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Monetary Policy Strategies to Foster Price Stability and a Strong Labor Market

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Abstract

I assess monetary policy strategies to foster price stability and labor market strength. The assessment incorporates a range of challenges, including uncertainty regarding the equilibrium real interest rate, mismeasurement of economic potential, and balancing the costs and benefits associated with employment shortfalls and labor market strength. I find that the ELB remains a significant constraint, hindering achievement of the inflation objective and worsening employment shortfalls. Symmetric policy reaction functions mitigate the most adverse effects of employment shortfalls by contributing to economic stability. Make-up strategies address ELB risks. These strategies call for policy to accommodate some period of inflation above its long-run objective following an ELB episode. I also consider an asymmetric shortfalls approach to policy. This approach provides accommodation in response to weak activity while foregoing tightening in response to strong activity. While the approach can, in principle, address ELB risks by raising inflation, it performs poorly. The shortfalls approach exacerbates economic volatility, worsens employment shortfalls, and creates excess inflationary pressures. Mismeasurement is not sufficient to limit the importance of strong responses to measured slack. Overall, monetary policy can promote price stability and labor market strength by focusing on economic stability, with a strategy targeted to address ELB risks.

Keywords: Monetary policy; Rules and discretion, effective lower bound, symmetric loss function, asymmetric loss function

JEL Codes: E52, E58, E37

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1. Introduction

Inflation targeting has become the standard monetary policy approach among advanced economies. Following adoption by a handful of central banks in the 1990s, over 60 central banks targeted inflation by the early 2020s, reflecting the success of the approach in promoting price and economic stability.[1] Nonetheless, inflation targeting must grapple with enduring and new challenges. Price stability and strong labor markets are complementary in the long run but may be in conflict at times. Low interest rates in the 2010s constrained the ability of central banks to achieve price and economic stability. The ability of forward guidance and quantitative easing to offset these constraints has been debated. Some have called for additional goals for monetary policy, such as greater focus on creating high pressure in labor markets and combating inequality.

Against this backdrop, I revisit three questions that recent experience suggests are critical for monetary policy strategies:

- Is the ELB likely to bind, and, if so, what strategies can mitigate any adverse effects?
- Should policy respond to measured slack and, if so, how forcefully and symmetrically?
- How can monetary policy promote labor market strength, with price stability?

The assessment includes factors that could limit the efficacy of a strategy. Uncertainty regarding the equilibrium real interest rate, r*, is considerable. A strategy should be robust to low values of the r*, such as those seen in the 2010s around the world, as well as to much higher values, such as those that prevailed in the 1980s and that may prevail going forward. The potential influence of mismeasurement in resource utilization requires incorporation of realistic, and potentially sizable, measurement error. Emphasis on employment shortfalls in monetary policy calls for a comparison of symmetric and asymmetric approaches to the promotion of full employment.

The results demonstrate that the ELB remains an important factor in monetary policy design. The quantitative analysis assumes that the distribution of the equilibrium real interest rate is centered on 2 percent, with only a 15 percent probability that the equilibrium real interest rate is below 1 percent as assumed in the FOMC's Summary of Economic Projections. Even so, the ELB has a sizable effect on economic performance.

[1] Kiley and Mishkin (2024) note that 64 countries were inflation targeters in 2022.

Because the ELB continues to represent an important constraint on stabilization policy, strategies to offset this constraint are needed. A broad set of make-up policy strategies ensure good economic performance. These make-up strategies provide additional accommodation following an ELB episode, with the degree of such accommodation tied to the achievement of policy objectives. A make-up strategy may condition liftoff from the ELB on the achievement of inflation above a threshold value and resource utilization rising to a sufficient level. Such approaches "make-up" forgone accommodation until the thresholds are reached and then revert to a symmetric rule. For example, the inflation threshold could involve inflation rising above its long-run objective and the resource utilization threshold could involve the unemployment rate falling to a level somewhat above its natural rate, with reversion to a standard policy rule when these thresholds are met. These approaches are versions of the Evans (2011) rule and the inflation threshold strategy of Bernanke, Kiley, and Roberts (2017). I show that these approaches, which involve a balanced approach to inflation and activity, limit economic volatility.

In addition to make-up strategies, central banks have deployed quantitative easing to provide accommodation when the ELB constrains the short-term policy interest rate. In the model simulations, make-up strategies are effective, in isolation, at mitigating ELB risks. This finding may overstate the efficacy of the forward guidance under make-up strategies. The prevalence of quantitative easing in practice suggest that it is important to assess how make-up strategies and quantitative easing interact. For example, make-up strategies and quantitative easing may, in combination, provide excessive stimulus. I show that strong and symmetric responses to inflation and activity in a policy rule guard against excessive stimulus, as such responses remove accommodation promptly when needed. Moreover, the benefits of strong and symmetric responses to inflation and activity are not affected significantly by mismeasurement in economic slack or the equilibrium real interest rate.

A different approach to offsetting adverse effects of the ELB introduces an asymmetry in policy to counteract indirectly the asymmetry induced by the ELB. Gust, Lopez-Salido, and Meyer (2017), Bundick and Petrosky-Nadeau (2023), and Penalver and Siena (2024) note that the ELB induces a downward bias in inflation. These authors emphasize that a monetary policy strategy that does not lean against labor market strength—and instead only acts to counteract employment shortfalls—can induce an upward bias to inflation and thereby mitigate ELB risks. This idea was also discussed in the FOMC's Tealbook B in 2016, with simulations of such an asymmetric approach presented regularly thereafter (based on the most recent versions available to the public). Fuentes-Albero and Roberts (2021), Papell and Prodhan (2022) and recent Federal Reserve *Monetary Policy Reports* present policy rules of this type. I show that this shortfall approach offsets ELB risks, but to a degree that is not tied to the degree of ELB risk. As a result, this approach is ineffective and can interact poorly with quantitative easing, risking excessive stimulus.

Monetary policy discussions have also emphasized costs to employment shortfalls and benefits to labor market strength (e.g., Bernstein and Bentele, 2019; Evans, 2024). The asymmetric loss functions and policy rules in Gust, Lopez-Salido, and Meyer (2017), Fuentes-Albero and Roberts (2022), Bundick and Petrosky-Nadeau (2023), and Penalver and Siena (2024) capture the idea that asymmetric benefits and costs of labor market outcomes may lead to asymmetric policy strategies. I show that an asymmetric shortfalls strategy can exacerbate economic volatility and worsen employment shortfalls, which may be costly to disadvantaged groups (Hotchkiss and Moore, 2022). Symmetric policy strategies mitigate the most adverse effects of employment shortfalls by contributing to stability. Earlier research also suggested that monetary policy can best promote the well-being of disadvantaged groups by focusing on stability (e.g., Romer and Romer, 1999).

The analysis uses two tools to explore the issues—a simple New-Keynesian model to illustrate some central issues and a large-scale policy model, the Federal Reserve's FRB/US model, to quantitatively assess alternative strategies. Section 2 provides motivation and background. Section 3 presents a New-Keynesian model. Section 4 quantitatively evaluates symmetric make-up strategies and their interactions with quantitative easing in FRB/US. Section 5 examines an asymmetric shortfalls monetary policy. Section 6 considers mismeasurement and risk-management issues. Section 7 concludes and highlights areas for further research.

2. Motivation

Developments since the Global Financial Crisis of 2008 have challenged aspects of the consensus strategy to achieve price stability and full employment. Across advanced economies, the prolonged period of low interest rates pointed to a lower level of the neutral real interest rate. In addition, inflation persistently fell (modestly) short of the 2 percent inflation objective in the 2010s. And policymakers continued to grapple with the measurement of slack. For example, the midpoint of the range of the central tendency of long-run value for the unemployment rate reported in the FOMC's Summary of Economic Projections fell from 5.6 percent to 4.1 percent between

2011 and 2019. The combination of unemployment falling to low levels with inflation remaining below objective led to questions on whether monetary policy should focus less on the level of resource utilization and more on employment shortfalls.

These considerations motivate the questions analyzed:

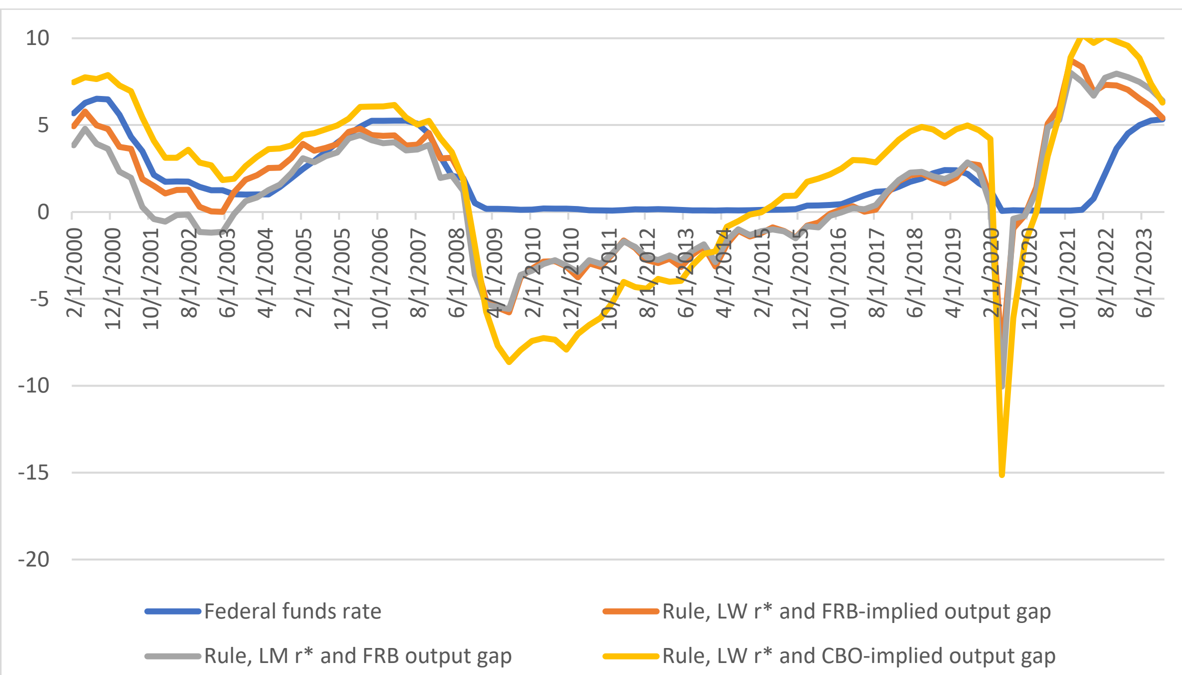
- Is the ELB likely to bind, and, if so, what strategies can mitigate any adverse effects?
- Should policy respond to measured slack and, if so, how forcefully and symmetrically?
- How can monetary policy promote labor market strength, with price stability?

Figure 1 provides some perspective on the salience of various factors for policy strategy by presenting prescriptions from the interest rate rule of Taylor (1999),

$$r(t) = r^*(t) + \pi^* + 1.5\{\pi(t) - \pi^*\} + \{y(t) - y^*\},$$

where $r^*(t)$ is the equilibrium real interest rate, π^* is the inflation objective, $\pi(t)$ is inflation (Core PCE inflation, over the previous four quarters), and $y - y^*$ is the output gap. Two measures of the equilibrium real interest rate (from Laubach and Williams, 2003, and Lubik and Matthes, 2015) and two measures of the output gap (from the CBO and the Federal Reserve Board) are used.

Figure 1: Simple rule with alternative r and output gap measures*



Source: Author’s calculations and Federal Reserve Bank of Atlanta.

Is the ELB likely to bind, and, if so, what strategies can mitigate any adverse effects?

