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Expected Social Welfare Under a Convex Phillips Curve and Asymmetric Policy Preferences

This paper evaluates the expected social welfare implications of monetary policy with a convex Phillips curve under a symmetric loss function and an asymmetric loss function corresponding to the "opportunistic approach" to disinflation. The convex—asymmetric specification yields an inaction range of inflation shocks for which the optimal monetary policy setting does not adjust. For parameter estimates relevant to the United States, numerical simulations show that the symmetric loss function dominates the asymmetric alternative in expected social welfare terms. Asymmetric policy preferences enhance social welfare only under extreme parameter values. This result is robust to sensitivity analysis with respect to inflation variability and the degrees of Phillips curve convexity and preference asymmetry, thereby supporting arguments for a tough anti-inflationary stance by the Federal Reserve regardless of the "true" social loss function.

RESEARCHERS OF MONETARY POLICY have put forward a range of arguments in support of alternative specifications of the short-run U.S. Phillips curve. Clark, Laxton and Rose (1996), Debelle and Laxton (1997), Tambakis (1999) and Turner (1995) propose a nonlinear and convex Phillips curve. Under convexity, positive shocks to aggregate demand raise inflation by more than negative shocks of the same magnitude lower it. As a result, the nonaccelerating inflation rate of unemployment—the unemployment rate consistent with stable average inflation rate—is greater in a stochastic setting than a deterministic setting. This property of convexity provides a rationale for stabilization policy, as a policymaker who succeeds in lowering unemployment variability also reduces its mean value. The asymmetric impact on inflation of aggregate demand shocks also suggests that early policy tightening can reduce the need for stronger disinflation later. A prominent study arguing the case in favor of a linear Phillips curve is Gordon (1997). In a linear world, the effects of positive and negative aggregate demand shocks on inflation are of equal magnitude and will average out, regardless of the response of mon-

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etary policy. Moreover, there is no incentive for preemptive policy tightening to counter expected inflationary pressure. Finally, Eisner (1996) and Stiglitz (1997) make the case for concavity. In contrast to the first two alternatives, under a concave short-run Phillips curve the sacrifice ratio is decreasing in the magnitude of disinflation. This provides incentives for aggressive probing of the economy's short-term capacity limits. Thus, concavity implies that active stabilization policy actually raises the average unemployment rate.

On the empirical front, the power of econometric tests to distinguish between linearity and convexity has been investigated by Laxton, Meredith, and Rose (1995) and Laxton, Rose, and Tambakis (1999). These authors show that, because policymakers have overall been successful in avoiding large boom and bust cycles, the statistical case for identifying modest convexity is weak based on typical historical U.S. estimates. Indeed, to the extent that convexity presents a rationale for successful stabilization policy, it further weakens the evidence upon which such policy is based. However, they also present Monte Carlo evidence suggesting that if there is convexity in the Philips curve, but monetary policy operates on the false assumption of linearity or concavity—a type-II policy error—the welfare losses can be severe. In contrast, a type-I error based on presuming convexity when the true Phillips curve is linear or concave is much less costly in expectation. Therefore, on balance the Federal Reserve's operating framework should presume that the short-run U.S. Phillips curve has modest convexity.

The expected welfare evaluation of such type-I and type-II policy errors is conditional to quadratic and symmetric policymaker preferences: opposite sign deviations of unemployment from its target rate are equally costly. The present paper studies the welfare implications of a convex Phillips curve under an asymmetric loss function corresponding to the "opportunistic approach" to disinflation. The preference asymmetry is intended to capture a disinflation strategy in which the central bank is guarding against any incipient rise in inflation, but waits for the next favorable inflation shock to lower inflation toward the target, rather than actively seeking to lower inflation in a manner that pushes the unemployment rate higher. Orphanides and Wilcox (1996) and Orphanides et al. (1996) introduced a monetary policy model with a linear Phillips curve rationalizing such an opportunistic disinflation strategy. Its foundations lie in the perception that the welfare of the policymaker and society depends negatively on the level of the unemployment rate, as well as on the variance of unemployment and inflation. This may be because unemployment deviations from target induce a greater social distortion than corresponding inflation deviations. For example, Blinder (1997) argues that unemployment at 2 percent above the natural rate implies that 2 percent of workers are fully unemployed, rather than all workers being 2 percent unemployed. An alternative rationale could be that the central bank's vulnerability to political attack makes it more sensitive to positive rather than to negative deviations of unemployment from its natural rate, as positive deviations could threaten its independence.

In line with the opportunistic argument, in this paper the quadratic loss function is extended by a term linearly increasing in the actual unemployment rate when the latter is above its average, and zero when unemployment is at, or below, the average. Symmetric policy preferences imply that the one-period equilibrium level of unemployment in a stochastic setting is always different from its deterministic counterpart. This is so regardless of the shape of the Phillips curve. In contrast, Tambakis (1999) shows that asymmetric preferences generate an inaction range of inflation shocks for which the optimal monetary policy setting does not adjust. This lowers the average unemployment rate at the expense of higher average and more variable inflation. Numerical simulations are used to obtain simulated distributions of the equilibrium levels of inflation and unemployment. The simulations make use of an iteration algorithm to derive model-consistent inflation expectations. Using empirical parameter values for the United States based on the methodology developed by Laxton, Rose, and Tambakis (1999), it is shown that, while the expected unemployment rate is lower, there is a positive expected inflation bias when policy preferences are asymmetric. The variances of inflation and unemployment are respectively higher and lower than their values under symmetric preferences.

