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Monetary Policy Strategy for Poets: The Case of Uncertain Inflation Persistence

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Highlights

- **Monetary policymakers often must reach decisions about the appropriate stance of monetary policy in an environment with a great deal of uncertainty about the economic outlook.**
- **Over recent years, uncertainty about the persistence of inflation has been a key risk factor.**
- **Faced with fundamental uncertainties, policymakers often seek to incorporate "risk management" considerations in the conduct of monetary policy.**
- **Alternative risk management frameworks take different approaches in evaluating the costs and benefits of potential policy actions.**
- **Risk management in the case of uncertain inflation persistence involves a judgement about how much policy restraint to "put in the pipeline" to address the risk of elevated future inflation.**

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"Given our inevitably incomplete knowledge about key structural aspects of an ever-changing economy and the sometimes asymmetric costs or benefits of particular outcomes, a central bank needs to consider not only the most likely future path for the economy but also the distribution of possible outcomes about that path. The decisionmakers then need to reach a judgment about the probabilities, costs, and benefits of the various possible outcomes under alternative choices for policy."

Chairman Greenspan, 1/3/2004

"The vast majority of participants noted an increased risk that inflation would take longer to return to the Committee's 2 percent objective than they had previously expected."

FOMC Minutes, 4/28/2026

Introduction

Monetary policymakers are often in the difficult position of making judgments about whether seemingly "one-time" shocks to prices are in fact an early sign of incipient sustained inflation pressures. Over recent years, a string of "supply shocks" including tangled supply chains following COVID, oil price surges following the Ukraine War and the war with Iran, and the effects of tariffs have all put upward pressure on prices. In theory such shocks should result in only a temporary boost to inflation as long as the Federal Reserve (Fed) conducts monetary policy in a way that keeps inflation expectations well anchored at levels consistent with the long-run inflation objective of 2 percent. However, particularly in the case of supply shocks, the Fed faces a challenge in seeking to head off potential inflation pressures but without restraining economic activity too much in the process. In this context, policymakers often note the importance of "risk management" in the conduct of policy. Often this is expressed as setting the stance of monetary policy to "balance the risks" to the Fed's dual mandate goals of maximum employment and 2 percent inflation. But what exactly does "balancing the risks" mean?

Risk Management and the Persistence Dilemma

As noted above, Chairman Greenspan famously emphasized the role of risk-management in the conduct of monetary policy. Over the years, a large (and very technical) literature has explored many aspects of risk management considerations in monetary policy strategy. The discussion below illustrates just a few of the key ideas in that literature in the context of a simple example. While the example here barely scratches the surface of the broader topic and the extant literature, the goal is to convey at least a flavor of some of the key issues.[2]

The basic idea underlying the example is straightforward. Policymakers are confronted with a large positive shock to inflation in the current period. Policy actions today affect the economy with a lag so there is little the central bank can do today to address elevated inflation in the current

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[2] Technical details of the example are provided in the appendix. See Clarida, Gali, Gertler (1999) for a classic discussion of monetary policy strategy in frameworks of the type used here.

period. However, the central bank can adjust the stance of policy today to address anticipated inflation pressures in the next period. In responding to the current period inflation shock then, the policymaker attempts to discern how much of today's inflation surge will carry forward into the future. If the current period inflation shock is entirely transitory, the policymaker might wish to simply "look through" today's elevated inflation, recognizing that inflation will likely return to normal in the next period without any policy tightening today. On the other hand, if inflation is persistent, the policymaker may wish to tighten policy some today in order to lean against inflation pressures that carry forward into the next period. In doing so, policymakers recognize that tightening policy to address inflation pressures comes with a cost in terms of restraining spending and depressing output and employment.

The persistence dilemma focuses on how monetary policymakers should respond today if there is a great deal of uncertainty about how much of today's elevated inflation will carry over to the next period. Tightening "too much" could needlessly depress economic activity and result in inflation running below the central bank's 2 percent objective. Conversely, tightening "too little" today would allow a continuation of elevated inflation coupled with strong demand that could, in turn, allow inflation pressures to build over time.

The core elements of the persistence dilemma—a required decision today with uncertain future payoffs—are present in many types of decision-making far removed from the realm of monetary policy. Should you carry an umbrella with you on the chance that the current sunny weather does not persist. Should you devote your time and money to develop particular workplace skills if the current strong job market for workers with those skills may not persist? Should you hold on to your reliable older car as the mileage starts to pile up? All of these kinds of decisions involve weighing potential costs and benefits of a decision now across different possible future outcomes.

Costs and Benefits of Policy Actions: The Central Bank Loss Function

In the world of monetary policy, the concept of a central bank "loss function" plays a key role in weighing costs and benefits of policy actions. The Federal Reserve seeks to achieve two long-run goals—maximum employment and inflation at 2 percent. The loss function is just a yardstick used to measure how far actual employment and inflation are from the Fed's goals.

The central bank can steer the economy toward its goals through its ability to influence interest rates and broader financial conditions in a way that affects the demand side of the economy. The Fed is then also able to indirectly affect the path of inflation through its influence on aggregate demand. For any given setting of the stance of monetary policy, there are corresponding outcomes for output and inflation and an associated value of the central bank's loss function. In choosing the "optimal" monetary policy, the central bank tries to set the policy rate at a level that results in the lowest value for the central bank loss function. The discussion below couches the discussion of policy in terms of "gaps" rather than levels of key variables. The "inflation gap" is the difference between actual inflation today and the Fed's goal of 2 percent. The "output gap" is the difference between actual output and a sustainable level determined by available workers, capital, technology, and other structural factors. And the "policy rate gap" is the difference between today's policy rate and the longer-run level of the policy rate consistent with inflation at 2 percent and the output gap at zero in the longer-run.

Figure 1 illustrates how this all works in the example. Absent any constraints, the Fed would always choose monetary policy to keep output and inflation gaps at zero (marked with the black star). At a point in time, however, shocks to the economy may constrain the ability of the Fed to move output and inflation gaps to zero. The dotted line in the diagram shows a hypothetical range of output and inflation gaps that may be achievable following a supply shock that pushes up the current rate of inflation relative to the Fed's 2 percent objective. The Fed still has some room to maneuver and can choose where to position the economy along that line. The "optimal" policy positions the economy at the heavy red dot because that is the point with the shortest distance to the Fed's long-term goals—the lowest value of the central bank loss function. If the Fed tightens policy, it would move the economy down and to the left (lower output, lower inflation denoted by the small black dot) along the feasible line. A Fed easing would move the economy up and to the right (higher output, higher inflation denoted by the small green dot) along the feasible line. In both cases, relative to the red dot, the value of the loss function would be higher than at the red dot.