While the ELB may appear to be a post-2008 development, there were signs of its relevance much earlier. Figure 1 highlights this point, as the rule prescriptions associated with the FRB-implied output gap and both the Lubik-Matthes (2015) and Laubach-Williams (2003) models hit the effective lower bound following the 2000 recession. Krugman (1998), in his analysis of Japan's 1990s ELB experience, highlighted the possibility that the ELB would bind elsewhere. More than three decades ago, Summers (1991) warned that the ELB could bind as inflation converged to levels below those of the 1980s. This literature informed analyses sent to policymakers when the Global Financial Crisis struck (e.g., Erceg, Kiley, and Levin, 2008).

The potential salience of the ELB, even for high equilibrium real interest rates, is easy to see. For example, consider an inflation target of 2 percent and an equilibrium real interest rate of 2. Reductions in the federal funds rate around recessions prior to the binding ELB period were five percentage points or more (Reifschneider, 2016; Kiley, 2018). Hence, if a recession were to begin with nominal interest rates around an implied steady-state level of 4 percent, the ELB would normally bind following a recession.

The effective lower bound on nominal interest rates became a significant constraint on monetary policy in the 2010s (Figure 1). The binding ELB reflected both the depth of the Great Recession and the trend decline in nominal and real interest rates from the 1980s to 2010s. This trend decline led to a substantial body of work on the long-run value of the real interest rate—often called the equilibrium real interest rate r*--including the contributions of Laubach and Williams (2003) and Lubik and Matthes (2015) used in Figure 1. By the 2010s, estimates suggested that the level of the equilibrium real interest rate had fallen below 1 percent (e.g., Kiley, 2020a). More recently, the federal funds rate has risen above 5 percent, against a backdrop of elevated fiscal deficits and a strong labor market. These developments have raised the question of whether the ELB remains a relevant policy consideration. The salience of the ELB pre-2008 suggests that the ELB may be relevant even if the post-2021 return of somewhat higher nominal interest rates signals a return of r* to pre-2008 levels.

Should policy respond to measured slack and, if so, how forcefully and symmetrically?

Figure 1 illustrates clearly how uncertainty regarding resource utilization and the equilibrium real interest rate has sizable effects on the policy guidance provided by rules. The range of prescriptions implied by alternative estimates of these unobservable variables is wide over the past two decades. A concern around measurement of economic slack and policy action is not new. Orphanides (2001) illustrated that real-time assessments of slack differed sizably from ex-post assessments and that these differences are important in understanding the course of monetary policy in the United States from the 1960s to the 1990s. Orphanides (2003) found that mismeasurement in the output gap and more forceful responses of monetary policy to the output gap during the 1970s were important in the failure of monetary policy to contain inflation at that time.[2] Orphanides and van Norden (2002) quantified the (sizable) degree of uncertainty regarding the output gap in real time. More recently, monetary policy analysis was increasingly focused on uncertainty about the long-run equilibrium real interest rate.[3]

The Taylor (1993) rule is a well-known example of a class of rules that promotes good economic performance. An extensive line of research supports stronger reaction coefficients than in Taylor (1993).[4] For example, Henderson and McKibbin (1993) find that a policy rule of the Taylor (1993) form, but with larger reaction coefficients to both inflation and activity, results in better economic performance than the baseline Taylor (1993) specification. The balanced approach rule of Yellen (2017), which draws from Taylor (1999), features such a stronger long-run response to activity relative to Taylor (1993).

Because good monetary policy calls for strong responses to the output gap in many models and mismeasurement in the output gap is sizable, there is the potential for strong policy responses to the output gap to induce excessive volatility. The implications for policy of mismeasurement for policy rules have been assessed in a number of macroeconomic models, with several broad takeaways.[5] Mismeasurement implies that policy responds to measurement errors, inducing unwanted volatility in inflation and activity. In general, mismeasurement of the output gap or

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[2] Boivin, Kiley, and Mishkin (2010) also identify changes in monetary policy consistent with Orphanides (2003).

[3] For example, Lubik and Matthes, 2015; Holston, Laubach, and Williams, 2017; Kiley, 2020a, 2020b.

[4] For example, Levin, Wieland, and Williams (1999), Rudebusch (2001), Orphanides and Williams (2005).

[5] The related literature is long. Contributions include Orphanides et al (2000), Rudebusch (2001), and Orphanides and Williams (2002, 2005, 2007). Taylor and Williams (2010) review the literature.

natural rate of unemployment calls for less response to output gaps in a monetary policy reaction function. However, this attenuation is not exceptionally large and does not imply zero response. This occurs because macroeconomic models often imply that sizable responses to output or unemployment gaps improve economic performance in the absence of measurement error and measurement error does not eliminate such improvement.

How can monetary policy promote labor market strength, with price stability?

Research in the 2010s re-emphasized potential benefits of a high-pressure labor market. For example, Aaronson et al (2019) find evidence that disadvantaged groups benefit more from strong labor markets. Bernstein and Bentele (2019) argue that the benefits of a high-pressure labor market for disadvantaged groups may suggest that monetary policy should pursue a high-pressure labor market. The idea that the socially desirable level of employment involves a high-pressure labor market is not new. For example, it is the basis of the inflationary challenges from time-inconsistency in Barro and Gordon (1983). Nonetheless, increases in inequality and advances in how macroeconomic models can account for inequality in labor market outcomes has renewed focus on how monetary policy can promote labor market strength or address inequality (e.g., Feiveson et al, 2020; Chang, 2022).[6]

More generally, research has suggested monetary policy loss functions or rules focused only on employment shortfalls may promote good policy. For example, Gust, Lopez-Salido, and Meyer (2017) and Penalver and Siena (2024) suggest that an asymmetric approach to activity, in which accommodation is provided when activity is weak but policy is not tightened in response to strong activity, may raise inflation and thereby limit ELB risks. Publicly available versions of Tealbook B since 2016 featured such asymmetric approaches. Researchers (e.g., Fuentes-Albero and Roberts, 2021; Prodhan and Papell, 2022) and the Federal Reserve's *Monetary Policy Report* have presented such shortfalls-based policy rules.[7]

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[6] Kiley and Mishkin (2024) provide references on discussions of inequality in central bank mandates.

[7] Fed Listens events emphasized the benefits of labor market strength and contributed to the focus on employment shortfalls in the FOMC's 2020 framework (as discussed in Evans, 2024). Altig et al (2020) and Clarida (2022) discuss the FOMC's 2020 framework, including the focus on shortfalls and the salience of the ELB.

3. Insights on Price Stability and Strong Labor Markets from a Simple Model

To assess a policy strategy, an objective function and instruments to execute the strategy are needed (Erceg, Kiley, and Lopez-Salido, 2011). I assume the inflation target is 2 percent.[8] The primary instrument is assumed to be the short-run policy interest rate. The quantitative analysis in the large-scale policy model will also consider quantitative easing.

The objective function is an area of debate. It is common for research to consider alternatives. One common form is a symmetric loss function around the inflation target and output around potential (e.g., Bernanke, Kiley, and Roberts, 2019). A second common form is a symmetric loss function with the desirable level of output above potential (Barro and Gordon, 1983). A form emphasized in recent work is a shortfalls loss function including only output below potential (Gust, Lopez-Salido, and Meyer, 2017; Penalver and Siena, 2024).[9] Policy analysis at central banks has also considered versions of these loss functions.[10] The analysis will consider all these loss functions and emphasize policy approaches that are good under each specification. Kiley (2024) develops the implications of asymmetric loss functions for activity shortfalls and inflation, including a characterization of the desirability of symmetric monetary policy approaches in cases where the social loss function is asymmetric.

A simple New-Keynesian model

The first tool used to answer the questions analyzed is a simple New-Keynesian model.[11] The small model takes a form familiar from academic research (e.g., Clarida, Gali, and Gertler, 1999; Woodford, 2003; Gali, 2008). Aggregate supply is represented by a New-Keynesian Phillips curve linking inflation to expected inflation, the output gap, and a cost-push (supply) shock, as in

Equation 1: $\pi(t) = E\{\pi(t+1)\} + \kappa y(t) + u(t)$.

In equation 1, π denotes inflation, $E\{\ \}$ is the expectations operator based in period t information, y is the output gap, u is the supply shock, and κ is a (positive) parameter. Note that a coefficient of unity is assumed on expected inflation to ensure the long-run neutrality of inflation.

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[8] A variety of factors contributed to a convergence on a 2 percent target across advanced economies prior to 2008; for example, see Kiley, Mauskopf, and Wilcox (2007).

[9] There are other ways to introduce asymmetry in a loss function, such as the linex specification in Surico, 2007.

[10] E.g., materials for the FOMC in 2018 at The Fed - Transcripts and other historical materials (federalreserve.gov)).

[11] Small models can illustrate properties that are shared by larger models (e.g., Kiley, 2016).

Inflation is positively related to expected future inflation (reflecting the role of future expected prices in current price-setting when prices are adjusted infrequently). Output above potential raises inflation.

The IS curve is given by

Equation 2: $y(t) = E\{y(t+1)\} - \sigma[r(t) - E\{\pi(t+1) - r^*(t)\}$.

In equation 2, r represents the short-term interest rate, r^* is an aggregate demand shock, and σ is a parameter. The deviation of output from potential depends negatively on the real interest rate.

Optimal (discretionary) policy with objectives that favor strong activity/employment

Optimal policy highlights the properties of good monetary policy. The analysis considers three specifications for the policymaker loss function, each involving inflation and the output gap. This analysis will look for commonalities in good policy across specifications will not take a stand on which loss function may be better for central banks' mandates.[12]

The first loss function is quadratic around the inflation target and potential output, with symmetric treatment of activity/the labor market:

$$L(t) = [\pi(t) - \pi^*]^2 + \alpha[y(t)]^2$$

With this loss function, policymakers view positive and negative deviations from the inflation objective and of output from potential as equally costly.

The second loss function is quadratic around the inflation target and a level of output $y^* > 0$:

$$L(t) = [\pi(t) - \pi^*]^2 + \alpha[y(t) - y^*]^2$$

With this loss function, policymakers prefer strong activity/labor markets ($y^* > 0$). This loss function can be derived as a second-order approximation to a micro-founded welfare criterion when the economy has frictions that imply that the steady-state level of activity is lower than socially desirable.

The third loss function is quadratic in deviations from the inflation target and output shortfalls $y(t) < 0$:

$$L(t) = [\pi(t) - \pi^*]^2 + \alpha \cdot [\min(\mathrm{y(t)}, 0)]^2$$

[12] The idea that a central bank can adopt, or be given, a loss function and then conduct monetary policy in light of that loss function is related to the central bank governance literature, for example the work of Walsh (1995).

With this loss function, policymakers view shortfalls of output from potential costly and do not perceive costs to any level of output above potential.

Table 1 presents the criteria that determine optimal policy (under discretion) for each loss function when the ELB may bind, with summaries of the implications of optimal policy for economic outcomes.

One key result across all policy approaches is that activity will equal potential, on average, under all the policy approaches. This occurs because of the structure of the Phillips curve (equation 1), in which expected inflation feeds into inflation one-for-one and there is no long-run tradeoff between inflation and activity. This property is the Friedman-Phelps insight on the distinction between the short-run tradeoff—where a Phillips curve operates—and long-run outcomes, where no such tradeoff exists. In general, research has adopted the absence of a long-run tradeoff between inflation and output.[13]

A second outcome common across policy approaches is that optimal policy should stabilize the economy in response to a demand shock absent the ELB. Under optimal policy for any of these loss functions when the ELB does not bind, inflation should have the opposite sign of the output gap—which implies stabilizing the effect on inflation and output of a demand shock. This property shapes the need for optimal policy to respond forcefully to both inflation and the output gap, discussed below.

[13] Milton Friedman (1968) and Edmund Phelps (1968) independently developed the natural rate hypothesis. Kiley and Mishkin (2024) feature this as one of the core principles in the science of monetary policy.