The paper proceeds to compare expected social welfare losses under each policy preference specification. In principle, the policymaker and society need not always share the same macroeconomic policy preferences. The loss function used to guide monetary policy may be different from that used by society to evaluate macroeconomic outcomes, as a result of appointing a conservative independent central banker or political economy reasons. Therefore, expected social welfare losses under the two loss functions have to be evaluated and compared for all combinations of the exogenous, "true" loss function used by society to evaluate macroeconomic outcomes, and the loss function used by the policymaker to guide the implementation of monetary policy. Restricting the difference to the asymmetric term in the loss function, it is found that the "consistent scenario" where both society and the policymaker use the symmetric loss function dominates the asymmetric alternative. Moreover, this result is shown to be robust to inflation shock variability and to the degrees of Phillips curve convexity and preference asymmetry. The intuition relates to the equilibrium moments of the target variables. Whereas the average unemployment rate is smaller under the asymmetric policy, the corresponding percentage increase in average inflation is much larger. However, inflation and output variability are roughly proportional under the two specifications, so overall expected symmetric social losses are smaller. In relative terms, policymaking guided by the symmetric policy does better in expectation than the asymmetric alternative under either "true" social loss function in most cases. The only cases when the asymmetric policy results in higher expected social welfare are when both the shock variance and the deterministic non-accelerating inflation rate of unemployment are large, and/or when inflation aversion is low and the preference asymmetry is large. Therefore, the asymmetric policy enhances social welfare only under extreme conditions.

The remainder of the paper proceeds as follows. Section 1 reviews the monetary policy model with a convex Phillips curve and asymmetric policy preferences underlying the opportunistic disinflation strategy. Section 2 discusses the model's equilibrium properties and presents simulated distributions of equilibrium inflation and unemployment for the United States. Section 3 analyzes the expected social welfare implications of the convex Phillips curve under the symmetric and asymmetric loss functions. The robustness of the results is examined with respect to inflation shock variability and the degrees of Phillips curve convexity and preference asymmetry. Section 4 concludes.

1. A MODEL OF CONVEXITY AND PREFERENCE ASYMMETRY

In the stylized one-period framework of Barro and Gordon (1983) the policymaker's and society's loss functions coincide. They are symmetric and quadratic in inflation and unemployment deviations from target:

$$L_t = (U_t - U^*)^2 + \alpha(\pi_t - \bar{\pi})^2 \,. \tag{1}$$

The inflation and unemployment targets are $\pi \geq 0$ and $U^* > 0$, respectively, where U^* is the nonaccelerating inflation rate of unemployment in a deterministic setting. The policymaker's policy preferences are given by the normalized inflation aversion coefficient $\alpha > 0$. The linear short-run Phillips curve is given by

$$\pi_t = E_{t-1}\pi_t + \gamma(U^* - U_t) + \varepsilon_t, \qquad \gamma > 0 \,. \tag{2}$$

Reduced-form models can analyze shocks to the unemployment rate or aggregate demand (U_t), inflation expectations ($E_{t-1}\pi_t$) and actual inflation (π_t). In this paper only the last type is considered: $\varepsilon_t \sim N(0,\sigma_\varepsilon)$ is an iid inflation shock realized after inflation expectations have been determined. The policymaker is assumed to control inflation directly.[1] The one-period optimal inflation and unemployment rates are then obtained by minimizing the symmetric loss function (1) subject to the linear aggregate constraint (2):

$$\pi_t = \bar{\pi} + \frac{1}{1+\alpha\gamma^2}\varepsilon_t, \;\; U_t = U^* + \frac{\alpha\gamma}{1+\alpha\gamma^2}\varepsilon_t \,. \tag{3}$$

Taking expectations in equation (3) implies that, in the absence of time-inconsistent preferences on the part of the policymaker, there is zero expected inflation bias ($E_{t-1}\pi_t = \bar{\pi}$) and average unemployment equals the natural unemployment rate U^*.[2]

1. Laxton, Rose, and Tambakis (1999), Stiglitz (1997), and Wieland (1996) examine the desirability of experimentation ("probing") with different policy rules in the face of uncertainty about the stochastic average unemployment rate.

2. A target unemployment rate less than U^* would imply a positive expected inflation bias with no decline in average unemployment.