Figure 1: The Least Cost Inflation and Output Combination

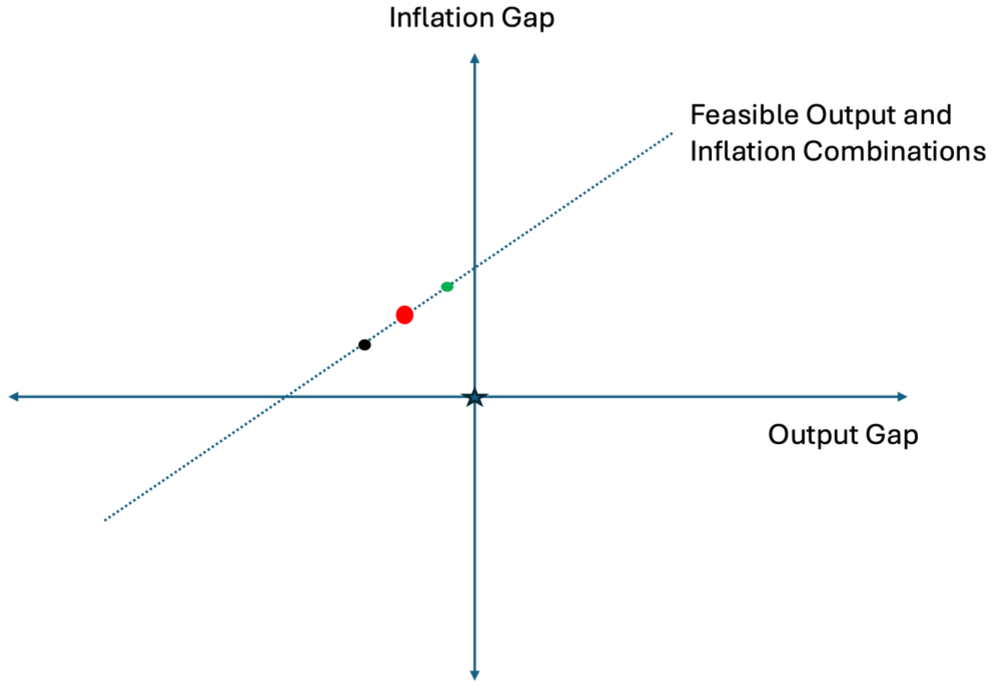
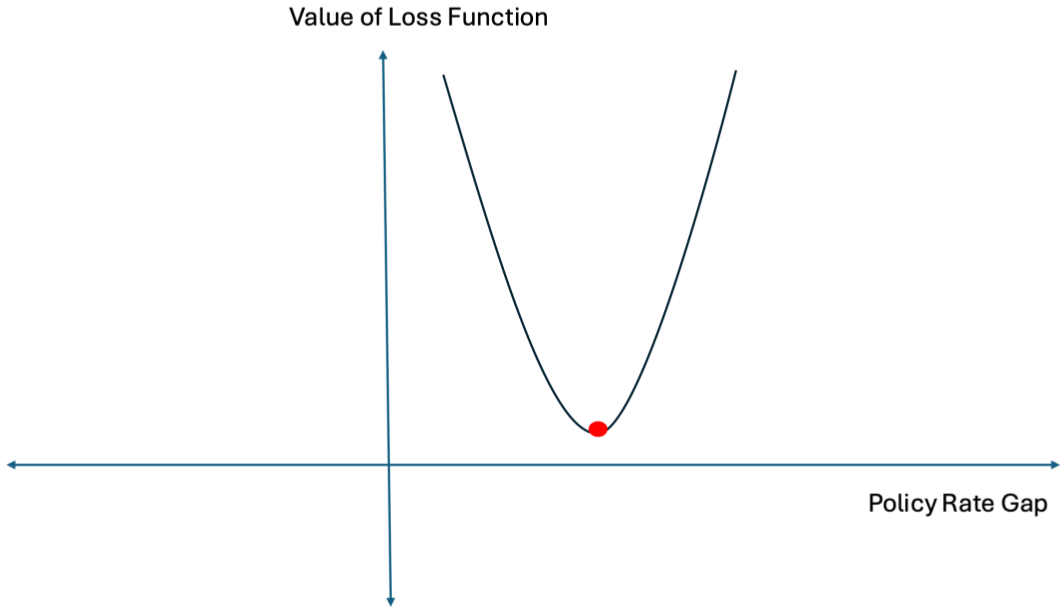


Figure 2 shows the value of the central bank's loss function for every possible setting of the policy rate. The "optimal" policy choice (the red dot in Figure 1) corresponds to the minimum point on this curve. As the policy rate is moved away from this optimal point, the central bank's loss function increases.

Figure 2: Value of the Loss Function and Policy Rate Gap



Three Basic Risk Management Benchmarks

The framework described above can be used to illustrate three important risk-management strategies—the modal outlook approach, the Bayesian approach, and the robust min-max approach—and how they contend with the persistence dilemma. In the examples discussed below, we'll assume the current period inflation shock boosts inflation by 1 percentage point. And we'll also assume that there is a 60 percent chance that this inflation shock is transitory and a 40 percent chance that it persists.

The Modal Outlook Approach

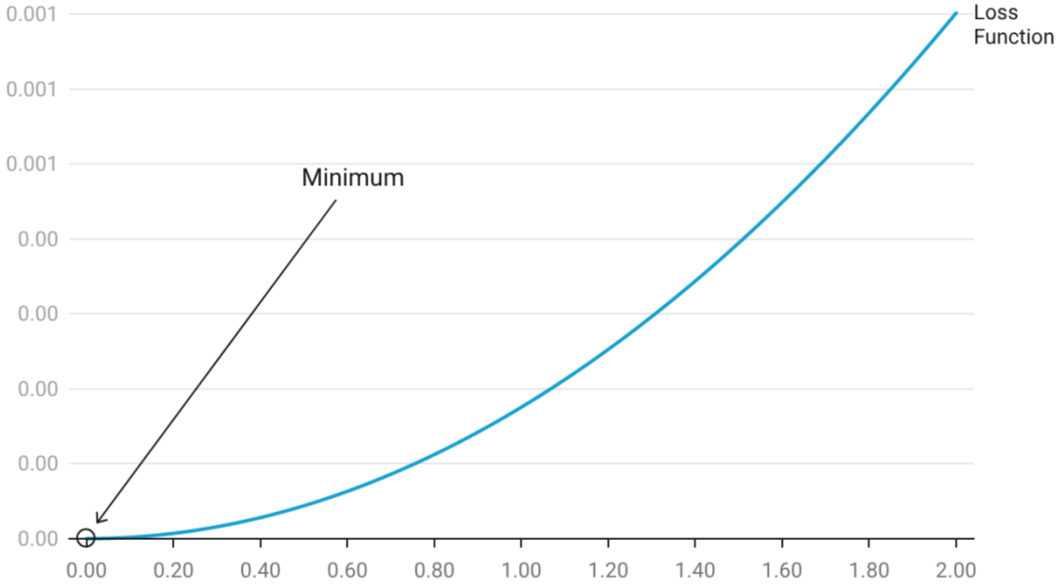
In the modal outlook approach, the policymaker sets the policy rate gap based on the most likely inflation persistence outcome. If policymakers believe that there is a 60 percent chance that today's inflation surge is transitory, the modal outlook approach to the inflation persistence dilemma is to "look through" today's elevated inflation and leave the policy rate unchanged.