Table 1: Equilibrium Dynamics in the New-Keynesian model under Optimal Discretionary Policy

<table>
<tr><td colspan="3">Structural equations</td></tr>
<tr><td colspan="3">Phillips curve: $\pi(t) = E\{\pi(t+1)\} + \kappa y(t) + u(t)$</td></tr>
<tr><td colspan="3">IS curve: $y(t) = E\{y(t+1)\} - \sigma[r(t) - E\{\pi(t+1) - r^*(t)\}$</td></tr>
<tr><td colspan="3">Effective lower bound: $r(t) > r_{elb}$</td></tr>
<tr><td colspan="3">Policymaker Loss Function</td></tr>
<tr><td>Symmetric treatment of strong/weak activity and labor market</td><td colspan="2">Asymmetric treatment of strong/weak activity, with policymakers preferring strong activity/labor markets</td></tr>
<tr><td>Quadratic loss function around inflation target and potential output
$L(t) = [\pi(t) - \pi^*]^2 + \alpha[y(t)]^2$

• Policymakers view +/- deviations from the inflation objective and of output from potential as equally costly.</td><td>Quadratic loss function around inflation target and socially efficient level of output $y^* > 0$
$L(t) = [\pi(t) - \pi^*]^2 + \alpha[y(t) - y^*]^2$

• Policymakers view shortfalls of output from potential as more costly than equivalent levels of output above potential—and perceive benefits to output somewhat above potential (i.e., to $0 < y(t) < y^*$).</td><td>Quadratic loss function around inflation target and for output shortfalls $y(t) < 0$
$L(t) = [\pi(t) - \pi^*]^2 + \alpha \cdot [\min(y(t), 0)]^2$

• Policymakers view shortfalls of output from potential as more costly than equivalent levels of output above potential—and do not perceive costs to any level of output above potential.</td></tr>
<tr><td colspan="3">Equilibrium dynamics</td></tr>
<tr><td>Optimal relationship between inflation and output
$\pi(t) = \pi^* - \frac{\alpha}{\kappa} \; y(t) - \lambda_{elb}(t)$</td><td>Optimal relationship between inflation and output
$\pi(t) = \pi^* + \frac{\alpha}{\kappa} \; y^* - \frac{\alpha}{\kappa} \; y(t) - \lambda_{elb}(t)$</td><td>Optimal relationship between inflation and output
$\pi(t) = \pi^* - \frac{\alpha^*}{\kappa} \; y(t) - \lambda_{elb}(t), y(t) < 0$
$\pi(t) = \pi^* - \lambda_{elb}(t), y(t) \geq 0$</td></tr>
<tr><td colspan="3">ELB complementary slackness condition
$\lambda_{elb}(t)[\, r(t) - r_{elb}] = 0, \lambda_{elb}(t) \geq 0$</td></tr>
<tr><td>Implications
• Means of inflation and output equal objective/potential absent ELB.
• ELB lowers inflation, on average, and results in a larger negative tail for output, although output equals potential on average.</td><td>Implications
• Preference for strong activity raises mean inflation while ELB lowers mean inflation
• Mean of output equals potential.
• Absent ELB, output and inflation volatility equal to symmetric case. With ELB, the higher mean inflation implies less binding ELB and hence smaller negative tail for output relative to symmetric case.</td><td>Implications
• Preference for strong activity raises mean inflation while ELB lowers mean inflation
• Mean of output equals potential.
• Absent ELB, output volatility larger than symmetric case with more frequent periods of output below potential and more extreme levels of output above potential
• With ELB, the higher mean inflation implies less binding ELB and hence smaller negative tail for output relative to case without ELB.</td></tr>
</table>

Another implication is that inflation is lower, on average, owing to the ELB, which is an implication of the first-order condition, the fact that output averages potential, and the positive value of the Lagrange multiplier on the ELB constraint $\lambda_{elb}(t)$. Conversely, under both asymmetric loss functions, inflation is higher than it otherwise would be.[14] In the presence of the ELB, the bias toward higher inflation associated with an asymmetric approach may be beneficial, as the ELB lowers inflation (FOMC Tealbook B in June 2016; Gust, Lopez-Salido, and Meyer, 2017; and Penalver and Siena, 2024). These benefits are two-fold. An offset to the disinflationary bias associated with the ELB may lead to inflation closer to objective, on average, although this depends on the magnitudes of the disinflationary bias from the ELB and the inflationary bias associated with time-inconsistency. In addition, higher inflation, on average, lowers the frequency of ELB episodes and allows for greater stabilization of inflation and activity. The more general idea that pursuing higher average inflation may be beneficial has led to suggestions that a somewhat higher inflation target may be beneficial, depending on the relative costs and benefits associated with higher inflation and the ELB.[15]

A result for the loss function that only includes losses from activity shortfalls is also important and will show up in the large model simulations. Under this asymmetric approach, the policymaker tolerates strong activity, as it has strong activity cost under the loss function. However, monetary policy cannot raise output, on average—there is no long-run inflation/output tradeoff. Therefore, toleration of strong activity implies more frequent weak activity. This occurs because expectations adjust to account for the asymmetric reaction of monetary policy to supply shocks, altering the pass-through of supply shocks to activity and inflation in a manner than preserves the long-run neutrality of monetary policy for the level of economic activity. Further, this approach exacerbates the volatility of activity. This outcome may be another type of adverse effect from time-inconsistency and asymmetric policy approaches that policymakers should consider.

[14] This is simply the time-consistency problem (Barro and Gordon, 1983). Rogoff (1985) discusses how a conservative central banker, defined as one with less weight on output. mitigates this potential problem. Constrained discretion may mitigate the problems associated with time-inconsistency (Bernanke and Mishkin, 1997). Kiley and Mishkin (2024) discuss the related literature.

[15] Kiley (2007) and Kiley, Mauskopf, and Wilcox (2007) discuss costs and benefits. On a higher inflation target, see Blanchard, Dell'Ariccia and Mauro, 2010; Ball, 2014; Kiley and Roberts, 2017; Mertens and Williams, 2019.

Implications for the questions analyzed from the simple model

The properties of optimal policy can inform the properties of a good simple rule and provide guidance to some of the questions addressed. The simple model is designed to provide qualitative insights and will not be used to guide the potential frequency of ELB episodes. Rather, the focus will be on the implications of the model for the forcefulness and symmetry of policy responses to output gaps, the way in which such responses affect labor market strength, and strategies to mitigate the ELB.

Should policy respond to measured slack and, if so, how forcefully and symmetrically?

Consider a simple rule of the standard Taylor (1993) form,

$$r(t) = r^{ss} + \pi^* + \varphi\{\pi(t) - \pi^*\} + \phi\{y(t) - y^*\}.$$

The cases with a quadratic loss function are most straightforward. Inspection of the rule and the optimality condition for optimal policy reveals that optimal policy can be implemented (ignoring the ELB) when ϕ/φ equals α/κ and both ϕ and φ are very large, with an appropriate choice for y^* depending on the loss function.[16] These properties of good policy are intuitive. Responses to inflation and activity should both be large, as larger responses to both objectives dampen the adverse effects of aggregate demand shocks. At the same time, maintaining appropriate relative responses to inflation and output ensure the desirable tradeoff between inflation and output objectives following supply shocks. Higher levels of φ and ϕ move the response to r^* shocks closer to the optimal response, preserving a balance in resulting volatility across the activity and inflation objective in response to u shocks.

The case in which the loss function involves only activity shortfalls can be implemented through an asymmetric rule

$$r(t) = r^{ss} + \pi^* + \varphi\{\pi(t) - \pi^*\} + \phi\min\,[y(t), 0]$$

when ϕ/φ equals α/κ and ϕ, φ are, very large. This asymmetric reaction function has the same form as the shortfalls rule in the Federal Reserve's *Monetary Policy* Report and in research such as Fuentes-Albero and Roberts (2021), Papell and Prodhan (2022) and Bundick and Petrosky-Nadeau (2023).

[16] Formally, $\phi = (\frac{\alpha}{\kappa})\nu$, $\varphi = \nu$, and $\nu \to \infty$ will implement optimal policy, as can be seen by inserting these values of the response function coefficients and taking the appropriate limit of the rule, yielding the optimality condition.

In both cases, the response to output gaps is forceful, as this contributes to an optimal balance between inflation and activity stability when paired with a forceful response to inflation. Depending on the loss function, the best response may not be symmetric. The simple model abstracts from measurement error in the output gap. Such measurement error would lower the optimal response to the output gap, as responding to measurement error induces noise in activity and inflation. At the same time, lower responsiveness to output gaps shifts the balance between output and inflation stability, and hence this effect may be muted. The quantitative assessment will explore this issue.

How can monetary policy promote labor market strength, with price stability?

To illustrate implications of the symmetric and asymmetric approaches for labor market strength, Figure 2 presents an example. The solid black line represents outcomes under symmetric optimal policy for a 2 percent inflation objective. For illustrative purposes, parameter values are chosen such that the outcomes for inflation and activity are mirror images of each other. This implies that the distributions of outcomes for inflation and output are identical in Figure 2 under optimal policy (the solid black line). The blue-dashed line show outcomes under a symmetric simple rule, and the red-dotted lines show outcomes under the asymmetric (shortfalls) simple rule.

The outcomes for inflation (the lower panel) illustrate how the ELB results in inflation below target, on average, under a simple symmetric rule. Further, asymmetric policy pushes in the opposite direction, and raises inflation relative to target (all else equal). In this illustrative case, this effect is large and inflation is notably above target, on average.

The outcomes for activity, in the upper panel, provide insight into the implications for labor market strength. In the simple model, inflation and monetary policy are neutral in the long run and hence the average level of activity is not affected by the ELB or the shortfalls approach: on average, output equals potential. Nonetheless, the asymmetries induced by the ELB and the shortfalls rules have important effects.

The ELB limits the ability of the central bank to respond to low levels of inflation and output associated with large, adverse aggregate demand shocks. As a result, the negative tail of the output distribution widens (as can be seen by comparing the blue-dashed and black lines for low levels of the output gap). This results in a shift in inflation expectations that alters the response of output to supply shocks, and this change shifts the distribution of output above potential. Output becomes more volatile, with larger negative and positive tails under the symmetric simple rule.

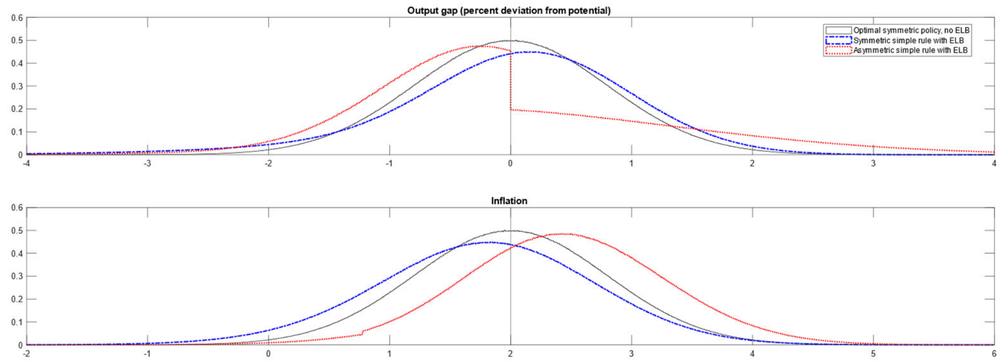
The shortfalls rule also adds additional volatility to activity. The shortfalls rule does not act to stabilize strong activity, which results in an activity distribution with more mass on very high levels of activity (as shown in the right tail associated with the red line). As a result, inflation expectations shift up, which alters the response of output to adverse supply shocks and increases the frequency of moderate shortfalls of economic activity from potential (as can be seen in the substantial increase in mass associated with output moderately below potential in the red line). On average, output is equal to potential. However, output is substantially positively skewed—there are large activity booms—and this positive skewness is offset by more frequent moderate shortfalls of activity from potential.