The first departure from the linear-symmetric model involves the convex Phillips curve. Its specification follows Debelle and Laxton (1997) and Laxton, Rose, and Tambakis (1999), and is based on the labor market model of Layard, Nickell, and Jackman (1991). In a two-period framework the time subscripts may be dropped:

$$\pi = E\pi + \gamma \frac{U^{*} - U}{U - \varphi(U^{*})} + \varepsilon, 0 < \varphi(U^{*}) < U^{*} . \tag{4}$$

The convex functional form of equation (4) is shown in Figure 1. The horizontal and vertical axes measure unemployment and unanticipated inflation, respectively. The slope parameter γ is a horizontal asymptote corresponding to the maximum rate of deflation. The parameter $\varphi(U^{*})$ is a vertical asymptote, reflecting the limiting effect of short-run capacity constraints on the unemployment rate lower bound as inflationary pressure grows. In general, φ may be defined either as a fixed constant or as an increasing function of U^{*}. In the subsequent numerical simulations the latter option is used:

$$\varphi(U^{*}) = \max(U, U^{*} - 4) . \tag{5}$$

The unemployment rate lower bound is constrained to zero if trend unemployment U^{*} is at or below 4 percent, and increases linearly with U^{*} when it rises above 4 percent. Figure 1 shows that the inflation-unemployment trade-off worsens at the margin as the unemployment rate falls below U^{*}. Moreover, the level of unemployment consistent with stable inflation exceeds U^{*} for any distribution of inflation shocks. Subsequently, the average unemployment rate EU in a stochastic equilibrium is referred to as the NAIRU, while the term *deterministic* NAIRU (DNAIRU) is reserved for U^{*}, the nonaccelerating inflation rate of unemployment in the absence of shocks.

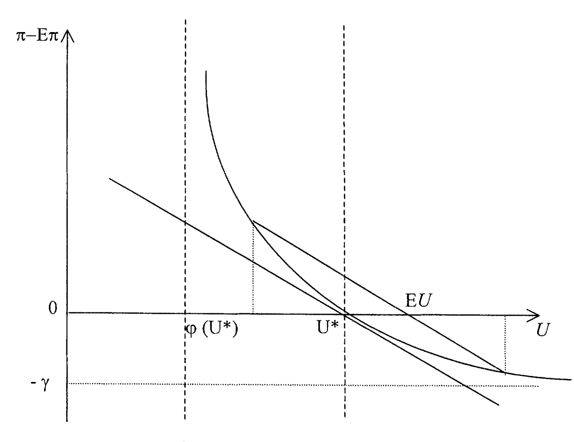

FIG. 1. Inflation/ Unemployment Trade-off

This result implies that successful stabilization over the business cycle will be inducing lower average unemployment. The gap between the NAIRU and the DNAIRU is increasing in the variance of the shock distribution, as well as in the degree of convexity in the Phillips curve. This is a restricted case of Scarth (1997), in which the slope is a function of unemployment but also of expected inflation. In the general case, lower expected inflation increases the absolute slope and is therefore "bad," as it widens the unemployment gap between the NAIRU and the DNAIRU.[3]

The second departure from the linear-symmetric model concerns the policymaker's preferences. In contrast to Laxton, Rose, and Tambakis (1999) and Wieland (1996), I follow Tambakis (1999) in assuming that when unemployment gets above the DNAIRU the policymaker cares about the *level*, as well as the variance of unemployment. In contrast, when the unemployment rate is to the left of the DNAIRU, preferences are symmetric. Put differently, unemployment rates above the DNAIRU impose first-order welfare costs to the policymaker. Such asymmetric preferences over the policy outcome can be modeled by introducing an extra term, which is linear in unemployment deviations from the DNAIRU if the economy is in the recession region ($U > U^*$), and zero if it is in the expansion region ($U \leq U^*$). The asymmetric loss function is

$$L = (U - U^*)^2 + \alpha(\pi - \overline{\pi})^2 + 2\psi \max(0, U - U^*), \quad \psi > 0\,. \tag{6}$$

Equation (6) captures the asymmetric effect on social welfare of the level of economic activity when the unemployment rate gets above the DNAIRU. A higher value of ψ indicates a higher degree of asymmetry. As argued above, policy rules based on such preferences—introduced by Orphanides and Wilcox (1996) and Orphanides et al. (1996) in a model of a linear Phillips curve—underlie the "opportunistic approach" to disinflation.

2. EQUILIBRIUM MONETARY POLICY

2.1 Analytics

The one-period equilibrium inflation and unemployment rates are at the intersection of the inflation and unemployment marginal loss schedules. The first-order conditions (FOC) of the nonlinear optimization problem can be expressed as a function of either target variable:

$$-L_U(\pi)\frac{\partial U}{\partial \pi} = L_\pi, \quad -L_\pi(U)\frac{\partial \pi}{\partial U} = L_U\,. \tag{7}$$

3. The general case is problematic because it is difficult to reconcile the positive effect on the unemployment gap of lower expected inflation with the negative effect of smaller inflation variance. In general, lower average inflation rates also tend to be less variable.

