perform better than rules based on current variables in an environment with temporary shocks to inflation. (See Taylor 1999a, 200.) In the United States, simple Taylor rules work well because inflation is mainly domestically generated and both output and inflation exhibit a high degree of persistence. The Taylor rule exploits the predictive power of past inflation and output for future inflation. In more open economies, inflation also reflects external developments, particularly exchange rate changes, which tend to have a high variance. In this case, being able to filter temporary shocks from more permanent ones by using an inflation-forecast rule will likely lead to better outcomes.[20]

One alternative is to augment Taylor-type rules with variables that help capture external influences. Ball (1999) provides some evidence that, for a small open economy, adding the exchange rate to a Taylor rule improves the stabilization properties. In particular, he finds that it significantly reduces output variability for a given amount of inflation variability. More studies are required to establish the robustness of this result.

Private sector expectations are critical

The characteristics of efficient policy rules depend critically on assumptions regarding private sector expectations. In Taylor rules augmented with a lagged dependent variable, the higher the degree of forward-lookingness, the lower would be the coefficients on inflation and output and the higher the coefficient on the lagged interest rate. When policy adjusts gradually to its desired position, forward-looking market participants will expect a small initial policy move to be followed by additional moves in the same direction. If aggregate demand depends in a major way on expected future short-term rates (or

17. Little can be concluded about the optimal size of the coefficients in the rule, since the results are model-specific. Nevertheless, a majority of studies using sticky-price aggregate demand / aggregate supply models have found that the coefficients on inflation and on output should be larger than those originally proposed by Taylor.

18. For more evidence that a simple Taylor-type rule can achieve results close to the optimal rule, see Peersman and Smets (1998), who use a model estimated for five large European Union countries, and Rotemberg and Woodford (1999) who use U.S. data.

19. Using data for Australia, de Brouwer and O'Regan (1997) also find that rules using forecast values outperform those based only on current values.

20. There is also some evidence that inflation-forecast-based rules perform better than simple Taylor rules in non-linear models, as shown by Isard, Laxton, and Eliasson (1999). According to Svensson (1999), this is because the inflation-forecast rule is more complicated and provides a closer approximation to the true optimal rule (which is non-linear) in a non-linear model.

equivalently, long-term rates) and not simply on current short-term rates, then policy will have a substantial impact on current output and inflation without requiring large interest rate movements.[21] In adaptive-expectations models, expectations are not dependent on the policy rule, and rules that imply very gradual adjustments work poorly and may even lead to instability.[22]

For the inflation-forecast-based rule, Batini and Haldane (1999) show that the optimal time horizon for responding to the deviations of forecast inflation from its target is sensitive to the model's lag structure, which in turn depends on private sector expectations. In general, the longer the transmission lag, the further into the future is the optimal forecast horizon. Behavioural shocks that lead to a shortening of the transmission lag, such as increased credibility in policy, must be accompanied by a shortening of the policy horizon. If not, the performance of the economy may actually worsen (Amano et al. 1999). When shocks hit the economy, something must change to dampen the resulting fluctuations in output and inflation. If the private sector looks ahead and adjusts its spending and price- and wage-setting in anticipation of the central bank's eventual response, the central bank need not be as forward-looking.

Ryan and Thompson (1999) provide another example in which expectations are important. Following Ball's argument that the measure of inflation should be stripped of exchange rate effects, they compare the performance of rules that use alternative definitions of inflation, that is, aggregate inflation, non-tradable-goods inflation, and unit labour costs. They find that using the latter two measures does not improve stability and, in some cases, even worsens economic performance. They attribute this result to the fact that in their model, all exchange rate shocks feed into private sector expectations. If policy does not aim to offset these shocks, they propagate into continuing inflation.

Uncertainty can have a major effect

As discussed above, in theory it is not obvious how uncertainty will affect optimal policy. A few studies have attempted to quantify the impact of different forms of uncertainty. To date, the results suggest that data uncertainty as well as general forms of model uncertainty can significantly affect the efficient feedback parameters in policy rules. Results concerning the impact of simple Brainard-style parameter uncertainty are mixed.