In the example, the adverse tail of economic activity—negative output gaps—is larger owing to the ELB and larger yet again owing to the shortfalls rule, owing to the destabilizing effects associated with the lack of response to positive output gaps under the asymmetric policy approach. The quantitative magnitudes are only illustrative. The main point is that a shortfalls approach may not have beneficial effects in terms of reducing employment shortfalls. Other approaches may be desirable to promote labor market strength.

What strategies can mitigate any adverse effects of the ELB?

This result highlights how the ability of a shortfalls rule to mitigate adverse effects of the ELB is not targeted to the ELB problem—the approach raises inflation, but there is no reason to expect the approach to raise inflation by the amount inflation is depressed by the ELB. Given this, the suggestion in Gust, Lopez-Salido, and Meyer (2017) and Penalver and Siena (2024) that a shortfalls approach may be helpful for ELB issues is directionally correct, but other approaches may be better. The literature has suggested targeted approaches to address ELB risks. Many of these have relied on commitment strategies that fall outside the optimal discretion approach used to deliver simple results. This includes strategies with history dependence such as price-level targeting (Woodford, 2003) and other make-up strategies (e.g., based on foregone interest rate reductions, as in Reifschneider and Williams (2000) or thresholds for inflation as in Bernanke, Kiley, and Roberts (2019). Moreover, the efficacy of make-up strategies has been assessed across a range of modeling approaches and assumption regarding expectations (e.g., Chung, Herbst, and Kiley, 2015; Hebden et al, 2020). The quantitative analysis will emphasize such make-up strategies.

Figure 2: Distributions of Activity and Inflation Under Symmetric Optimal Policy, a Symmetric Rule, and a Shortfalls Rule



Source: Author's calculations

Additional considerations

The ELB and shortfall rules alter volatility and skewness, but not the level of output in the long run. In the quantitative analysis, I will focus on the effects of policies on volatility and skewness. Under some policies, simulations will show substantial deviations of output from potential, on average, owing at least in part to computational issues that prevent use of a global solution method. This is standard in the related literature (e.g., Williams, 2009; Kiley and Roberts, 2017; Bernanke, Kiley, and Roberts, 2019). Because of this computational issue, simulation results that show substantial deviations of output from potential, on average, signal a failure of the policy approach to stabilize output in a manner consistent with expectations in the model. This suggests such policies are weak and the quantitative results should be viewed as highlighting policy challenges. This is consistent with the emphasis in earlier work on policy strategies that ensure that output equals potential in the long run.[17]

[17] Bundick and Petrosky-Nadeau (2023) use stochastic simulations of a dynamic-stochastic-general-equilibrium model to explore the implications of a shortfalls rule. Their model is small, and hence they can use a global solution algorithm.

4. A Quantitative Evaluation Using FRB/US

A large-scale policy model

FRB/US is a large-scale model of the U.S. economy that has been extensively used to quantify the implications of alternative monetary policy strategies.[18] A recent summary of its use is presented in Brayton and Reifschneider (2022) and the discussion herein draws on their treatment.[19] FRB/US was developed at the Federal Reserve Board: the earliest versions were developed in the mid-1990s and entered day-to-day use in 1996. Typical applications include forecasting, policy simulations, and research projects similar to this analysis. FRB/US shares features with typical New-Keynesian models. However, the link between the structure of equations and microeconomic theory is looser in FRB/US, which permits its equations to better capture patterns in historical data. This flexibility also allows the model to capture economic activity in greater detail—with, for example, modeling of components of consumer expenditure, business investment, and government expenditure, transfers, and taxes.

As emphasized in previous work, including Brayton and Reifschneider (2022), FRB/US has the flexibility to model expectations in different ways, including model-consistent (or "rational") expectations. In addition to model-consistent expectations, a core approach in FRB/US is to assume economic agents form expectations using a vector-autoregression (VAR), which derives expectations from the average historical dynamics of the economy. The simulations herein assume that expectations that determine asset prices and long-term interest rates are model consistent, which ensures that the link between policy strategies and actions, including the effect of the lower bound on nominal interest rates, are captured in the transmission of monetary policy to financial conditions. Expectations in wage and price setting—the Phillips curves in the model—are also assumed to be model consistent, reflecting the strong emphasis on expectations in inflation determination in central bank research and practice. Expectations in other areas (e.g., households' computation of permanent income) are assumed to be governed by VAR expectations. These choices are similar to those in related research (e.g., Bernanke, Kiley, and Roberts, 2019, and

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[18] FRB/US has often been used to quantify the implications of strategies, e.g., Reifschneider and Williams, 2000; Williams, 2009; Kiley and Roberts, 2017; Bernanke, Kiley, and Roberts, 2019; Bernanke, 2020; Arias et al, 2020.

[19] Additional detail and code for the FRB/US model is available from the Federal Reserve Board at https://www.federalreserve.gov/econres/us-models-about.htm.

Brayton and Reifschneider, 2022). In broad terms, the results are similar if model-consistent expectations are used throughout the model.

Versions of FRB/US are available for use by the public. This research uses the linearized version of Brayton and Reifschneider (2022). Linear versions have been extensively used in analyses of monetary policy because of the speed with which they can be simulated and their relative computational simplicity, which allows consideration of effective lower-bound issues (e.g., Reifschneider and Williams, 2000; Williams, 2009; Kiley and Roberts, 2017; and Bernanke, Kiley, and Roberts, 2019). The Model and Code Appendix provides details on the simulation approach and associated replication codes.

The core approach is stochastic simulation using the toolkit provided by Brayton and Reifschneider (2022). In general, reported results reflect 5000 simulations of 200 quarters (1,000,000 observations). The 200 quarters are drawn from the end of a 600-quarter simulation, with the initial 400 quarters used to develop a distribution of equilibrium real interest rates and initial conditions. The stochastic simulations use a bootstrap procedure to draw errors from the historical equations' residuals for the period from 1970Q1 to 2019Q4. The use of a long time period, including the 1970s, ensures that the model captures periods of sizable supply shocks and economic volatility as well as the more stable period after 1983, as in Kiley and Roberts (2017) and Bernanke, Kiley, and Roberts (2019). This is appropriate under the assumption that macroeconomists have an imperfect understanding of the reasons for changes in macroeconomic volatility over time. Other researchers have used more recent data or otherwise adjusted the residuals to lower macroeconomic volatility, arguing that the volatility of the 1970s reflected policy choices that are unlikely to be repeated. For example, Brayton and Reifschneider, 2022, consider such alternatives. The bootstrap procedure follows Gonzalez-Astudillo and Vilan (2019) in drawing from expansionary and recessionary states, which induce a degree of asymmetry in economic activity (e.g., a positive skew in unemployment, with high levels of unemployment relative to typical levels more likely than low levels).[20]

[20] The main simulations also assume that fiscal policy is deployed in an extraordinary manner to stabilize the economy if the output gap reaches -15 percent; this assumption prevents severe and prolonged depressions (and is common when simulating FRB/US, e.g., Brayton and Reifschneider, 2022).

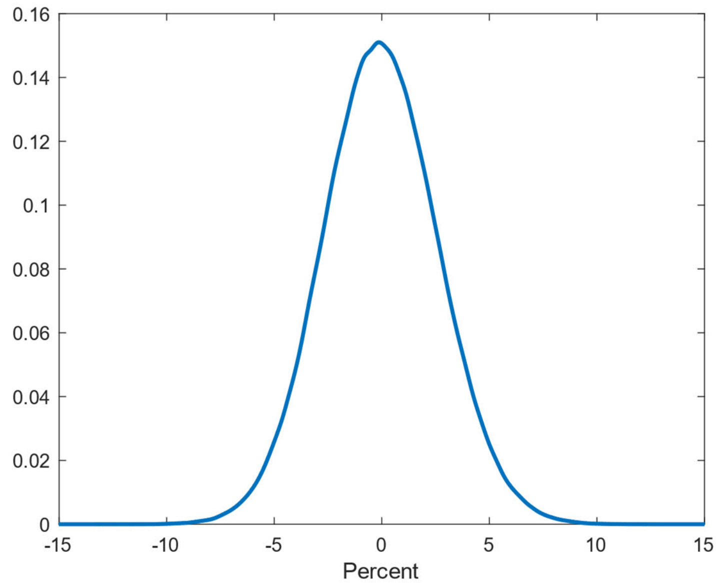
Implementation of r and measurement error in resource utilization*

While many of the simulation assumptions are similar to those in earlier work, two differences are important to emphasize. First, the simulations include a time-varying stochastic process for the equilibrium real interest rate that captures the dynamics and uncertainty regarding the equilibrium real interest rate emphasized in work such as Laubach and Williams (2003) and Kiley (2020a). The specification is inspired by del Negro et al (2017). Second, the simulations include stochastic measurement error in estimates of economic slack, to highlight the importance of such mismeasurement, in a manner drawn from Orphanides and van Norden (2002).

To assess the implications of measurement error in the output gap, an error in the estimate of the output gap perceived by the monetary authority is added to the policy rule. The size of measurement error is drawn from Orphanides and van Norden (2002). These authors find substantial measurement error, with the standard error from initial to final estimates in the neighborhood of 2 ½ percentage points and the autocorrelation of these errors near 0.9. Based on these findings, I assume measurement error is an AR(1) process with an AR coefficient of 0.92 and an error process that generates a standard error of the measurement error equal to 2.66 percentage points. This measurement error, shown in Figure 3, is sizable, as the standard error of estimates of the output gap are often near 3 percentage points or smaller.

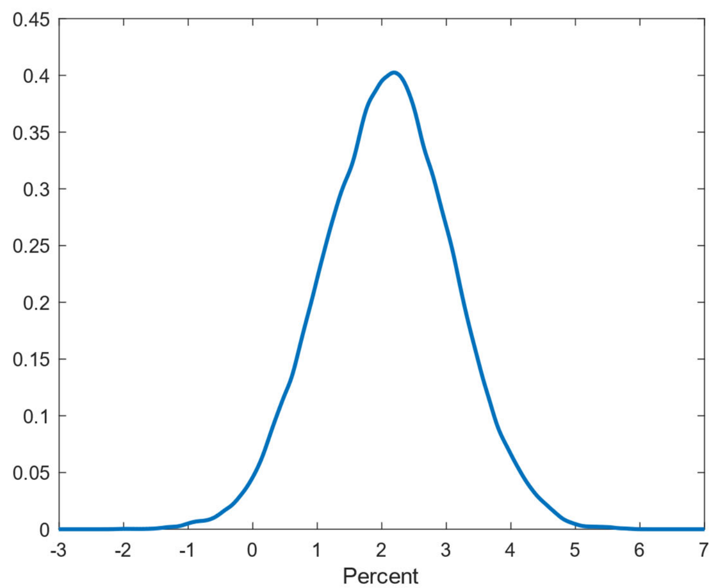
The inflation target is assumed to be 2 percent and center the equilibrium real interest rate at 2 percent, implying a central tendency for the nominal federal funds rate (absent ELB distortions) of 4 percent. To model a stochastic equilibrium real interest rate, a random-walk shock is introduced in the FRB/US model's equations for the risk/term premiums on long-term government bonds. This shock broadly affects financial conditions in the FRB/US model—the costs of borrowing, equity prices, and the exchange rate—and thereby influences the equilibrium real interest rate. Given the structure of the FRB/US model, the assumed shock to risk/term premiums translates one-for-one to the long-run equilibrium real interest rate (real federal funds rate). I assume that the standard deviation of changes in the equilibrium real interest rate is about ¼ percentage point per decade. Under this assumption, the distribution of the equilibrium real interest rate across the simulations when the initial equilibrium real interest rate equals 2 percent is given by Figure 4, which is centered on 2 percent and has a standard deviation of 1 percentage point. For reference, the standard deviation of the two-sided Holston-Laubach-Williams (2017) estimate of R* from 1968 to 2023 is 1.2 percentage points.