Without loss of generality, attention is restricted to the FOC with respect to the unemployment rate. The marginal loss function of unemployment is linear with unit slope and discontinuous and nondifferentiable at $U = U^*$ because of the asymmetry. Its two segments correspond to the expansion and recession regions of the economy. The one-period equilibrium unemployment rate is given by

$$U \leq U^* : \frac{\alpha\gamma^2(U^*-\varphi)^2}{(U-\varphi)^3} + \frac{\alpha\gamma(U^*-\varphi)}{(U-\varphi)^2}(E\pi - \bar{\pi} - \gamma + \varepsilon) = U - U^* . \quad (8)$$

$$U > U^* : \frac{\alpha\gamma^2(U^*-\varphi)^2}{(U-\varphi)^3} + \frac{\alpha\gamma(U^*-\varphi)}{(U-\varphi)^2}(E\pi - \bar{\pi} - \gamma + \varepsilon) = U - U^* + \psi . \quad (9)$$

The left-hand sides of equations (8) and (9) are identical, so the FOC can be written as

$$\frac{A_1}{(U-\varphi)^3} + \frac{A_2}{(U-\varphi)^2} = -L_\pi(U)\frac{\partial\pi}{\partial U} \quad (10)$$

where

$$A_1 = \alpha\gamma^2(U^*-\varphi)^2, \quad A_2 = \alpha\gamma(U^*-\varphi)(E\pi - \bar{\pi} - \gamma + \varepsilon) . \quad (11)$$

Tambakis (1999) shows that real-valued solutions for unemployment exist if and only if the value of the inflation marginal loss function at the DNAIRU, $-L_\pi\partial\pi/\partial U$ (U^*), is outside the discontinuity range $(0,\psi)$ of L_U. In other words, if $-L_\pi\partial\pi/\partial U$ (U^*) is within the range of discontinuity, then the two marginal loss segments do not intersect. The relevant inaction range of inflation shocks for this to occur is

$$\bar{\pi} - E\pi \leq \varepsilon \leq \frac{\psi(U^*-\varphi)}{\alpha\gamma} + \bar{\pi} - E\pi \quad (12)$$

Over the range of shocks given by inequalities (12) the optimal policy setting does not adjust and the one-period equilibrium unemployment rate is U^*. Importantly, the nonintersection of the marginal loss schedules is caused by the asymmetry in the loss function and not by convexity in the Phillips curve. The properties of the inaction range are as follows: (i) More asymmetric preferences (larger ψ) widen the inaction range, as unemployment levels above U^* become relatively more costly. (ii) Higher inflation aversion (larger α) induces a narrower inaction range: a more inflation-averse policymaker pursues a tighter monetary policy, hence she is more likely to disinflate in any given period, other things equal. (iii) Ceteris paribus, a more convex Phillips curve (larger γ and/or φ) implies a smaller sacrifice ratio and a higher incentive to disinflate, consequently the inaction range narrows.[4] (iv) Higher inflation shock variability yields more shock realizations outside the inaction range, thereby inducing more proactive monetary policy.

2.2 Numerical Simulations for the United States

The equilibrium levels of inflation and unemployment are evaluated as a function of simulated inflation shocks from an inflation shock distribution with zero mean and standard deviation $\hat{\sigma}_\varepsilon = 1.29$ percent (quarterly, at annual rates), which is approximately the estimate reported by Gordon (1997) in a linear model with a twenty-four-quarter distributed lag of past inflation. However, under the asymmetric loss function under consideration, solving the nonlinear FOC using the inflation target as an estimate of expected inflation yields an average inflation rate different from $\bar{\pi}$. Expected inflation would then not be model consistent. Therefore, unlike the linear model, $\bar{\pi}$ cannot be substituted for the equilibrium expected inflation rate. As argued in Tambakis (1999), this problem is resolved with the following numerical algorithm. First, guess an arbitrary initial value of equilibrium inflation bias: $\beta_0 = E\pi - \bar{\pi} > 0$. Computing the one-period equilibrium level of inflation for a large number of shocks yields an inflation sample mean of $\hat{\pi}(\beta_0)$. This generates an equilibrium expected inflation bias of $b_0 = \hat{\pi}(\beta_0) - \bar{\pi} > 0$ corresponding to β_0. If the guessed and the estimated average inflation are different ($\beta_0 \neq b_0$), a second iteration uses $\beta_1 = b_0$ as an updated bias estimate. Repeated iteration of this process yields a value β^* arbitrarily close to the actual bias estimate $b^* = \hat{\pi}(\beta^*) - \bar{\pi}$.[5] Therefore, β^* is self-sustaining as a fixed point for the expected inflation bias under the particular inflation shock distribution, and the resulting inflation sample mean $\hat{\pi}(\beta^*)$ can be used in the FOC to derive the equilibrium outcomes.

The structural parameter estimates for the United States follow the methodology of Laxton, Rose, and Tambakis (1999). The unobserved time-varying DNAIRU and the Phillips curve parameters are jointly estimated using the Kalman filter. The estimated value of the Phillips curve slope on quarterly data for 1968:Q1 to 1997:Q1 is $\hat{\gamma} = 4.71$. The average unemployment rate over the sample is 6.4 percent and the average of the estimated model-consistent $\hat{U}_t^*$ series is 6.1 percent, implying an average gap between the NAIRU and the DNAIRU of the order of 0.3 percent.[6] The benchmark value of the inflation target is set to $\bar{\pi} = 2$ percent, while the inflation aversion and asymmetric preference coefficients are set to $\alpha = \psi = 1$.