Simply using the "most likely" value for inflation persistence is an ad hoc approach but may work reasonably well over time. Moreover, in practice, policymakers often consult baseline economic forecasts centered on a "modal outlook" for the economy. The modal outlook approach for inflation persistence fits well with this common practice.

In terms of the central bank loss function, as shown in Figure 3, a policymaker minimizing the loss function with a known value of the persistence parameter equal to a most-likely value of zero would also set the policy rate gap equal to zero. Policymakers recognize that any setting of the policy rate today affects the economy with a lag. And if the current period inflation shock is not expected to persist, setting the policy rate gap at zero today leaves the expected value of the inflation and output gaps in the next period at zero as well.

Of course, given the uncertainty about the persistence parameter, the modal approach involves a degree of risk. If inflation in fact turns out to be persistent, the central bank's setting of the policy rate today would be too easy and the inflation and output gaps in the next period will be positive. Indeed, in the example, the modal outlook approach does not really seek to manage risks at all. It ignores the risks associated with low probability high-cost outcomes and focuses entirely on the most likely outcome.

Figure 3: Modal Outlook Approach



Horizontal axis shows policy rate gap in percentage points.

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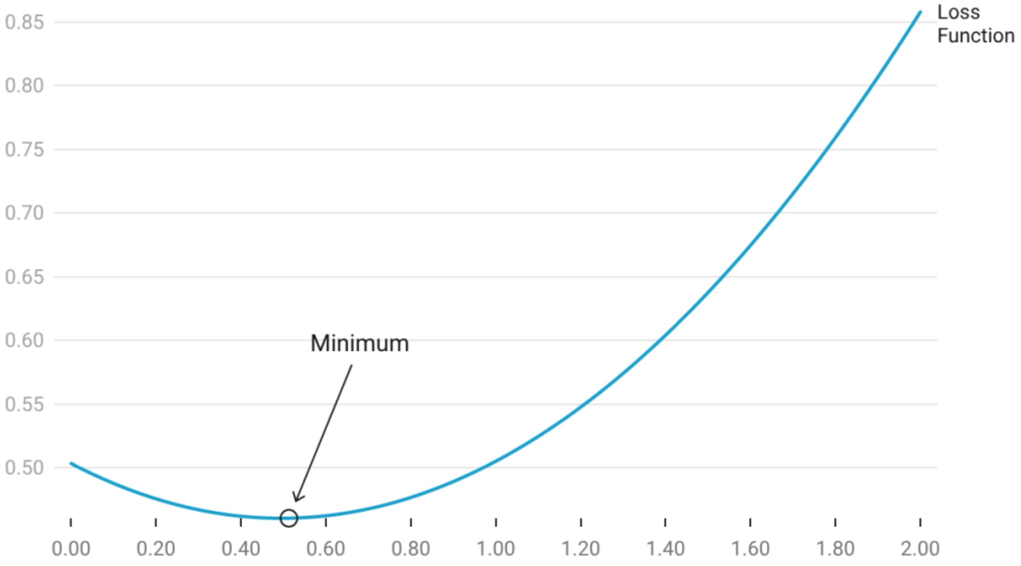
The Bayesian Approach

While the modal outlook approach may be convenient and practical, policymakers could adopt a strategy with a stronger analytical foundation by choosing the setting of the policy rate gap to minimize the expected value of losses. In this approach, policymakers use their subjective assessment of the probabilities associated with all possible inflation persistence outcomes, not just the most likely outcome.

The expected value of the loss function then weights the loss function in each scenario for the persistence parameter by the probability of that scenario. For example, the policymaker would assign a 60 percent chance to the scenario in which inflation is transitory and then a 40 percent chance to the scenario in which inflation is persistent.

Figure 4: Bayesian Approach



Horizontal axis shows policy rate gap in percentage points.

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As shown in figure 4, the expected loss function is shifted to the right relative to the loss function for the modal outlook case. As a result, the loss minimizing point corresponds to a tighter setting of the policy rate gap than in the modal outlook approach. As shown in the appendix, the optimal choice for the setting of the policy rate gap is determined by the expected value of the persistence parameter.[3] In the example, the expected value of the persistence parameter is a little higher than the modal value of zero.

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[3] This “certainty equivalence” property in connection with inflation persistence holds in this one-period setting but does not hold in more general models. See Soderstrom (2002).

Under the Bayesian approach, the policymaker effectively hedges some of the risks of a high persistence outcome by running a tighter policy than under the modal approach. If current period inflation proves to be temporary, policy will be a little too tight and the inflation and output gaps next period will drop a little below zero. However, if current-period inflation turns out to be persistent, the tighter policy setting in the current period will help to lean against those inflation pressures in the next period.

You could think of the difference between the optimal policy rate in the Bayesian approach and the policy rate under the modal approach as a measure of the "risk management" considerations in the stance of policy. In the example, the magnitude of this gap is directly related to the probability associated with the persistent inflation scenario.

Robust Min-Max Approach

In contrast to the modal outlook approach and the Bayesian approach, the robust min-max approach considers the case in which policymakers are so uncertain about inflation persistence that they cannot even assign probabilities to the different inflation persistence outcomes. In the robust min-max approach, policymakers instead look at the "worst case scenario" for every possible setting of the policy rate gap.[4] They then choose the setting that minimizes the loss among all of these worst case scenarios. As discussed in the appendix, it turns out that with the parameterization for the example, the robust policymaker chooses an optimal policy action as if the high persistence scenario is certain to occur. This is a very conservative strategy in which the central bank tightens policy quite aggressively even in cases when the high persistence scenario could be very unlikely.

Figure 5 illustrates how the robust min-max strategy works in terms of the loss function. The policymaker looks at the loss functions corresponding to the scenarios with transitory and persistent inflation. For each possible setting of the policy rate, the policymaker focuses on the higher of the two losses and then adjusts the stance of policy to make the cost of the "worst case" scenario as low as possible.

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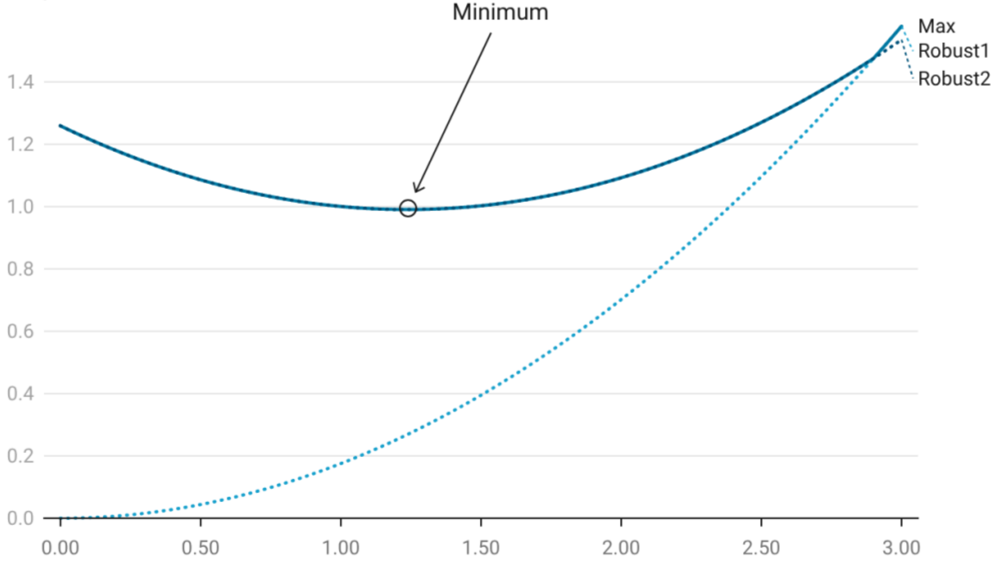
[4] See Barlevy (2009) for a very useful introduction to this approach.