Figure 3: Measurement error for the output gap in the monetary policy rule



Source: Author's calculations

Figure 4: Distribution of equilibrium real federal funds rate in stochastic simulations



Source: Author's calculations

Returning to Figure 4, approximately 15 percent of the mass for the equilibrium real interest rate lies below 1 percent and approximately 2.5 percent lies below 0 percent. At the end of 2023, the Summary of Economic Projections by FOMC participants placed the equilibrium real interest rate at ½ percent, which suggests that the lower values in the assumed distribution used in the simulations is relevant for policy. Alternatively, the level of real interest rates implied by longer-term Treasury Inflation Protected Securities reached levels near 2 percent in 2023. Moreover, uncertainty about the equilibrium real interest rate is high, owing to both modeling and statistical uncertainty (Kiley, 2020a). As a result, it is useful to consider the degree to which monetary policy approaches are robust to the range of uncertainty regarding the equilibrium real interest rate shown in Figure 4.

Is the ELB likely to bind, and, if so, what strategies can mitigate any adverse effects?

The frequency of the ELB

The first simulations illustrate the implications of a balanced approach for the frequency and consequences of ELB episodes. The baseline case involved the balanced-approach rule of Yellen (2017), with inertia/partial adjustment, which is an inertial version of a rule in Taylor (1999).

Balanced approach rule:

$$r(t) = 0.85 * r(t-1) + 0.15(r^*(t) + 2 + 1.5\{\pi(t) - 2\} + 1\{y(t) - y^*\}).$$

The rule contains a simple estimate of the long-run equilibrium real interest rate, $r^*(t)$. Because the long-run value of the equilibrium funds rate is time-varying but unobservable, the central banks estimates $r^*(t)$ as a distributed lag of realized real interest rates

$$r^*(t) = 0.995r^*(t) + .005 * \{r(t) - \pi(t)\}.$$

The degree of smoothing in the updating rule implies that the standard deviation of the central bank's estimate of the equilibrium real interest rate equals the actual standard deviation of the true equilibrium real interest rate (1 percentage point across simulations).[21]

Two summary assessments of economic performance—loss functions—are presented:

Symmetric Quadratic Loss: $L(t) = [\pi(t) - 2]^2 + y(t)^2$,

Asymmetric (Shortfalls) Loss: $L(t) = [\pi(t) - 2]^2 + \min{[y(t), 0]}^2$.

Table 2 presents summary statistics for simulations with and without the ELB, highlighting ELB effects. Results are reported for the mean and standard deviation of inflation and the output gap.

[21] Core results in the analysis remain even absent the updating rule. Updating rules that are more sensitive to observe real interest rates can be destabilizing when the ELB is a significant constraint.

In addition, the ELB amplifies downside risk. Skewness can inform the importance of this consideration. The measure of skewness reported is the sum of the 5th and 95th percentiles of simulated outcomes. Finally, the frequency and duration of ELB episodes is reported.

Table 2: Outcomes Using the Balanced Approach Rule

	Mean	Standard Deviation	Skew	Mean	Standard Deviation	Skew
	Without ELB			With ELB=0		
Output	0.0	3.1	-1.3	-0.5	3.7	-3.3
Inflation	2.1	2.0	-0.9	1.4	2.5	-3.2
ELB frequency				14.9		
ELB duration				8.3		
Symmetric Loss	13.9			20.4		
Shortfalls Loss	9.5			15.8		

Source: Author's calculations. Note: Output and inflation outcomes are reported in percent/percentage points. Skew is defined as the sum of the 95th and 5th percentile of simulated outcomes relative to objective. ELB frequencies are reported in quarters. The symmetric loss equals $L(t) = [\pi(t) - 2]^2 + y(t)^2$ and the shortfalls loss equals $L(t) = [\pi(t) - 2]^2 + \min\,[y(t), 0]^2$.

Despite the fact the equilibrium real interest rate averages 2 percent and only 15 percent of its distribution lies below 1 percent, the ELB has sizable effect on the distribution of outcomes. Under the symmetric balanced approach rule, economic activity is negatively skewed: the 5th percentile (low resource utilization) is more than 3 percentage points larger (in absolute value) than the 95th percentile for the output gap when accounting for the ELB. This suggests large costs under the balanced approach rule to a policymaker concerned about shortfalls in activity. Further, inflation averages below target under the balanced approach rule owing to the ELB. In contrast, inflation continues to average above target under the shortfalls rule and output averages above potential. All told, the ELB is a significant constraint, with sizable effects on economic performance, despite the high mean value for the distribution of r*. It is important to note that the balanced approach rule fails to stabilize the economy in a manner consistent with assumptions for expectations in the model. Because of this, caution should be used when interpreting the magnitudes. The main takeaway is that alternative strategies are needed to ensure strong economic performance, as the simulations exhibit poor properties given the ELB.

Make-up approaches to mitigate ELB risk

The inability of the balanced approach rule to stabilize the economy highlights the need to consider other approaches. The ELB literature has considered make-up strategies. The make-up rule from Reifschneider and Williams (2000) accumulates the degree to which policy is constrained by the ELB and lowers future interest rates until the stock of foregone accumulation is depleted. Additional accommodation following an ELB period is determined by a weighted average of inflation and the output gap over the ELB period, relative to values called for by the inertial rule. This rule, shown below, illustrates key elements of make-up strategies.

Make-up (Reifschneider-Williams (2000)) rule:

$$base\ rule(t) = 0.85 * r(t-1) + 0.15(r^*(t) + 2 + 1.5\{\pi(t) - 2\} + 1\{y(t) - y^*\})$$

$$rule(t) = base\ rule(t) + RW(t),$$

$$RW(t) = \min[RW(t-1) + base\ rule - r(t), 0].$$

Simulation results are reported in Table 3. Overall, the make-up strategy is effective in addressing the deterioration in economic performance. The means and volatility of inflation and activity are similar to those under the balanced approach rule without the ELB. This demonstrates that the make-up strategy mitigates ELB risk. As a result, economic losses are close to those absent the ELB as well, for both the symmetric and shortfalls loss function. The ELB binds frequently—nearly ¼ of the time, despite the assumed distribution of the equilibrium real interest rate centered on 2 percent.

Table 3: Outcomes Under Make-up Strategy

	Mean	Standard Deviation	Skew
Output	0.0	3.3	-1.4
Inflation	2.1	2.0	-0.8
ELB frequency	22.0		
ELB duration	20.0		
Symmetric Loss	15.1		
Shortfalls Loss	10.2		

Source: Author's calculations. Note: Output and inflation outcomes are reported in percent/percentage points. Skew is defined as the sum of the 95th and 5th percentile of simulated outcomes relative to objective. ELB frequencies are reported in quarters. The symmetric loss equals $L(t) = [\pi(t) - 2]^2 + y(t)^2$ and the shortfalls loss equals $L(t) = [\pi(t) - 2]^2 + \min[y(t), 0]^2$.

Preemptive make-up strategies

The simulation results, in this analysis and in related research, suggest that make-up strategies are effective. Looking over related research, simple rules are found to promote the stabilization objectives of central banks, including in cases where uncertainty regarding the equilibrium real interest rate and natural rate of unemployment are notable. However, debate remains over the nature of effective policy strategies: for example, Eggertsson and Kohn (2023) and Kiley and Mishkin (2024) point to the potential need for monetary policy to act preemptively to prevent the emergence of imbalances. Erceg et al (2018) discuss potential unintended consequences of strong labor markets.

Tackling the potential for simple policy approaches to act preemptively and to promote strong labor markets requires a definition of preemption. These concepts are most often referred to in loose terms. One idea would be to link preemption to a policy rule that responds to forecasts. This is intuitive. However, forecasts in model simulations are simply translations of the history of state variables, implying that model-based analyses find that rules that respond to forecasts or to the current state of the macroeconomy yield comparable results. An alternative is to define preemption in terms of the size and rapidity of the policy response—a more preemptive policy is one that responds more, and more quickly, to inflation and activity. I adopt this definition.

I consider alternative parameterizations of the simple policy rule

$$base\ rule(t) = \rho * r(t-1) + (1-\rho)\begin{pmatrix} r^*(t) + 2 + a_1\{\pi(t) - 2\} + \\ b_1\{y(t) - y^*\} \end{pmatrix}$$

$$rule(t) = base\ rule(t) + RW(t),$$

$$RW(t) = \min[RW(t-1) + base\ rule - r(t), 0].$$

The rule includes the Reifschneider-Williams (2000) make-up strategy. The strength of the policy response to inflation and output is governed by the rule parameters, a_1 and b_1. The inertia/smoothing parameter, ρ, affects the short-run response.

To explore the characteristics of good policy within this rule, permutations of values of the parameter set are presented, with

- $\rho = [0, 0.33, 0.67, 0.85\}$
- $a_1 = \{1.01, 1.5, 2, 3\}$
- $b_1 = \{0, 1, 2{,}3\}$.

These (64) combinations illustrate how parameters translate to outcomes. To summarize the results, box plots of the loss functions (symmetric and shortfalls) and the root-mean squared deviations from objective of the output gap and inflation are presented for the permutations of parameters. Because the make-up strategy implies output and inflation average values near objective, the root-mean squared deviations tend to be dominated by the standard deviations of the series. In the box plots, the median outcome across parameter permutations is the centered line in each plot. The box is the interquartile range for the root-mean-squared deviation across parameter permutations. The whiskers—the outer lines—are the maximum/minimum values.

Figure 5 presents results. Outcomes for rules without an output gap response are poor (as indicated by the results when the output gap coefficient is zero). This is true for both the symmetric and shortfalls loss functions. The deterioration in performance is more notable for activity: for example, the median outcome for inflation when the output gap coefficient is zero remains near a root-mean square deviation of 2 percentage points, whereas the root-mean square deviation for the output gap exceeds 5 percentage points when the output gap response is zero.

Second, stronger responses to the levels of activity and inflation perform better (within the range of parameter values considered), for both loss functions. A stronger response to the output gap tends to stabilize inflation and a stronger response to inflation tends to stabilize output. This may be counterintuitive, as the variance tradeoff frontier across objectives has been well-known since Taylor (1979). However, the variance tradeoff occurs along the efficient policy frontier. In contrast, the rules examined herein center around the values for rule parameters consistent with the balanced approach rule. These parameters are insufficiently responsive: more robust long-run responses to the level of inflation (than, for example, the baseline of 1.5) and to the output gap (than, for example, the baseline of 1) are likely to be closer to the efficient frontier. Because more responsive rules move closer to the efficient policy frontier, the simulations do not show a variance tradeoff for more robust responses to inflation and output than under the balanced approach rule. This result should be expected from an extensive line of work finding that good rules have strong responses to inflation and output (Henderson and McKibbin, 1993; Levin, Wieland, and Williams, 1999; Rudebusch, 2001; Orphanides and Williams, 2005; Kiley and Roberts, 2017).