Convergent moments of the inflation and unemployment distributions are computed for ten thousand simulated normally distributed inflation shocks with mean zero and estimated standard deviation $\hat{\sigma}_\varepsilon = 1.29$ percent. The simulation exercise consists of three alternative scenarios. Panel A is the benchmark scenario in which

4. If φ were constant, then an exogenous increase in the DNAIRU would widen the shock inaction range. The Phillips curve would then be flatter at U^*.

5. The inflation shock distribution is assumed to be ergodic so that convergence occurs for finite sample sizes after a finite number of iterations.

6. It should be noted that estimates of the NAIRU have been falling recently as inflation has been stable while the actual unemployment rate has dropped.

$U^* = 6.1$ percent, $\bar{\pi} = 2$ percent, $\varphi = 2.1$ percent and $\alpha = \psi = 1$. It follows from (12) that the amplitude of the inflation shock inaction range then is 0.85 percent. In Panel B the inflation target is set to $\bar{\pi} = 0$, while Panel C considers an exogenous rise in the DNAIRU to $U^* = 10$ percent. Recalling from equation (5) that $\varphi(U^*)$ is specified to be a linearly increasing function of the DNAIRU, a hypothetical increase of the DNAIRU from 6 to 10 percent would raise the minimum unemployment rate from 2 to 6 percent. The simulated equilibrium moments of the target variables under the symmetric and asymmetric policies are reported in Table 1.

First, the gap between the average unemployment rate and the DNAIRU is less than 0.1 percent in all three cases, confirming the findings of Laxton, Rose, and Tambakis (1999) that convexity in the Phillips curve is difficult to identify when policymakers are overall successful at stabilizing the business cycle. Also, underlying the small gap are the relatively neutral preferences between unemployment and output stabilization ($\alpha = \psi = 1$). In that respect, Tambakis (1999) shows that reproducing an estimated gap of the order of 0.3 percent requires a very large inflation aversion coefficient ($\alpha = 10$) and a very small degree of preference asymmetry ($\psi = 0.1$). The sensitivity of monetary policy outcomes to the preference parameters is examined further in section 3.

Second, under the asymmetric policy loss function, all parameterizations yield positive equilibrium expected inflation bias ($E\pi > \bar{\pi}$) ranging from 0.60 percent in

TABLE 1
SIMULATED INFLATION AND UNEMPLOYMENT DISTRIBUTIONS

	Inflation Symmetric	Asymmetric	Unemployment Symmetric	Asymmetric
A. Benchmark parameter values				
Mean (percent)	2.03	2.62	6.18	6.13
S.D. (percent)	0.56	0.77	0.57	0.39
Skewness	1.12	0.48	−0.12	−0.33
Kurtosis	4.31	2.55	2.68	4.22
B. Zero inflation target ($\bar{\pi} = 0$)				
Mean (percent)	0.02	1.26	6.39	6.33
S.D. (percent)	0.55	0.68	0.55	0.37
Skewness	1.08	0.50	−0.17	0.07
Kurtosis	3.97	3.53	2.70	3.75
C. Large DNAIRU ($U^* = 10\%$, $\varphi = 6\%$)				
Mean (percent)	2.01	2.63	10.08	10.02
S.D. (percent)	0.55	0.75	0.57	0.39
Skewness	1.00	0.42	−0.23	−0.40
Kurtosis	3.79	2.60	2.74	4.43

NOTES: Inflation and unemployment equilibrium levels are computed over ten thousand simulated inflation shocks drawn from a $N(0,\hat{\sigma}_\varepsilon)$ distribution with $\hat{\sigma}_\varepsilon = 1.29\%$. The benchmark set of parameter values is $\hat{U}^* = 6.1\%$, $\hat{\gamma} = 4.71$, $\varphi = 2.1\%$, $\bar{\pi} = 2\%$ and $\alpha = \psi = 1$.

Panels A and C to over 1.20 percent in Panel B. This reflects the asymmetry in the policymaker's behavior: policy does not tighten unless a positive inflation shock exceeds the inaction range threshold. Moreover, the variance of the equilibrium unemployment rate is always greater under the asymmetric policy. The intuition relates to the asymmetric welfare costs of an unemployment rise on either side of U^*: the asymmetric policy penalizes unemployment deviations from target less than the asymmetric alternative. The equilibrium level of unemployment variance is therefore larger under the symmetric loss function, and vice versa for inflation. The higher order moments of the target variables indicate their distributions are not normal.