In the diagram, the worst case scenarios for each setting of the policy rate are depicted by the solid blue line. In the example, the lowest cost option among all these worst-case scenarios occurs at the minimum of the loss function for the case with persistent inflation.

Figure 5: Robust Min Max



Horizontal axis shows policy rate gap in percentage points.

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Risk Management Wisdom from Bobby Jones

"The difference between a sand trap and a water hazard is the difference between a car crash and an airplane crash. You have a chance of recovering from a car crash." Bobby Jones

Bobby Jones was the greatest golfer of his era (the 1920s) and, based on his quote above, might have excelled in monetary policy strategy too. Mapping his concept of risk management to our example, the golfer below faces a difficult shot to the green. A water hazard guards the right side of the fairway and the green. And compounding matters, gusty wind conditions greatly complicate the decision about where to aim. The golfer could luck out and hit the shot when the wind is calm. In that case, the ball would end up exactly where he aimed (in theory anyway!). On the other hand, a sudden wind gust could catch the ball and carry it well to the right of where the golfer aims. What to do in this situation?

Of course, if you happen to be Bobby Jones (or these days Scottie Scheffler or Nelly Korda), following a modal outlook approach in this situation by aiming directly over the modal stake would likely turn out very well with the ball landing close to the hole. For the rest of us mortals, however, aiming along the modal outlook line would be a daring strategy. It might work but it might also be disastrous if the wind comes up at the wrong time. In that situation, the golfer could end up in the dreaded water hazard.

A golfer aiming along the line for Bayesian approach marker would follow a safer strategy. A shot aimed at that marker would be unlikely to end up in the water hazard even in the case of a strong wind gust. And if the wind stays calm, the ball should land reasonably close to the green for an easy next shot.
The golfer aiming along the robust min-max line would follow a very conservative approach. A shot along this line would completely eliminate the risk that a gust of wind would carry the ball into the water hazard. But if the wind is calm, the golfer will end up far from the green on the next shot and might even land in the sand trap.

Variations on the Basic Risk Management Approaches

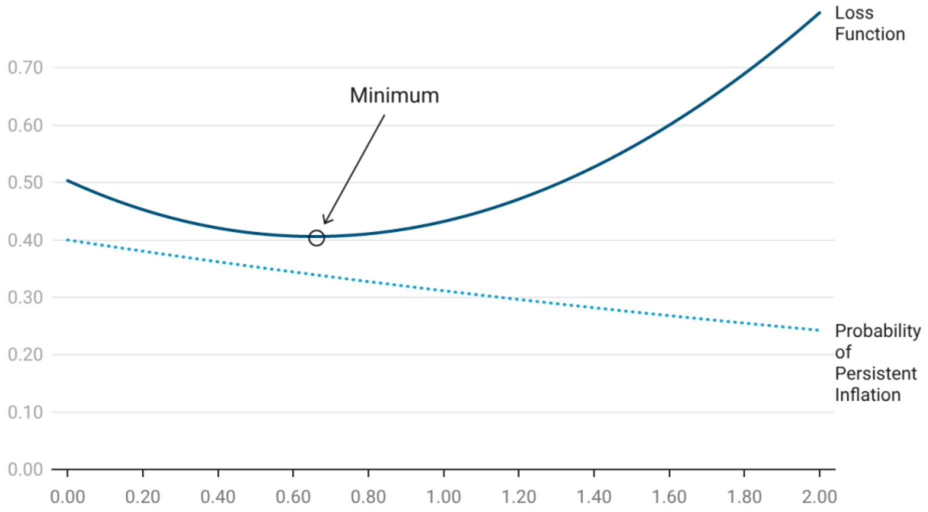
There are many variations on the Bayesian and robust approaches discussed above. One variation on the Bayesian approach is what might be termed the "Credibility Hawk"—the case in which policy actions may have some effect on the likelihood of future adverse outcomes. The regret-robust min max strategy, also discussed below, is a variation on the robust strategy.

Credibility Hawk

In the credibility hawk example, additional risk management considerations in connection with inflation persistence may arise when policymakers perceive that the actions they take could influence the likelihood of an adverse outcome. For example, they may judge that maintaining a relatively tight policy with elevated inflation today could be warranted if that policy stance helps to anchor inflation expectations and reduces the risk that current elevated inflation persists. As discussed in the appendix, the credibility hawk policy is a variation on the Bayesian approach with the added wrinkle that policy actions today affect the likelihood of inflation persistence outcomes. As shown in Figure 6, in the example, the credibility hawk runs a somewhat tighter policy than the basic Bayesian policymaker reflecting the perceived extra benefit from a tighter policy in reducing the likelihood of the high persistence outcome. The dotted line shows the reduction in the risk of persistent inflation stemming from policy tightening. Under the parameterization in the example, the optimal policy rate gap of 66 basis points in this scenario is associated with a decline in the probability of persistent inflation from 40 percent to about 34 percent.

One way of thinking about the credibility hawk approach in terms of the golf analogy discussed in the box is to view the golfer as aiming a little to the left of the Bayesian line and intentionally hitting a very low shot that stays out of the wind. (Not too difficult for Bobby Jones). In that case, the golfer would effectively eliminate the risks that a wind gust would affect the flight of the ball.

Figure 6: Credibility Hawk



Horizontal axis shows policy rate gap in percentage points.