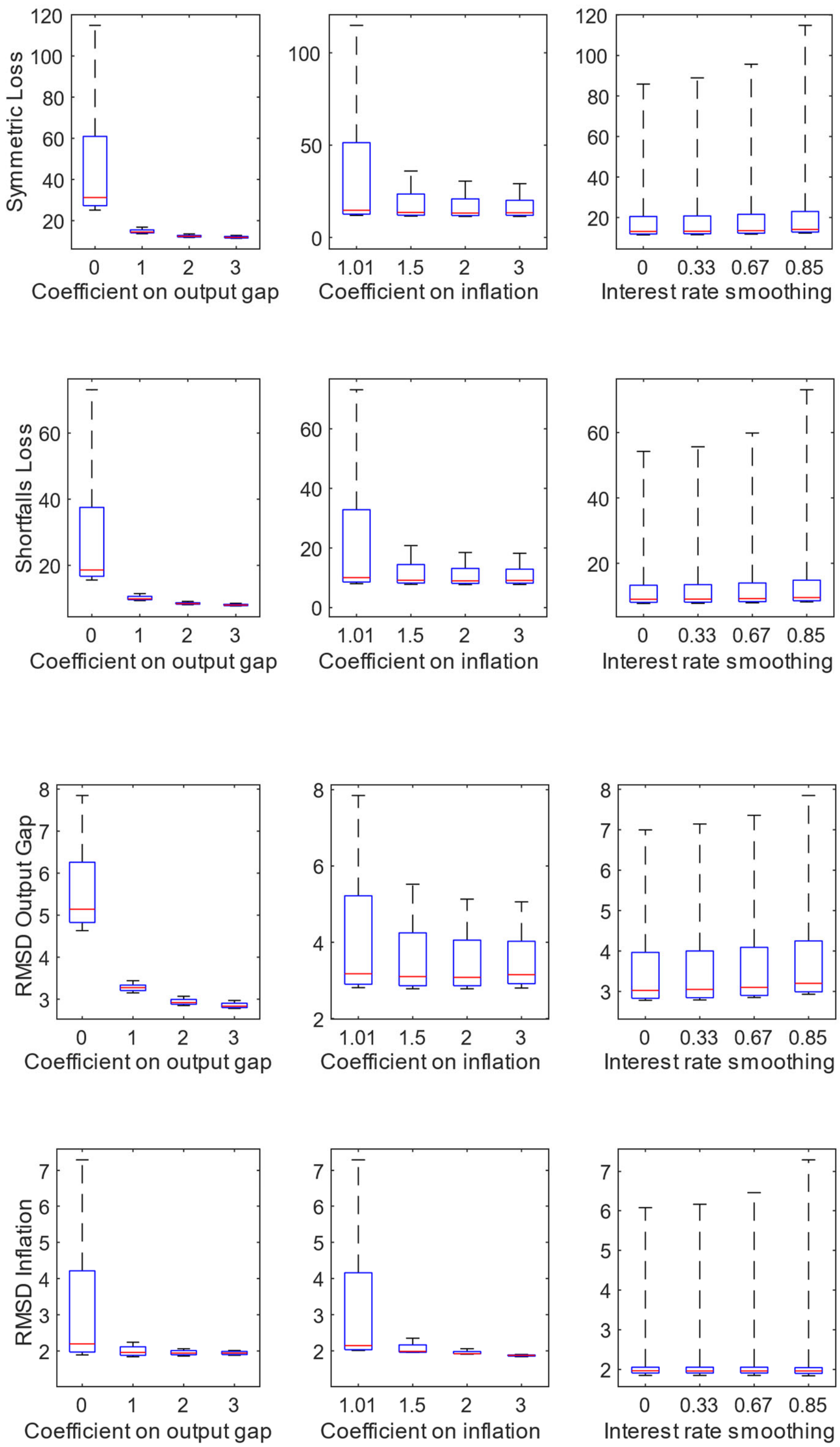
Third, interest rate smoothing has modest effects, but leads to a very slight deterioration in performance. In the simulations, interest rate smoothing reduces the short-run response to inflation and output—that is, reduces the speed of the changes in policy or the degree of preemption.

Overall, the best rules tend to have large responses to inflation and activity, so reducing the short-run response leads to a modest deterioration in performance. Nonetheless, there may be costs associated with large changes in policy. For this reason, analyses often include a term for the change in the nominal interest rate in a policymaker loss function. Given the broad similarities in outcomes across rules with good properties, I will emphasize the rule with smoothing equal to 0.67 and long-run responses to output and inflation equal to 2. I will denote this the preemptive rule.

The effect on employment shortfalls can be seen through an examination of the output gap under different approaches. Figure 6 presents the density functions for outcomes under the balanced approach rule, the Reifschneider-Williams (2000) make-up approach for the balanced approach rule, and the generalized rule (the preemptive rule) with make-up. The preemptive rule trims extremes in economic activity, in both directions. Focusing on employment shortfalls, fifteen percent of outcomes for the output gap fall below -2.8 percent under the preemptive rule, with the corresponding number for the others equal to -4.0 percent and -3.30 percent for the balanced approach and balanced-approach make-up rules. That is, the preemptive policy rule as among the best at limiting employment shortfalls. In other words, economic stability limits employment shortfalls and is promoted by strong (symmetric) responses to the output gap and inflation.

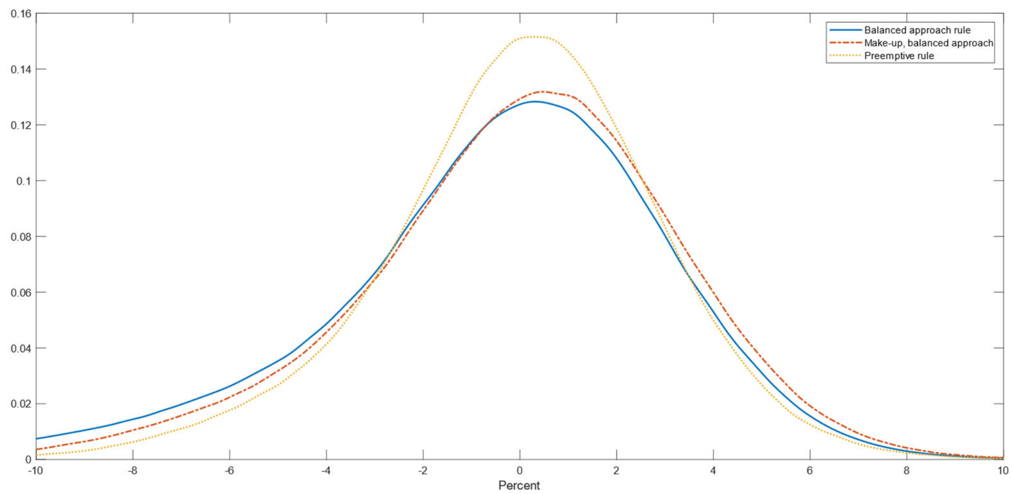
One additional insight is the salience of the ELB, even under the assumed distribution for the equilibrium real interest rate that implies only a 15 percent probability that the equilibrium real interest rate is below 1 percent. Under the preemptive rule, policy responds forcefully to activity, including downturns. As a result, the ELB is a sizable constraint, binding nearly 30 percent of the time across simulations. This result echoes the finding that the ELB should be a large factor in monetary policy approaches emphasized in other studies with similarly large ELB frequencies, such as Kiley and Roberts (2017).

Figure 5: Loss functions and root-mean square deviations for alternative rule parameters



Source: Author's calculations.

Figure 6: Density of output gap for alternative rules



Source: Author's calculations.

Intuitive and explainable make-up strategies

The analysis suggests that the ELB remains a salient consideration for monetary policy. Further, make-up strategies are effective at addressing ELB risks and limit extreme activity shortfalls. Nonetheless, the example of a make-up strategy tied to foregone reductions in interest rates, as in the Reifschneider and Williams (2000) or Kiley and Roberts (2017) analyses, are convenient in model simulations, but potentially difficult to explain to the public. Moreover, such approaches only indirectly relate to the achievement of central banks objectives.

As a result, policy and research have focused on strategies in which additional accommodation following an ELB episode is tied to the achievement of policymaker objectives. A range of approaches commit to providing additional accommodation and hence can be effective make-up strategies. One example is temporary average inflation targeting, in which a central bank seeks to achieve inflation above its long-run objective following a period in which policy was constrained by the ELB and inflation was below objective. Such policies can be effective (e.g., Bernanke, Kiley, and Roberts, 2019; Mertens and Williams, 2019).

Another make-up strategy that is simple to communicate involves thresholds for the removal of accommodation. For example, a central bank could communicate that it will maintain the policy rate at the ELB at least until activity reaches a certain level and/or inflation reaches a certain level. This approach is easy to communicate, in part because it is directly tied to progress toward the achievement of the central bank's objectives. For this reason, the approach has been adopted—

first by the FOMC in late 2012 and following the 2020 pandemic.[22] Research has suggested this approach can be effective (e.g., Bernanke, Kiley, and Roberts, 2019; Bernanke, 2020).

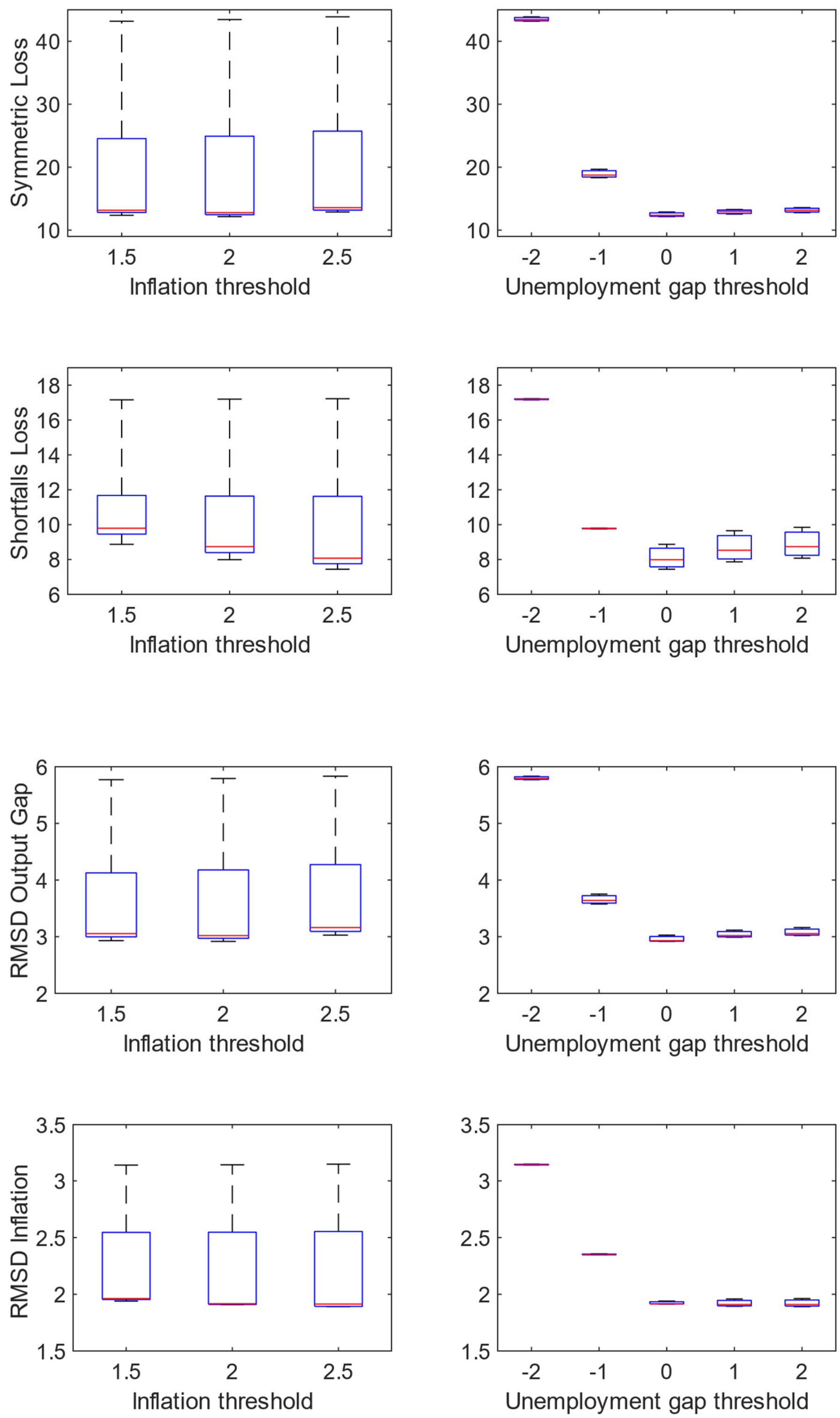
While a threshold approach can be effective, weak thresholds may provide insufficient policy accommodation to mitigate ELB risk. Conversely, overly aggressive thresholds may result in excessive inflation or boom-bust cycles in activity. To understand these issues, simulations of the preemptive rule—with interest rate smoothing of 0.67 and responses to output and inflation of 2—were conducted for a range of thresholds for inflation and the unemployment rate around the inflation objective (2 percent) and the steady-state (or natural) rate of unemployment. In these simulations, the thresholds replace the Reifschneider-Williams make-up term. Figure 7 summarizes results, reporting the range of losses and root-mean-square deviations of objectives associated with (15) permutations of inflation thresholds ranging from 1.5 to 2.5 percent and unemployment gap thresholds ranging from -2 to 2 percentage points. The unemployment gap thresholds include exceptionally low unemployment thresholds to highlight the effects of efforts to promote a very strong labor market.