Peersman and Smets (1998), Rudebusch (1999), and Orphanides (1998) find that errors in measuring potential output (and inflation in the latter two studies) lead to a marked reduction in the size of the efficient parameters of simple rules if these errors are large. (See also Isard et al. 1999.) In the first two of these, the authors conclude that parameter uncertainty as defined by Brainard reduces the efficient feedback parameters only marginally. A similar conclusion is reached by Estrella and Mishkin (1999). In contrast, Sack (1998) and Martin and Salmon (1999) find that parameter uncertainty substantially dampens the response of interest rates. Sack argues that parameter uncertainty can account for the interest rate smoothing that is found in historical estimates of Taylor rules. The studies that find little effect from parameter uncertainty use small structural models, while the other two use unrestricted vector autoregressions (VARs). According to Rudebusch, the large effects found in the latter may reflect the additional uncertainty associated with the wide standard errors of some superfluous variables in the VARs.

There is some evidence that simple rules are more robust across models than more complicated rules.

Stock (1999), Sargent (1999), and Williams (1999) estimate the impact of uncertainty using robust control techniques. Sargent examines rules that are robust to changes in the serial correlation structure of the model, while Stock and Williams look for rules that

21. This argument was first suggested by Goodfriend (1991). In a model with purely forward-looking expectations, Rotemberg and Woodford (1999) find that the optimal coefficient on lagged interest rates is larger than 1.

22. In theory, adaptive-expectations models may not be well suited for evaluating the long-run properties of rules since the model parameters are implicitly assumed to be policy-invariant (Lucas critique). However, this problem will not be too severe if the rules that are analyzed do not differ significantly from those experienced historically. Moreover, results obtained from these models may also be relevant over short periods if the formation of expectations adjusts gradually to changes in policy. On the other hand, there is an element of circularity in rational-expectations models since they assume that the policy rule is fully credible and that the public has certain knowledge of the model. But in practice there is much uncertainty, and probably a diversity of views, about the model. Indeed, models of inflation have evolved over time.

are robust to different values of parameters in the demand and price equations. Using small-scale, adaptive-expectations models, both Stock and Sargent find that, in order to guard against the worst-case scenario (either policy ineffectiveness or a pattern of persistent errors), the authorities should be more aggressive than in the certainty case. In contrast, Williams, who uses a large-scale, rational-expectations model, finds that policy should be more cautious than in the certainty case.

As expected, there is some evidence that simple rules are more robust across models than more complicated rules. Levin, Wieland, and Williams (1999) and Taylor (1999b) provide results that suggest that simple Taylor-type rules perform quite well in various types of models. Preliminary work done at the Bank of Canada by Amano suggests that simple Taylor rules are more robust to changes in economic behaviour than inflation-forecast-based rules. Nevertheless, as argued by Christiano and Gust (1999) and Isard and Laxton (1999), one needs to be cautious before drawing strong conclusions concerning the robustness of a particular rule, since until recently, the vast majority of studies have used the same class of linear sticky-price models. More evidence is required on the performance of rules in other classes of models.

Conclusion

In the last few years, considerable work has been done on policy rules. There has been significant progress on the conceptual representation of the problem faced by central banks; that is, how best to keep inflation close to its desired rate without creating excess variability elsewhere in the economy. There has also been progress in the theoretical understanding of how various forms of uncertainty complicate the choice of optimal policy. Advances in computer technology have allowed researchers to undertake extensive simulation analysis of macroeconomic models to evaluate the relative performance of various policy rules. Since the optimal policy rule in one model is unlikely to perform well in another model, some attention has been given to finding rules that will do reasonably well across models. However, as noted by Freedman (1999), a comparison of the benefits of complex but optimal rules, on the one hand, and simple but robust rules, on the other hand, remains an important subject for future research.

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