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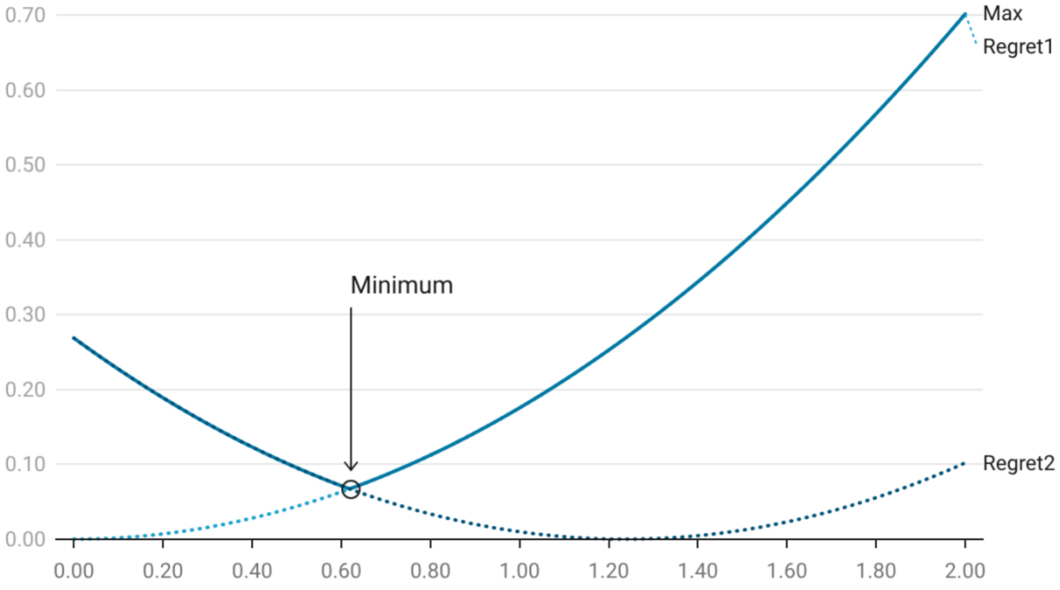
Regret-Robust Min-Max

The regret-robust min-max approach is similar in spirit to the robust min-max approach except that the losses in each scenario are defined relative to the best that could be achieved if the policymaker knew in advance which scenario would occur. This notion of the loss relative to the best that could have been achieved given the shocks is the concept of a "regret." As shown in figure 7, with this definition of regrets, the optimal policy setting always occurs at the point where the two curves intersect. As discussed in the appendix, in our example, this approach would end up falling halfway between the modal approach and the robust min-max approach.

The regret-robust min max approach is substantially less conservative than the standard robust min max strategy because the latter effectively puts weight on factors over which the central bank has no control. As shown in figure 1, a positive persistent supply shock makes it impossible for the central bank to attain zero inflation and output gaps no matter what policy rate gap it chooses. This unavoidable increase in the central bank's loss function is included in the scenario analysis under the standard robust min max approach and could be viewed as a form of "double counting" that strongly favors the appropriate policy for a known persistent shock. The regret-robust min max approach avoids this double counting and puts the two scenarios on a more equal footing by focusing only on the costs relative to the best the central bank could achieve in the scenario it faces.

Figure 7: Regret Robust



Horizontal axis shows policy rate gap in percentage points.

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Robust Simple Rules

In all of the examples above, apart from the uncertainty about inflation persistence, policymakers know a great deal about the economy and exactly how it operates. Moreover, in reaching policy decisions, they only need to consider two scenarios corresponding to the two possible outcomes for inflation persistence. In the real world, the extent of uncertainty faced by policymakers is far more extensive than that captured by the illustrative examples in this note. In practice, policymakers may judge that key aspects of the structure of the economy and monetary policy transmission are changing over time. And they may be considering the risks associated with a multitude of relevant scenarios.

In light of these challenges, a very important strand of the literature has focused on developing “robust simple rules” describing the setting of the policy rate as a function of observed values of output and inflation.[5] The goal is to develop rules that perform well across a number of different types of models and subject to a range of shocks. As a result, the prescriptions from such rules may be viewed as embodying an element of risk management.

The Taylor Rule is the most famous example of this type of rule. The simplest form of the Taylor rule prescribes a policy rate gap that is 1.5 times the inflation gap and 0.5 times the output gap. Importantly, the Taylor rule is primarily “outcome-based”—it does not rely on estimates of numerous structural parameters for a particular model of the economy or on model-specific forecasts of key variables. (Admittedly, the Taylor Rule does depend on estimates of potential output and the equilibrium real interest rate, both of which are difficult to pin down.) Because the standard Taylor rule looks only at contemporaneous inflation, its prescription for the policy rate gap in our example is rather tight. Many variations on the Taylor rule have been developed over time that are also helpful policy benchmarks.[6]

In terms of the golf analogy, a rule-based approach might be something like “whenever you face a difficult direct shot to the green, always play a shot that gets you back to the middle of the fairway in the most direct way possible.” You might be able to do better than the rule in specific situations (particularly if you’re Nelly Korda or Scottie Scheffler) but that rule likely would perform reasonably well over time in various situations on various courses.

Summing Up

Table 1 below presents the policy rate gaps for all the policy strategies discussed above. Perhaps the most notable aspect of the table is that the policy prescriptions from alternative approaches to risk management vary considerably even when the basic model of the economy and the nature of the uncertainties bearing on the economic outlook are well understood. Taken literally, for example, if the set up in the example were seen as broadly consistent with the current economic

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[5] See Taylor and Williams (2011) for a very useful overview of this literature.

[6] See, for example, “Monetary Policy Rules in the Current Environment” in the Federal Reserve’s Monetary Policy Report to Congress.

situation, the pure modal approach would suggest the Federal Reserve should ease the policy rate from its current level near 3.6 percent to the long-run normal level of about 3 percent. The Bayesian, credibility hawk, and regret-robust minmax approaches would suggest maintaining the policy rate at around its current level. And the robust minmax approach and Taylor Rule would suggest substantial policy firming. Of course, the results in Table 1 are only illustrative and not intended as a guide to policy in the current environment. That said, the range of prescriptions does highlight the extent to which policymakers' perceptions of risks and their views about the best strategy to follow in managing those risks can become a focal point in debates regarding the appropriate stance of policy. In March, FOMC participants continued to judge the uncertainty surrounding the outlook for inflation to be higher than average over the last twenty years with risks to the inflation outlook weighted to the upside. Judging from FOMC communications, developments since then have only added to that sense of uncertainty and risks. Against that backdrop, we can be certain about one thing—the FOMC will be focusing intently on risk management issues over coming meetings.