The results are intuitive. First, extremely low unemployment thresholds are counterproductive. Low unemployment rate thresholds lead to excessive volatility in economic activity and, as a result, lead to more volatile unemployment and a worsening in economic losses even under the shortfalls loss function. This result partly owes to the inflationary pressure created by low unemployment thresholds, which precipitates tight policy to restore price stability and hence worsens employment shortfalls by increasing the volatility of economic activity. In this sense, a monetary policy approach focused on economic stabilization contributes to the mitigation of employment shortfalls and the promotion of a strong labor market—a them that will re-emerge in the discussion of shortfalls rules.

Second, a wide range of unemployment rate thresholds result in similar performance, if the threshold is not too low. This can be seen in the pattern of root-mean-square deviations for the output gap and inflation, where outcomes are fairly similar for unemployment rate thresholds at or above the natural rate. The loss outcomes (symmetric and shortfall) also illustrate this finding.

[22] Evans (2011) introduces the idea that thresholds for inflation and unemployment can be an effective way to frame communications regarding the state-dependent timing of liftoff from the ELB.

Figure 7: Loss functions for inflation and unemployment thresholds under the preemptive rule



Source: Author’s calculations.

Third, inflation thresholds are helpful, but in conjunction with unemployment thresholds. This can be seen through the fact that the shifts in outcomes across policy permutations are most sizeable for changes in the unemployment thresholds. This finding reinforces the value of the Evans (2011) rule, which combined inflation and unemployment thresholds, with an unemployment rate threshold moderately above the natural rate.

All told, thresholds for the unemployment rate and inflation rate are among the effective set of make-up strategies. Alternative make-up strategies are also effective. The crucial point is that the sizable implications of ELB imply that make-up approaches are needed to prevent sizable employment shortfalls.

Interactions of make-up strategies and quantitative easing

For mitigation of ELB risks, quantitative easing is an alternative or complementary approach to make-up strategies. Make-up strategies associated with forward guidance, such as the inflation and output threshold approaches, may also interact with quantitative easing. It is important to consider how a make-up strategy can work with quantitative easing and the degree to which both approaches to mitigating ELB risks are necessary.

Incorporating quantitative easing is straightforward but requires specifying and calibrating a set of additional relationships. Research on the effects of quantitative easing have focused on portfolio-balance channels, in which central bank purchases of long-term government bonds reduce the supply of long-duration assets available to the public and thereby reduce the yield on such securities, widely affecting financial conditions. In general, research shows these policies to be effective, but there is wide variation in the effects on financial conditions and in modeling how such changes in financial conditions affect macroeconomic aggregates. As the interest herein is in the degree to which make-up strategies and quantitative easing interact, the approach used is simple and based on Reifschneider (2016) and Kiley (2018).[23] The central bank engages in asset purchases to lower term premiums. I implement such purchases whenever the ELB is binding and in a magnitude sufficient to lower term premiums by the amount that the policy interest rate is constrained by the ELB over the next 10 years: that is, quantitative easing acts to fully offset the effect of the ELB on the 10-yr. Treasury yield, with broad effects as implied by the FRB/US model. The implementation of quantitative easing is also one-sided: quantitative easing actively provides

[23] Chung et al (2023) discuss issues associated with the modeling of QE.

stimulus when the ELB bonds, but reduction in asset purchases occur at a rate of 5 percent per quarter, passively.

It is important to keep in mind that the threshold policies I have considered also largely offset the effect of the ELB. Therefore, the interaction of a threshold policy and QE could be significant. The extent to which outcomes are robust to these interactions highlights the strength of the policy rule in limiting, through the removal of accommodation after ELB periods, the potential for excessive stimulus.

Table 4 presents results. Quantitative easing is effective and results in good outcomes. In this case, the assumed size of quantitative easing is aggressive and well calibrated to address ELB risks. Specifically, the policy is calibrated to fully offset any effect of the ELB on the 10-yr Treasury yield. This yield is an important influence on financial conditions in the model. As a result, outcomes are exceptionally good under quantitative easing. Given uncertainty regarding the efficacy and quantitative impact of quantitative easing, the results should not be overinterpreted. Real-world implementation may not be as effective.

More importantly, quantitative easing is robust to thresholds and vice-versa, as the preemptive policy rule corrects any excessive stimulus. It is also interesting to note that the combination of strong quantitative easing, thresholds for liftoff from the ELB, and the preemptive rule results in the lowest value for the shortfalls loss function across all strategies analyzed herein. While this result should not be overinterpreted, this finding and the other results on make-up policies hints at the following conclusions. Strategies that address ELB risks are a means for monetary policy to limit the most severe downside risks to economic activity, which curtail the most severe losses from employment shortfalls. Strong and symmetric responses of the policy interest rate away from the ELB are a means through which monetary policy can preserve price stability and limit economic volatility, which also curtails losses from economic shortfalls. As a result, a monetary policy strategy that combines strong and symmetric responses to inflation and economic activity with elements to address ELB risks is a means for monetary policy to limit the costs of employment shortfalls.

It is also important to note that the analysis of quantitative easing has not touched on how the volatility in central bank net income may affect public support. Kiley and Mishkin (2024) note such challenges, and Adrian et al (2024) provides a quantitative evaluation.

Table 4: Outcomes under preemptive rule and quantitative easing, with and without make-up strategies

	Preemptive rule, $\pi^{threshold} = 2$ & $(u - u^*)^{threshold} = 1$, and no quantitative easing			**Preemptive rule, no make-up, and quantitative easing**			**Preemptive rule, $\pi^{threshold} = 2$ & $(u - u^*)^{threshold} = 1$, and quantitative easing**		
	Mean	Standard Deviation	Skew	Mean	Standard Deviation	Skew	Mean	Standard Deviation	Skew
Output	0.0	3.0	-1.2	0.0	2.6	-0.8	0.3	2.9	-0.2
Inflation	2.0	1.9	-0.9	1.6	1.9	-1.7	2.0	1.9	-0.9
ELB frequency	31.4			11.9			26.0		
ELB duration	14.2			4.3			11.6		
Symmetric Loss	12.5			10.8			12.0		
Shortfalls Loss	8.5			7.6			7.5		

Source: Author's calculations. Note: Output and inflation outcomes are reported in percent/percentage points. Skew is defined as the sum of the 95th and 5th percentile of simulated outcomes relative to objective. ELB frequencies are reported in quarters. The symmetric loss equals $L(t) = [\pi(t) - 2]^2 + y(t)^2$ and the shortfalls loss equals $L(t) = [\pi(t) - 2]^2 + \min[y(t), 0]^2$.

5. A shortfalls approach to monetary policy

Consequences of asymmetric reactions to economic slack

The analysis has considered symmetric policy rules. The only asymmetries analyzed have been those associated with the ELB through make-up policies for short-term interest rates or quantitative easing. But a key emphasis in policy discussions has been asymmetric benefits and costs from labor market strength and weakness. Perhaps owing to this focus, the policy simulations presented to the FOMC in the staff's Tealbook B from 2016 through the most recently released versions involved optimal policy using the shortfalls loss function discussed above. In addition, Evans (2024) suggests that these asymmetric costs and benefits, as communicated to the FOMC in Fed Listens events, influenced the focus on employment shortfalls in the FOMC's 2020 framework. Finally, recent versions of the Federal Reserve's Monetary Policy Report have featured prescriptions from a shortfalls policy rule. I consider a shortfalls rule from Fuentes-Albero and Roberts (2021) and Papell and Prodhan (2022), which changes the balanced approach rule from Yellen (2017) to respond only to negative values of the output gap.

Shortfalls rule:

$r(t) = 0.85 * r(t-1) + 0.15(r^*(t) + 2 + 1.5\{\pi(t) - 2\} + 1min\{y(t) - y^*, 0\})$.

Table 5 presents summary statistics for simulations of this shortfalls rule, along with the preemptive rule with inflation and unemployment thresholds.

The shortfalls rule results in larger economic volatility, output averaging above potential, and inflation notably above target. As noted when discussing the outcomes under the simple model, simulation results showing sizable deviations from targets suggest that the policy rule fails to stabilize the model, which suggests caution in interpreting results. Nonetheless, the comparison of the preemptive rule and the shortfalls rule the balanced approach rule performs better, even under the shortfalls loss function, because of the volatility in output and inflation under the shortfalls rule. Inflation averages above target under the shortfalls rule and output averages above potential. In other words, the shortfalls rule offsets the downward bias in inflation from the ELB as suggested by Gust, Lopez-Salido, and Meyer (2017) and Penalver and Siena (2024). However, this approach is not targeted at ameliorating ELB risks and performs poorly because failure to lean against strong economic activity raises overall economic volatility, including downside risk. This finding echoes the insight from the simple model and is explored more thoroughly in Kiley (2024). Finally, the symmetric preemptive rule with inflation and unemployment thresholds performs much better, even under the shortfalls loss function.

Table 5: Simulation results under the preemptive rule with thresholds and the shortfalls rule

	Preemptive rule, $\boldsymbol{\pi^{threshold} = 2 \text{ \& } (u - u^{*})^{threshold} = 1}$			**Shortfalls rule**		
	Mean	Standard Deviation	Skew	Mean	Standard Deviation	Skew
Output	0.0	3.0	-1.2	1.8	4.5	3.1
Inflation	2.0	1.9	-0.9	3.6	2.4	1.8
ELB frequency	31.4			8.0		
ELB duration	14.2			5.7		
Symmetric Loss	12.5			31.2		
Shortfalls Loss	8.5			13.3		

Source: Author's calculations. Note: Output and inflation outcomes are reported in percent/percentage points. Skew is defined as the sum of the 95th and 5th percentile of simulated outcomes relative to objective. ELB frequencies are reported in quarters. The symmetric loss equals $L(t) = [\pi(t) - 2]^2 + y(t)^2$ and the shortfalls loss equals $L(t) = [\pi(t) - 2]^2 + \min\,[y(t), 0]^2$.

Can the shortfall approach be improved?

The weaknesses in the shortfalls rule were specific to the parameterization, based on the balanced approach rule, and other parameterizations could yield different results. Table 6 reports results for the preemptive rule parameterization, but with a shortfalls (asymmetric) approach, with and without inflation and unemployment thresholds. The shortfalls approach still performs poorly. The value of the loss function, including the shortfalls loss function, is worse than for the symmetric preemptive rule with thresholds, inflation averages above target, and output averages above potential. These outcomes suggest failure of the shortfalls approach to stabilize the economy in a manner consistent with stability in expectations.

The last set of columns in Table 6 combine a shortfalls approach and a threshold make-up strategy. The interaction of the two approaches does not improve outcomes in a material way. If the thresholds allowed more overshooting, results would worsen appreciably (not shown). In such cases, the amount of stimulus is overkill and leads to a deterioration in performance. One reason performance deteriorates is that the shortfalls approach prevents the tightening when stimulus proves to be large. In contrast, a symmetric rule works well with other sources of stimulus—make-up/threshold strategies, quantitative easing, or additional fiscal stimulus—because a symmetric approach has a self-correction mechanism. For example, the symmetric preemptive policy rule responds forcefully when output or inflation rise strongly, thereby short-circuiting unwanted boom-bust cycles under the threshold approach or in the face of quantitative easing.