3. EXPECTED SOCIAL WELFARE

The expected social welfare implications of the convex Phillips curve depend on the possible combinations of policymaker and social preferences. These correspond to the two alternative "true" social loss functions used to evaluate policy outcomes, each coupled with the same choice of loss function for guiding monetary policy. The resulting four combinations reflect the fact that the policymaker and society—median voter, or representative agent—need not have the same loss function. If they do, that is, if the same loss function is used both by the policymaker for guiding monetary policy and by society for evaluating the expected macroeconomic outcome, then the two relevant combinations are referred to as *consistent*. If they do not, the two combinations are *inconsistent*: society uses an asymmetric loss function but the policymaker implements monetary policy using a symmetric loss function, or vice versa. Thus the policymaker maximizes expected social welfare only under the consistent scenarios.

At any particular point in time, the monetary authority may be uncertain of society's "true" policy preferences. In principle, such uncertainty on the part of the policymaker regarding the loss function used by society to evaluate policy outcomes could exist along a number of dimensions—in this paper it is restricted to the asymmetric term in the unemployment rate.[7] The macroeconomic policy preferences of society and the policymaker need not coincide because of a conservative central banker argument, or because the incumbent political party changes in midterm and does not reflect the median voter's policy preferences. Arguably, however, the difference in the loss functions is unlikely to be sustainable in the long term because of political considerations.

Expected social welfare is computed using equations (1) and (2). Under symmetric policy preferences, a particular policy rule outperforms another in expectation if it yields lower average inflation and less variable inflation and unemployment. Expected losses involve the first two moments of the target variables:

7. Society is also uncertain about the policymaker's preferences, as modeled by the literature on the optimal degree of central bank secrecy (for example, Eijffinger, Hoeberichts, and Schaling 2000 and Garfinkel and Oh 1995).

$$EL = \sigma_U^2 + \alpha\sigma_\pi^2 + EU(EU - 2U^*) + \alpha(E\pi - \bar{\pi})^2 + U^{*^2} \ . \tag{13}$$

Under the asymmetric loss function in equation (6), expected losses are also increasing in the gap between the average unemployment rate and the DNAIRU. They are given by

$$EL = \sigma_U^2 + \alpha\sigma_\pi^2 + EU(EU - 2U^*) + \alpha(E\pi - \bar{\pi})^2 + U^{*^2} + 2\psi E[\max(0, U - U^*)] \ . \tag{14}$$

The asymmetric term in equation (14) requires averaging only the outcomes of those shocks for which the equilibrium unemployment rate exceeds U^*. The expected social welfare comparisons evaluate the two alternative policy loss functions conditional upon a given social loss function. The converse scenario of changes in expected social welfare *given* policy preferences is not rational because changing from the symmetric to the asymmetric social loss function yields lower expected social welfare by definition. Expected social welfare is evaluated as follows. The benchmark set of structural and preference parameter values from section 2.2 is assessed against changes to the variance of the inflation shock, the degree of convexity in the Phillips curve, and the degree of relative inflation aversion and preference asymmetry. In each of the first two comparisons nine parameter combinations are evaluated, while the last comparison considers six parameterizations. The first-order conditions are solved for ten thousand inflation shocks using three different standard errors. The respective moments of the target variables are then substituted in equations (13) and (14) to evaluate the expected social welfare losses for each parameter combination. The sensitivity of expected social welfare to inflation shock variability is presented in Table 2.

The results indicate, first, that the symmetric policy delivers lower expected social losses—equivalently, higher expected social welfare—than the asymmetric alternative for most parameter values. The intuition centers on the equilibrium moments of the target variables entering (13) and (14). On one hand, Table 1 showed that the gap between average unemployment and the DNAIRU is somewhat narrower under the asymmetric loss function, but that the corresponding increase in average inflation is much larger. On the other hand, the relation between inflation and output variability is roughly proportional. Therefore, expected social losses are lower under the symmetric policy. Second, the expected social welfare differential is decreasing in inflation variability: the differential is bigger in Panel A when the inflation standard error is small (σ_ε = 0.25 percent). Moreover, imposing a zero inflation target yields significantly higher expected welfare losses unless inflation variability is very small.

Importantly, in Panel C (high inflation shock standard error) the asymmetric policy delivers expected welfare losses of the same order as the symmetric one. Indeed, the asymmetric policy yields lower expected social losses when both the shock vari-

TABLE 2

EXPECTED SOCIAL WELFARE LOSSES AND INFLATION VARIABILITY

A. Small inflation shock standard error ($\sigma_\varepsilon = 0.25\%$)

Social Loss Policy Loss	Symmetric Symmetric	Asymmetric	Asymmetric Symmetric	Asymmetric
1. Benchmark	**0.03**	0.65	**0.23**	0.81
2. $\bar{\pi} = 0$	**0.04**	0.70	**0.28**	0.87
3. $U^* = 10\%$	**0.03**	0.73	**0.25**	0.91

B. Estimated inflation shock standard error ($\hat{\sigma}_\varepsilon = 1.29\%$)

Social Loss Policy Loss	Symmetric Symmetric	Asymmetric	Asymmetric Symmetric	Asymmetric
1. Benchmark	**0.68**	1.16	**1.68**	1.83
2. $\bar{\pi} = 0$	**1.18**	2.25	**2.33**	3.12
3. $U^* = 10\%$	**0.67**	1.11	**1.61**	1.77