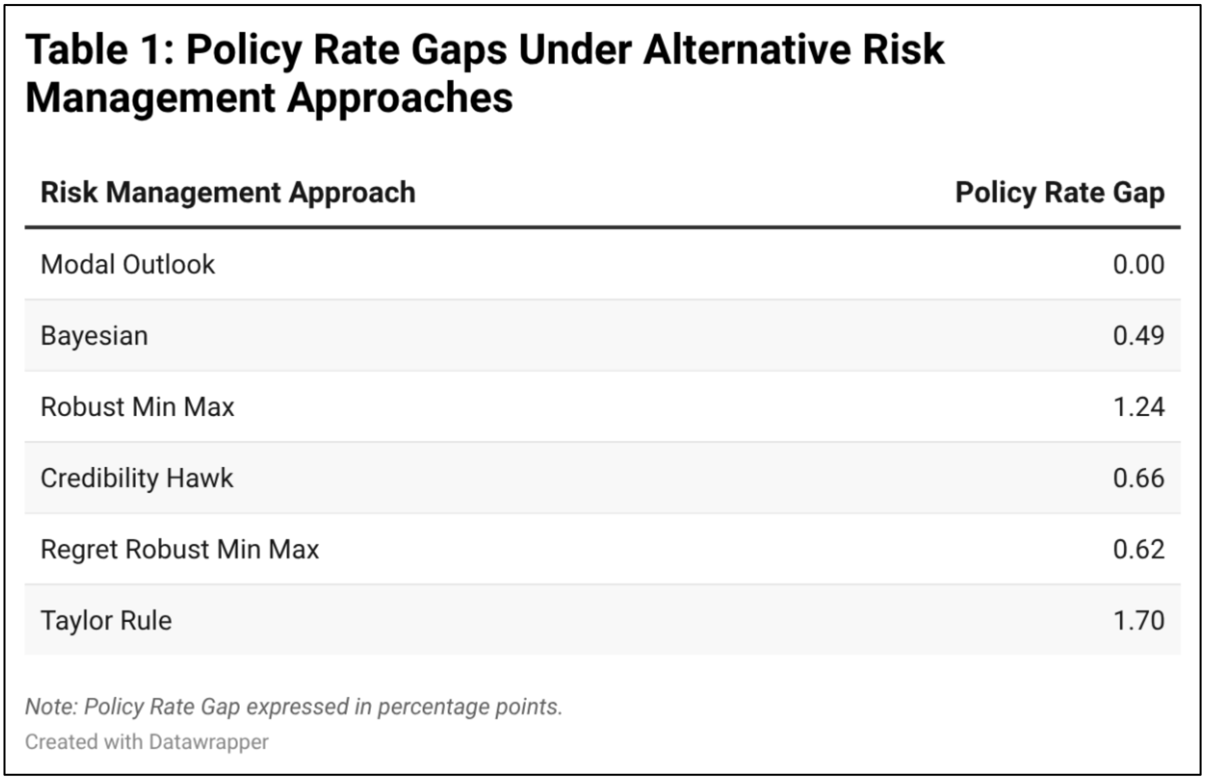

Table 1: Policy Rate Gaps Under Alternative Risk Management Approaches

Risk Management Approach	Policy Rate Gap
Modal Outlook	0.00
Bayesian	0.49
Robust Min Max	1.24
Credibility Hawk	0.66
Regret Robust Min Max	0.62
Taylor Rule	1.70

Note: Policy Rate Gap expressed in percentage points.

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Appendix: Technical Details

1. Basic Structure

The basic model includes an IS curve, equation (1), specifying the output gap as a function of the real interest rate gap. The central bank's choice of the nominal interest rate gap, r_t, affects output with a lag of one period. The Phillips curve, equation (2), expresses the inflation gap in the current period as a function of the current-period output gap and the prior period inflation gap. The persistence of inflation is determined by the coefficient ρ on the lagged inflation gap. Using (1), and (2), equations (3) and (4) determine the values of the next period inflation and output gaps as a function of the current period choice of the nominal interest rate gap (hereafter, the policy rate gap).

$$y_t = -\alpha(r_{t-1} - \pi_t) + u_t \tag{1}$$
$$\pi_t = \rho\pi_{t-1} + \beta y_t + v_t \tag{2}$$
$$\pi_{t+1} = \rho\pi_t + \beta y_{t+1} + v_{t+1} = \rho\mu\pi_t - \mu\beta\alpha r_t + \mu\beta u_{t+1} + \mu v_{t+1} \tag{3}$$
$$y_{t+1} = -\alpha\mu r_t + \alpha\rho\mu\pi_t + (1 + \alpha\mu\beta)u_{t+1} + \alpha\mu v_{t+1} \tag{4}$$
$$\mu = 1/(1 - \beta\alpha)$$
$$y_t = \mathit{output\ gap\ in\ period\ t}$$
$$\pi_t = \mathit{inflation\ gap\ in\ period\ t} = \Pi_t - \Pi^*$$
$$\Pi_t = \mathit{inflation\ in\ period\ t}$$
$$\Pi^* = \mathit{central\ bank\ inflation\ target}$$
$$r_t = \mathit{nominal\ policy\ rate\ gap\ in\ period\ t} = R_t - R^*$$
$$R_t = \mathit{policy\ rate\ in\ period\ t}$$
$$R^* = \mathit{long\_run\ normal\ level\ of\ policy\ rate} = \Pi^* + EQRR$$
$$EQRR = \mathit{long\_run\ equilibrium\ real\ rate}$$

2. Central Bank Objective Function and Optimal Policy With Known Persistence

Optimal policy when the value of the persistence parameter, ρ, is a known value is a useful reference point. The central bank is assumed to minimize a standard quadratic objective function of the form shown in equation (5).

$$V = E\{\pi_{t+1}^2\} + E\{y_{t+1}^2\} \tag{5}$$

Using the definitions in equation (3) and (4):

$$E\{\pi_{t+1}^2\} = (\rho\mu\pi_t + (1 - \mu)r_t)^2 + \mu^2\beta^2\sigma_u^2 + \mu^2\sigma_v^2 \tag{5.1}$$
$$E\{y_{t+1}^2\} = (-\alpha\mu r_t + \alpha\rho\mu\pi_t)^2 + (1 + \alpha\mu\beta)^2\sigma_u^2 + (\alpha\mu)^2\sigma_v^2 \tag{5.2}$$

The optimal value of the policy rate gap satisfies the first order condition:

$$foc: (\rho\mu\pi_t + (1 - \mu)r_t)(1 - \mu) + (-\alpha\mu r_t + \alpha\rho\mu\pi_t)(-\alpha\mu) = 0$$

And the solution for the optimal choice of the policy rate gap is then:

$$r_t = \left(\frac{1+\frac{\beta}{\alpha}}{1+\beta^2}\right) \rho\pi_t \qquad (6)$$

The response of the policy rate gap to the current-period inflation gap is larger when inflation is more persistent. With this solution for the policy rate gap, the expected next period values of the output and inflation gaps are:

$$E\{y_{t+1}\} = -\left(\frac{\beta}{(1+\beta^2)}\right)\rho\pi_t \qquad (7)$$

$$E\{\pi_{t+1}\} = \left(\frac{1}{(1+\beta^2)}\right)\rho\pi_t \qquad (8)$$

Using equations (6) and (8), the optimal choice for the policy rate gap can be expressed equivalently as:

$$r_t = (1 + \frac{\beta}{\alpha})E\{\pi_{t+1}\}$$

The upshot is that the solution for the policy rate gap satisfies the so-called Taylor Principle; the nominal policy rate gap, r_t, moves up more than one for one with changes in expected inflation.

3. Uncertainty About the Persistence Parameter

Policymakers do not know the persistence parameter for inflation with certainty and indeed may be quite uncertain about its value. A useful case to consider in analyzing the effects of uncertainty about the persistence parameter is one in which the persistence parameter is a random variable, $\tilde{\rho}$, that takes on a value of 0 (no persistence) or 1 (full persistence). In the following discussion, the outcome with full inflation persistence is viewed as a tail risk and the probability of the full persistence outcome is $\theta < 1/2$.

$$\tilde{\rho} = 0 \; with \; probability \; (1-\theta) \; and \; \tilde{\rho} = 1 \; with \; probability \; \theta$$

What exactly are policymakers supposed to do when faced with this uncertainty? The following sections work through a number of possible risk management approaches.