Table 6: Outcomes Under Preemptive and Alternative Shortfalls Approaches

	Preemptive rule Parameters, shortfalls approach			**Preemptive rule Parameters, shortfalls approach $\pi^{threshold} = 2$ & $(u - u^{*})^{threshold} = 1$**		
	Mean	Standard Deviation	Skew	Mean	Standard Deviation	Skew
Output	1.4	3.9	1.9	1.5	3.7	2.3
Inflation	3.1	2.1	1.0	3.2	2.0	1.3
ELB frequency	17.1			21.0		
ELB duration	6.8			10.5		
Symmetric Loss	22.5			21.6		
Shortfalls Loss	10.1			9.3		

Source: Author's calculations. Note: Output and inflation outcomes are reported in percent/percentage points. Skew is defined as the sum of the 95th and 5th percentile of simulated outcomes relative to objective. ELB frequencies are reported in quarters. The symmetric loss equals $L(t) = [\pi(t) - 2]^2 + y(t)^2$ and the shortfalls loss equals $L(t) = [\pi(t) - 2]^2 + \min\,[y(t), 0]^2$.

A related question is whether less aggressive shortfalls approaches would perform better. In unreported simulations, approaches in which the response to employment shortfalls was greater than the response to strong activity were investigated (i.e., less extreme versions than zero response to positive output gaps). In general, these approaches simply move the response toward the outcomes under the symmetric rule, while still resulting in worse performance. It is likely that some type of shortfall approach would be partially effective, but the nature of such an approach calls for more research. In a much simpler model, Kiley (2024) shows that there are benefits to (near) symmetry in responses to resource utilization.

6. Additional Considerations: Mismeasurement, Policy Rules, and Risk Management

Mismeasurement and resource utilization in a policy rule

The policy rules considered respond to the level of resource utilization. But resource utilization is measured with error. The simulations have included substantial measurement error—with such error being highly persistent (with an autocorrelation coefficient over 0.9) and sizable (with a standard deviation of nearly 3 percentage points). Despite this large measurement error, the rules—with make-up elements—perform well. Nonetheless, there is a case to be made for responding to changes in activity, in addition to deviations from objective or as a replacement for such level responses. Responding to changes in activity lowers risks of responding incorrectly to misperceptions of the level of resource utilization (Orphanides and Williams, 2007). Responding to a rapid deterioration in economic activity, prior to activity reaching a low level, may limit the likelihood of reaching, and adverse effects of, the ELB (Reifschneider and Williams, 2000).

I consider alternative parameterizations of the simple policy rule

$$base\ rule(t) = \rho * r(t-1) + (1-\rho)\begin{pmatrix} r^*(t) + 2 + a_1\{\pi(t) - 2\} + \\ b_1\{y(t) - y^*\} + b_2\{y(t) - y(t-4)\} \end{pmatrix}$$

$$rule(t) = base\ rule(t) + RW(t),$$

$$RW(t) = \min[RW(t-1) + base\ rule - r(t), 0].$$

The rule includes the Reifschneider-Williams (2000) make-up strategy. The strength of the policy response to inflation and output is governed by the rule parameters, a_1 and b_1. The inertia/smoothing parameter, ρ, affects the short-run response.

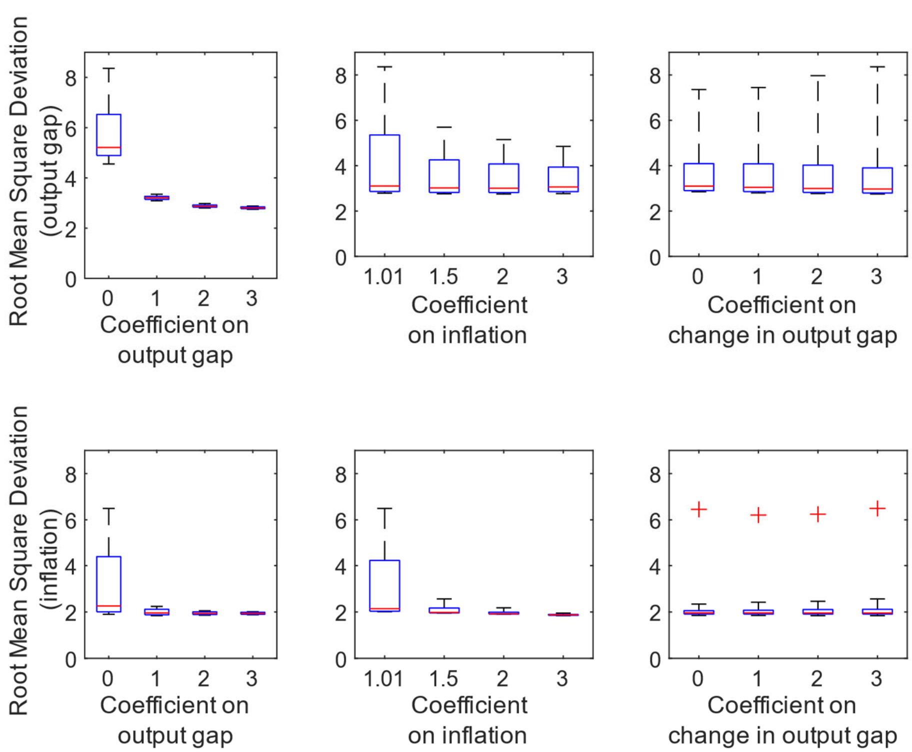
To explore the characteristics of good policy within this rule, permutations of values of the parameter set are presented, with

- $\rho = [0.67\}$
- $a_1 = \{1.01, 1.5, 2, 3\}$
- $b_1, b_2 = \{0, 1, 2,3\}$.

These (64) combinations illustrate how parameters translate to outcomes and allow for the possibility that reactions to the change in resource utilization are superior to reactions to the level of resource utilization. Note that I fix the interest rate smoothing coefficient at 0.67, as previous results demonstrate that key properties are insensitive to a reasonable range of interest rate smoothing. Figure 8 summarizes results, focusing on root-mean-square deviations of inflation and the output gap in the same format as Figure 5. (Earlier results show that root-mean-square deviations map closely to results for losses, under both the symmetric and shortfalls specification.)

Three results stand out. Even with a response to the change in activity, a response to the level of activity is outcome improving. Overall, the best rules tend to have large responses to inflation, activity, and the change in activity. However, the benefits of responding to the change in activity are small—that is, outcomes improve, but to a modest extent relative to, for example, ELB risks. This conclusion is similar to that of Rudebusch (2001), who showed that measurement error had only modest effects on the best parameterization of simple rules. Finally, a strong response to the change in economic activity can be counterproductive in the absence of a response to the level of activity, as can be seen by the poor outcomes for the worst parameterizations responding to the change in the output gap in the final row of Figure 8. At the ELB, a strong response to improving activity, without a response to the level, can lead to the premature removal of accommodation (i.e., the opposite of make-up), worsening outcomes (Kiley and Roberts, 2017).

Figure 8: Root-mean-square deviations for the output gap and inflation with policy response to change in the output gap



Source: Author's calculations.

Risk management considerations

On balance, the results suggest that a symmetric, preemptive approach limits employment shortfalls while preserving price stability. There may be additional risk management considerations that suggest efforts to strongly stabilize the economy, rather than pursue high resource utilization, promote good outcomes and contribute to monetary policy objectives associated with limiting the adverse effects of employment shortfalls.

One additional consideration is the degree to which policy is robust to fiscal stimulus. For example, fiscal stimulus was large in 2020 and after, and economists have debated the effect of such stimulus on the economy and inflation.[24] The preemptive make-up rule is robust to extraordinary fiscal stimulus, as it is robust to quantitative easing. Shortfalls approaches are not robust to extraordinary fiscal stimulus.

In addition, the simple model and the FRB/US model have linear Phillips curve, so extraordinarily strong activity affects inflation in the same manner as somewhat strong or weak activity. Research has suggested that the Phillips curve may be nonlinear at elevated levels of resource utilization in a manner that may interact with the strong activity fostered by the shortfalls rule (e.g., Benigno and Eggertsson, 2023). Further, strong activity and buoyant financial markets may increase medium-term risks to economic activity in ways not captured in typical models (e.g., Adrian et al, 2022).

Finally, there are important risk management considerations that may point to a greater role for focusing on employment shortfalls. In particular, the models analyzed assume the natural rate hypothesis—that is, assume that potential economic activity is independent of monetary policy. This hypothesis is a core element of monetary policy research (from Friedman, 1968, and Phelps, 1968, to Kiley and Mishkin, 2024). But it is possible that the separation between aggregate demand and aggregate supply may not be complete. Research on this possibility is nascent, but some work (e.g., Cerra, Fatás, and Saxena, 2023) suggest that hysteresis effects may be significant. Much of the evidence may reflect scarring effects of weak demand, rather than beneficial effects of strong demand. Nonetheless, more work is needed to consider the quantitative significance of such effects

[24] For a discussion of stimulus over 2020 and 2021, see Romer (2021). Romer and Romer (2019) discuss fiscal space and Blanchard (2023) reviews research on the role of fiscal policy in stabilization.

for monetary policy relative to the potential adverse effects associated with an asymmetric policy approach.

7. Conclusions

I examined the ability of monetary policy to foster price stability and labor market strength. The analysis considered key issues, including uncertainty regarding the equilibrium real interest rate, mismeasurement of economic potential, and the benefits and costs of employment shortfalls. The simulations assumed a reasonable distribution for the equilibrium real interest rate and found a high probability that the ELB will bind. The results demonstrate that the ELB has a sizable effect on economic performance. Make-up policy strategies are needed to ensure satisfactory performance. Simple make-up strategies, using thresholds for both inflation and the unemployment rate to determine when the policy interest rate lifts off from the ELB, are effective.

Symmetric and preemptive policy reaction functions mitigate the most adverse effects of employment shortfalls by contributing to economic stability. Mismeasurement is not sufficient to limit the importance of strong responses to measured output gaps. A strong response to the output gap ensures that a policy rule is robust to multiple forms of stimulus, including the interaction of make-up policies and quantitative easing or fiscal stimulus.

An asymmetric shortfalls approach to monetary policy—providing accommodation in response to weak activity while foregoing tightening in response to strong activity—can exacerbate employment shortfalls and create inflationary pressures. The potential for monetary policy approaches to destabilize expectations is a critical consideration for policy and is important when considering asymmetric policy approaches based on employment shortfalls.[25] The analysis of the New-Keynesian model showed how a focus on shortfalls can shift expectations in a manner that promotes large booms, while also exacerbating activity shortfalls. A shortfalls-based policy also performed poorly in the large-scale policy model simulations. The long-run neutrality of monetary policy is a powerful force, and efforts to circumvent this force, even unintentionally, can backfire. One way in which such efforts can backfire is high inflation, as emphasized in the time-inconsistency literature. Another way is through heightened economic volatility, as the analysis herein has demonstrated.

[25] This channel is simply the lesson of Lucas (1976).

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Model and Code Appendix

The simulations use the model and code from Brayton and Reifschneider (2022). Replication codes are provided for Matlab. All results were produced using Matlab version R2022a. (The compatibility of the replication files with Octave has not been checked, but it is likely that the replication files will work in Octave with minimal changes.)

Several modifications to their code were made.

1. Adjustments to the code provided by the authors were made to impose the ELB and asymmetric rules, which was not operative in the baseline code.
2. Measurement error in the output gap was added to the FRB/US model and enters the perceived output gap in monetary policy reaction functions when measurement error is introduced.
3. An equation for the shock affecting the equilibrium real interest rate was added and this process enters the equations for term premiums on long-term bonds.
4. The shortfalls rule and generalized rule for consideration of parameter permutations were added to the suite of monetary policy rules.

The replication package provided will reproduce the results in each figure and table. The package assumes that the results will be replicated in the order they appear in the paper—that is, the replication codes need to be executed in order, as some of the results needed in later figures or tables may depend on results produced in earlier files. The replication files are named "figure_1.m", etc. Each file calls on additional files for simulation, etc., which are also included in the replication package.

The list below indicates the set of figures and tables produced in the appropriate order.

List of replication files