C. Large inflation shock standard error ($\sigma_\varepsilon = 10\%$)

Social Loss Policy Loss	Symmetric Symmetric	Asymmetric	Asymmetric Symmetric	Asymmetric
1. Benchmark	**56.84**	57.82	**62.04**	62.63
2. $\bar{\pi} = 0$	**212.9**	221.8	**219.8**	228.0
3. $U^* = 10\%$	55.9	**53.0**	61.1	**57.6**

NOTES: Inflation and unemployment equilibrium levels are computed over ten thousand simulated inflation shocks drawn from the appropriate distribution (Panels A–C). The benchmark set of parameter values is $\hat{U}^* = 6.1\%$, $\hat{\gamma} = 4.71$, $\varphi = 2.1\%$, $\bar{\pi} = 2\%$ and $\alpha = \psi = 1$.

ability and the DNAIRU are large ($\sigma_\varepsilon = 10$ percent, $U^* = 10$ percent). In that case the shock realization is not often within the inaction range. The latter is invariant to the increase in U^* as φ also adjusts upward. Consequently, the variance of inflation increases, albeit somewhat more than under symmetric preferences. However, although the positive gap between EU and the DNAIRU widens under both policies, it is narrower under the asymmetric alternative, and the variance of unemployment is significantly lower. Therefore, asymmetric policy preferences can enhance social welfare but only under extreme parameter values.

Turning to the sensitivity of the expected welfare differential to the degree of convexity, it is apparent geometrically that the degree of convexity is increasing in the horizontal and vertical asymptotes of the Phillips curve, γ and φ respectively (see Figure 1). Inequalities (12) showed that, given the preference parameters (α,ψ) and the level of the DNAIRU, more convexity—larger γ and/or φ—induces a narrower inaction range because it implies a smaller sacrifice ratio. Conversely, less convexity implies a greater sacrifice ratio: a 1 percent disinflation is costlier in terms of unemployment. As argued above, switching to the asymmetric policy increases expected inflation by more than it decreases expected unemployment. Thus, because under the asymmetric policy more convexity induces a smaller expected inflation bias and a higher expected unemployment rate, the net impact on expected welfare of a larger degree of convexity should be positive. By the same argument, less convexity should have a negative effect on expected welfare with the asymmetric policy.

Expected welfare losses are evaluated for one case of large convexity and two cases of small convexity. Regarding the former, Panel A sets $\gamma = 9.5$, implying a narrowing of the inaction range to 0.425 percent and a substantially smaller sacrifice ratio. For small convexity, Panel B sets $\gamma = 2.35$, inducing a doubling of the inaction range from its benchmark value of 0.85 percent to 1.70 percent, while Panel C sets $\varphi = 0$. The results are in Table 3.

The symmetric policy loss function again delivers lower expected social losses irrespective of the social loss function in place. In particular, note that with the large degree of convexity (Panel A) expected losses under the asymmetric policy are still greater than under the symmetric policy. However, expected losses are much smaller than in Table 2, Panel B, the estimated benchmark convexity case of $\hat{\gamma} = 4.71$. Indeed, when convexity is large and social preferences are asymmetric, the asymmetric policy yields expected social losses very similar to the symmetric policy. This is because the smaller sacrifice ratio induces a correspondingly narrower inaction range, and consequently the asymmetry in the social loss function is not binding. Meanwhile, expected social losses under small convexity in Panels B and C, although both higher than Panel A, are of the same order of magnitude, suggesting that

TABLE 3

EXPECTED SOCIAL WELFARE LOSSES AND CONVEXITY

A. Large convexity ($\gamma = 9.5$)

Social Loss Policy Loss	Symmetric Symmetric	Asymmetric	Asymmetric Symmetric	Asymmetric
1. Benchmark	**0.25**	0.38	**1.03**	1.07
2. $\bar{\pi} = 0$	**0.28**	0.62	**1.06**	1.34
3. $U^* = 10\%$	**0.22**	0.36	**0.95**	0.99

B. Small convexity ($\gamma = 2.35$)

Social Loss Policy Loss	Symmetric Symmetric	Asymmetric	Asymmetric Symmetric	Asymmetric
1. Benchmark	**1.46**	2.31	**2.36**	2.73
2. $\bar{\pi} = 0$	**3.21**	4.30	**4.40**	4.87
3. $U^* = 10\%$	**1.46**	3.92	**2.35**	4.46

C. Small convexity ($\varphi = 0$)

Social Loss Policy Loss	Symmetric Symmetric	Asymmetric	Asymmetric Symmetric	Asymmetric
1. Benchmark	**1.01**	1.69	**1.97**	2.29
2. $\bar{\pi} = 0$	**2.08**	3.93	**3.36**	4.78
3. $U^* = 10\%$	**1.48**	3.41	**2.33**	3.91

NOTES: Inflation and unemployment equilibrium levels are computed over ten thousand simulated inflation shocks drawn from a $N(0,\hat{\sigma}_\varepsilon)$ distribution with $\hat{\sigma}_\varepsilon = 1.29\%$. The benchmark set of parameter values is $\hat{U}^* = 6.1\%$, $\hat{\gamma} = 4.71$, $\varphi = 2.1\%$, $\bar{\pi} = 2\%$ and $\alpha = \psi = 1$.

the social welfare impact of varying γ and φ is similar. Note also that, as in Table 2, imposing a zero inflation target induces significantly higher expected welfare losses unless inflation variability is very small.