4. "Looking Through" Uncertainty with the Modal Outlook

One possible approach to policy in this environment might be to simply use the optimal choice for the policy rate in the case with certainty but substitute the most likely value of $\tilde{\rho}$ for ρ in equation (6). The most likely value of the persistence parameter in this example is 0, (recall we assumed $\theta < \frac{1}{2}$), so the choice of the policy rate gap following this strategy would also be set at 0, ignoring any potential for persistence of inflation. Of course, the modal outlook approach is not very attractive from an analytical perspective. On the other hand, if the tail risk probability θ is fairly low, the ex-post policy mistakes from following this approach would be infrequent and the stance of policy in most circumstances would be consistent with output close to potential and inflation close to target.

5. The Bayesian Approach and Subjective Uncertainty About ρ

While there may be some merits to the modal outlook approach in some cases, there are obvious shortcomings as well. The modal outlook approach takes no account of the risks and costs associated with a very adverse outcome. A standard approach to more fully incorporating uncertainty about inflation persistence focuses instead on minimizing the expected value of the central bank's loss function.[7,8]

$$V(\theta,r_t) = E\{y_{t+1}^2\} + E\{\pi_{t+1}^2\}$$
$$= \theta(\mu\pi_t + (1-\mu)r_t)^2 + (1-\theta)((1-\mu)r_t)^2 + \theta(-\alpha\mu r_t + \alpha\mu\pi_t)^2 + (1-\theta)(-\alpha\mu r_t)^2$$

The optimal choice of the policy rate gap in this case satisfies the first order condition:

$$\theta(\mu\pi_t + (1-\mu)r_t)(1-\mu) + (1-\theta)\big((1-\mu)r_t\big)(1-\mu) + \theta(-\alpha\mu r_t + \alpha\mu\pi_t)(-\alpha\mu) +$$
$$(1-\theta)(-\alpha\mu r_t)(-\alpha\mu) = 0$$

The solution for the optimal interest rate gap is:

$$minimum\colon r_t = \left(\frac{1+\frac{\beta}{\alpha}}{1+\beta^2}\right)\theta\pi_t = \left(1+\frac{\beta}{\alpha}\right)E\{\pi_{t+1}\} \qquad (9)$$

This expression looks very similar to equation (6) in the case with a certain persistence parameter but with ρ replaced with the probability parameter θ. Under our assumptions, $\theta = E\{\tilde{\rho}\}$, so the Bayesian approach replaces the certain value of ρ in equation (6) with the expected value of $\tilde{\rho}$. This is an example of the so-called certainty equivalence property that often arises in connection with analysis of uncertainty with quadratic loss functions. The policy rate gap again incorporates the Taylor principle by responding more than 1 for 1 to expected inflation.[9]

Similar to the expressions above, the expected value of the next-period output and inflation gaps are given by:

$$E\{y_{t+1}\} = -\left(\frac{\beta}{1+\beta^2}\right)\theta\pi_t$$
$$E\{\pi_{t+1}\} = \left(\frac{1}{1+\beta^2}\right)\theta\pi_t$$

6. Robust Min Max Policy

In the Bayesian approach to uncertainty, policymakers are assumed to have a subjective probability distribution for the range of possible outcomes for the persistence parameter. In some cases, policymakers may be so uncertain that they cannot even assign a probability to different outcomes. In this case, the central bank could use a scenario-based approach following a "robust min-max" strategy.[10] In this approach, the policymaker examines the worst-case outcome for each possible setting of the policy rate gap in the current period and then chooses the policy rate gap to minimize the losses associated with the worst-case outcome. In this approach, the policymaker may choose a relatively high setting for the policy rate even if the true unknown probability for that scenario is quite low.

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[7] Aspects of the Bayesian approach to decision making under uncertainty were developed in the 19th century. The seminal paper by Savage (1951) is often cited as laying the foundation for the much of the work on Bayesian analysis in following years.

[8] The variance terms $\mu^2\beta^2\sigma_u^2 + \mu^2\sigma_v^2$ and $(1+\alpha\mu\beta)^2\sigma_u^2 + (\alpha\mu)^2\sigma_v^2$ in equations 5.1 and 5.2 play no role in the analysis and are suppressed in all that follows for convenience.

[9] The certainty equivalence result regarding uncertainty about inflation persistence holds in this simple two-period example but does not hold in general. When the policymaker is considering optimal policy over a longer horizon, uncertainty about inflation persistence interacts directly with policy decisions. (See Soderstrom, 2002).

[10] Wald (1949) is often credited with introducing the robust min-max approach to decision-making under uncertainty.

The value of the central bank objective function in each scenario is given by:

$$V(\tilde{\rho} = 0, r_t) = \left((1-\mu)r_t\right)^2 + (-\alpha\mu r_t)^2$$

And

$$V(\tilde{\rho} = 1, r_t) = (\mu\pi_t + (1-\mu)r_t)^2 + (-\alpha\mu r_t + \alpha\mu\pi_t)^2$$

There are two points that could be the min max solution: (i) the minimum point for $V(\tilde{\rho} = 1)$ or the point at which $V(\tilde{\rho} = 0) = V(\tilde{\rho} = 1)$. The value of the policy rate gap corresponding to the minimum point for $V(\tilde{\rho} = 1)$ is:

$$r_t = \left(\frac{1+\frac{\beta}{\alpha}}{1+\beta^2}\right)\pi_t \tag{10}$$

And the point at which $V(\tilde{\rho} = 0) = V(\tilde{\rho} = 1)$ is given by:

$$((1-\mu)r_t)^2 + (-\alpha\mu r_t)^2 = (\mu\pi_t + (1-\mu)r_t)^2 + (-\alpha\mu r_t + \alpha\mu\pi_t)^2$$

Or

$$\hat{r}_t = \left(\frac{1+\alpha^2}{2\cdot(\alpha^2+\beta\alpha)}\right)\pi_t \tag{11}$$

The robust min-max choice for the policy rate gap is determined by either equation (10) or equation (11). For positive values of π_t, $V(\tilde{\rho} = 1, r_t) > V(\tilde{\rho} = 0, r_t)$ when $r_t < \hat{r}_t$. In addition, the value of the objective function evaluated at the equality point $\hat{r}_t$ must be greater or equal to the minimum of $V(\tilde{\rho} = 1, r_t)$. So the solution in (10) will be the min-max solution if:

$$\left(\left(\frac{1+\frac{\beta}{\alpha}}{1+\beta^2}\right)\right) < \left(\frac{1+\alpha^2}{2\cdot(\alpha^2+\beta\alpha)}\right)$$

When this condition holds, the minimum value of $V(\tilde{\rho} = 1, r_t)$ will be the worst case scenario for the corresponding value of the policy rate and that value of the loss function at that point will be lower than the value of the objective function evaluated at the equality point (11). For the parameterizations used in this note with $\beta = 0.1$ and $\alpha = 0.4$, this condition holds and the candidate solution in equation (10) is the min-max solution in this case.

7. Regret-Robust Policy

In the robust min-max approach, the central sees the persistent inflation outcome as very costly no matter what policy rate gap is chosen. As a result, this approach may be viewed as overweighting the persistent inflation outcome in the determination of the policy rate gap. A variation of the robust min-max approach addresses this potential shortcoming by focusing only on “regrets” rather than absolute values of the loss function.[11] Regrets are defined as the value of the loss function relative to what could have been achieved with perfect information. In our example, this approach puts the two scenarios on a more equal footing.

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[11] Savage (1951) introduced the concept of regret in decision analysis.

The solution for the regret-robust approach is always determined by the equality condition. And in the example, the solution occurs at a point halfway between the optimal choice of the policy rate assuming zero persistence and the optimal choice of the policy rate assuming full persistence. Formally, the regrets defined in this way for the two scenarios are:

$$Regret(\tilde{\rho}=0,r_t)=\left((1-\mu)r_t\right)^2+(-\alpha\mu r_t)^2$$

And

$$Regret(\tilde{\rho}=1,r_t)=(\mu\pi_t+(1-\mu)r_t)^2+(-\alpha\mu r_t+\alpha\mu\pi_t)^2-\left(\frac{1}{1+\beta^2}\right)\pi_t^2$$

The equality condition, $Regret(\tilde{\rho}=1)=Regret(\tilde{\rho}=0)$, determines the regret-robust min-max solution at:

$$r_t=(\tfrac{1}{2})(\tfrac{1+\frac{\beta}{\alpha}}{1+\beta^2})\,\pi_t \qquad (12)$$

This point is half way between the argmin for $V(\tilde{\rho}=0,r_t)$ and the argmin for $V(\tilde{\rho}=1,r_t)$.

8. Credibility Hawk: Bayesian Objective Function Where the Distribution of Outcomes is a Function of Policy Actions

Yet another twist on risk management may arise in cases in which policymakers believe that their actions can affect the likelihood of particular outcomes. This might be the case, for example, if policymakers judged that a policy action would reinforce the central bank's credibility as an inflation fighter and thus keep inflation expectations well anchored at levels consistent with the central bank's long-run inflation objective. In this case, the policymaker might act like a Bayesian but recognize that the choice of the policy instrument could affect the shape of the probability distribution over potential future outcomes. This may give the policymaker more incentive to tighten policy in the face of a potential adverse inflation shock because doing so both directly helps to mitigate future inflation and also lowers the probability that today's inflation shock will be persistent.

The expected value of the loss function is the same as in the Bayesian case:

$$V(\theta,r_t)=\theta(\mu\pi_t+(1-\mu)r_t)^2+(1-\theta)((1-\mu)r_t)^2+\theta(-\alpha\mu r_t+\alpha\mu\pi_t)^2+(1-\theta)(-\alpha\mu r_t)^2$$

However, the probability of the adverse outcome in this case is itself a function of the policy rate gap, $\theta=\theta(r_t)$ with the derivative $\theta_{r_t}<0$. With this structure, the first order condition is:

$$V_{r_t}=V_{r_t}(Bayesian,r_t)+(\theta_{r_t}/2)(V(\tilde{\rho}=1,r_t)-V(\tilde{\rho}=0,r_t))=0 \qquad (15)$$

The solution for the policy rate gap thus involves an additional term beyond that associated with the simple Bayesian loss function. The simple Bayesian solution sets the first term on the right hand side of equation (15) equal to zero but the second term would be negative. With the parameterization in this note and a simple assumption about the form of $\theta(r_t)$, the credibility hawk solution will involve somewhat tighter policy than the simple Bayesian approach. The function $\theta(r_t)$ is specified as $\theta(r_t)=.4\cdot\exp(-\tau\cdot r_t)$. In the example, τ is set at 25 implying that a 1 percentage point increase in the interest rate gap reduces the probability of persistent inflation by 25 percent.

9. Robust Simple Rules

The various approaches to uncertainty described above all have some appeal but there are very significant challenges in applying such approaches in practice. Perhaps most importantly, optimizing approaches require policymakers to have a common model of the economy. In addition, the nature of the uncertainty faced by policymakers is much more extensive than that captured by the illustrative example in this note. In light of these challenges, a very important strand of the literature has focused on developing "robust simple rules" describing the setting of the policy rate as a function of observed values of output and inflation. The robust simple rules literature focuses on rules that perform well across a number of different types of models and all subject to a range of shocks. Robust simple rules are often specified as functions of the observed values of a selected economic variables. Of course, the Taylor Rule is the most famous example of this type of rule. Outcome-based policies of this type are largely "model-free" in that they do not typically depend on expectations of future variables.

The original version of the Taylor Rule is specified as:

$$R_t = EQRR + \Pi_t + 0.5 \cdot (\Pi_t - \Pi^*) + 0.5 \cdot y_t$$

Expressed in terms of the notation used throughout this note, the Taylor rule is:

$$r_t = 1.5 \cdot \pi_t + 0.5 \cdot y_t$$

The original Taylor Rule thus prescribes a value of the policy rate gap that is 1.5 times the contemporaneous value of the inflation gap and 0.5 times the contemporaneous value of the output gap. In the example, an inflation shock in the current period pushes current period inflation gap up by 1 percentage point. Moreover, the increase in inflation depresses the current period real interest rate and boosts the current-period output gap by about 40 basis points. Given these inputs, the Taylor Rule prescribes an increase of about 170 basis points in the policy rate gap chosen in the current period.

Parameterization

The parameterizations for β and α above are chosen so that the impulse responses of a 1 percentage point policy tightening on inflation and output roughly match those reported by Laforte (2018) for the FRB/US model. Figure 2 in Laforte shows plots of the FRB/US impulse responses indicating that a 100 basis point shock to the funds rate lowers the output gap by about 0.4 percentage points after four quarters and reduces PCE inflation by about 0.04 percentage points after four quarters. The effect of a 100 basis point shock in this note is embedded in the coefficient on the interest rate gap term in equations (3) and (4) above. Using the parameter settings for the Phillips curve and IS curve coefficients, the coefficients on the policy rate gap in equations (3) and (4) are 0.042 and 0.42, respectively. As discussed in the text, the probability of persistent inflation is set at 0.4. And the shock to current period inflation, v_t, is set at 0.0096 – a value that pushes up current period inflation by 1 percentage point. Values of all other shocks in the current period as well as inflation from the prior period are set at zero. The expected values of future shocks to output and inflation are zero as well.

Name	Variable	Values
Inflation Shock	v_t	0.0096
Probability of persistent inflation	θ	0.4
Slope of Phillips Curve	β	0.1
Slope of IS Curve	α	0.4

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