Finally, the sensitivity of the expected welfare comparison is assessed with respect to the policymaker's and society's relative preferences for inflation and output stabilization. These are given by the normalized inflation aversion coefficient (α) and the degree of preference asymmetry (ψ). I examine two extreme parameter combinations, a case of low inflation aversion—equivalently, large recession aversion—and large preference asymmetry ($\alpha = 0.1$, $\psi = 10$), and a case of high inflation aversion and small asymmetry ($\alpha = 10$, $\psi = 0.1$). The results are in Table 4.

Panel A indicates that when society's preferences are very asymmetric and inflation aversion is low, asymmetric policy preferences yield significantly lower expected social losses than the symmetric policy. Moreover, the expected social welfare losses under the asymmetric policy loss function are identical for both social loss functions. This is the only parameter specification in Tables 2–4 for which the consistent scenario of asymmetric social and policy preferences outperforms the inconsistent scenario of asymmetric social and symmetric policy preferences. However, conditional upon symmetric social preferences the symmetric policy loss function yields lower expected losses than the asymmetric alternative even under such extreme preferences in favor of unemployment stabilization.

Panel B shows that the consistent scenario outperforms the inconsistent alternative when the inflation aversion coefficient is very large ($\alpha = 10$) and the degree of preference asymmetry very small ($\psi = 0.1$). For the extreme preferences under consideration, however, the asymmetric term in the loss function effectively becomes negligible. Consequently, conditioning upon society's asymmetric loss function im-

TABLE 4

Expected Social Welfare Losses and Policy Preferences

A. Low inflation aversion and large asymmetry ($\alpha = 0.1$, $\psi = 10$)

Social Loss Policy Loss	Symmetric Symmetric	 Asymmetric	Asymmetric Symmetric	 Asymmetric
1. Benchmark	**0.12**	0.19	2.23	**0.19**
2. $\bar{\pi} = 0$	**0.46**	0.71	4.28	**0.71**
3. $U^* = 10\%$	**0.20**	0.79	2.82	**0.79**

B. High inflation aversion and small asymmetry ($\alpha = 10$, $\psi = 0.1$)

Social Loss Policy Loss	Symmetric Symmetric	 Asymmetric	Asymmetric Symmetric	 Asymmetric
1. Benchmark	**1.41**	1.51	**1.60**	1.71
2. $\bar{\pi} = 0$	**1.90**	1.92	**2.10**	2.13
3. $U^* = 10\%$	**1.85**	2.13	**2.04**	2.33

Notes: Inflation and unemployment equilibrium levels are computed over ten thousand simulated inflation shocks drawn from a $N(0,\hat{\sigma}_\varepsilon)$ distribution with $\hat{\sigma}_\varepsilon = 1.29\%$. The benchmark set of parameter values is $\hat{U}^* = 6.1\%$, $\hat{\gamma} = 4.71$, $\varphi = 2.1\%$, $\bar{\pi} = 2\%$ and $\alpha = \psi = 1$.

plies that the expected welfare differential resulting from the policymaker's symmetric and asymmetric preferences is relatively narrow.

4. CONCLUSION

This paper studied the expected social welfare implications of a convex Phillips curve and an asymmetric policy loss function corresponding to the "opportunistic approach" to disinflation. For parameter values corresponding to the modest degree of convexity present in U.S. data, stochastic simulations suggested that policy based on the symmetric loss function dominated policy based on the asymmetric alternative in expectation. In most cases, the symmetric policy loss function yielded lower expected social losses regardless of the "true" social loss function used by society to evaluate macroeconomic outcomes. This result was shown to be robust to the degree of convexity, inflation shock variability and asymmetry in the loss function. The only cases when the asymmetric policy can enhance expected social welfare involved extreme and, arguably, unrealistic parameter values, notably high inflation shock variability and a large DNAIRU and/or very low inflation aversion and a large degree of preference asymmetry.

Overall, the findings provide tentative support to arguments favoring a tough anti-inflationary stance by the Federal Reserve regardless of any possible differences with the "true" social loss function in place. It should be stressed that the welfare comparison was specific to the chosen asymmetric functional form, and that the resulting policy implications are conditional. In that respect, future work should consider alternative functional forms and further study the relationship between "opportunistic" and standard symmetric policy reaction functions. The finding that an asymmetric loss function under convexity yields positive expected inflation bias whose magnitude is increasing in the degree of asymmetry also merits research attention.

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