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Endogenous objectives and the evaluation of targeting rules for monetary policy ☆

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Abstract

Recent research in monetary economics has followed the advice of McCallum [1988. Robustness properties of a rule for monetary policy. Carnegie-Rochester Conference Series on Public Policy 29, 173–203] and investigated the robustness properties of monetary policy rules by evaluating them in a variety of models. Evaluation across models is typically based on an exogenously specified loss function. However, the theory on which many recent monetary policy models are based implies that changes in the structure of the model also have consequences for the policy objectives the central bank should pursue. Objectives are endogenous, not exogenous to the model. In this paper, I investigate the impact of endogenous objectives on the evaluation of targeting rules for monetary policy.

Keywords: Monetary policy; Targeting rules; Robustness

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1. Introduction

There is a fundamental dichotomy that underlies most monetary policy analysis. On the one hand, there is the model of the economy, consisting of a set of structural equations that characterize the private sector's behavior. On the other hand, there are the preferences of the policy maker. This dichotomy allows economists to provide the policy maker with a menu of alternative choices, leaving it to the policy maker to choose from among the available options. This view is reflected in a recent paper by McCallum and Nelson:

> Accordingly, it can be useful to explore the way in which difference properties of a modelled economy—e.g., the variances of the endogenous variables—are related to policy rule parameters, leaving it to actual policy makers to assign the relevant weights [to policy objectives]. McCallum and Nelson (2004b, p. 5).

Recent work in macro, most prominently by Woodford (2003), calls into question this dichotomy between economic structure and policy objectives. He shows that the standard quadratic loss function that has been a common component of much of the monetary policy literature can be, under certain conditions, interpreted as a second-order approximation to the welfare of the representative agent. But critically, this interpretation of the loss function breaks the dichotomy between economic structure and objectives; the relative weights on the variables appearing in the loss function, and even the list of variables that should appear, depend on the structure of the economic model.[1] The policy maker cannot find the marginal rate of substitution between the target variables in a manner that is independent of the transmission mechanism that governs the marginal rate of transformation between them. Even the definition of the target variables will depend on the policy maker's views of the transmission mechanism.

This has two important implications. First, it will rarely be appropriate to combine the same loss function with different structural models of the economy. Different models will imply different loss functions. Second, in assessing model and parameter uncertainty, uncertainty about key structural parameters will also imply uncertainty about the correct loss function.[2]

At a practical level, the endogeneity of objectives has implications for the assessment of policy robustness. It may, for example, be inappropriate to take a rule designed to minimize a loss function in one model and evaluate its performance in a different model using the original loss function. The objective function appropriate for one model cannot be used directly to evaluate outcomes in a different model. Thus, McCallum's influential recommendation to use multiple models to explore the robustness of policy rules (McCallum, 1988, 1999) may be less straightforward than it appears.

There is another implication of the dependence of objectives on structure. Just as one could follow McCallum and evaluate the consequences of using a rule optimized

[1] See, for example, Erceg et al. (2000), Steinsson (2003), and Amato and Laubach (2003).

[2] See Levin and Williams (2003b) and Kimura and Kurozumi (2003).

for one structural model in a different structural model, one similarly needs to investigate the consequences of employing a rule optimized for one objective function when the true social objective is different. To be specific, what are the consequences of implementing a policy rule that is optimal from the perspective of the standard quadratic loss function in inflation and output gap volatility if the economy is actually characterized by a model that implies welfare should be measured by a different loss function?

In work closely related to this paper, Levin and Williams (2003b), Kimura and Kurozumi (2003), and Kurozumi (2003) also investigate the consequences of parameter uncertainty for policy when objectives are endogenous and depend on the model's structural parameters. They study Bayesian policies and show how optimal monetary policy is affected when the objective function depends on structural parameters whose values are uncertain.[3] Levin and Williams show how Brainard's classic finding that multiplicative uncertainty leads to caution can be overturned when the effects of uncertainty on the loss function are appropriately accounted for. For example, they find that the optimal interest rate response to a cost shock is unaffected by uncertainty about the output elasticity of inflation, once the implications of this uncertainty for the central bank's objective function are incorporated into the analysis. Kimura and Kurozumi show how uncertainty about inflation dynamics can lead to more aggressive policy responses to shocks as the nature of these dynamics alter the weight the central bank places on its price stability objective.

In contrast to these paper, I do not deal with optimal policy under uncertainty. Instead, I follow the bulk of the literature on optimal monetary policy and consider policy rules that ignore parameter uncertainty. Monetary policy is represented in terms of targeting rules which are based on the first-order conditions from the central bank's policy decision problem (Svensson, 2003; Svensson and Woodford, 2005). These targeting rules depend, therefore, on both the nature of the central bank's objectives and the constraints imposed by the economy's structure. I focus on how the failure to recognize the link between structural parameters and the loss function affects the evaluation of alternative targeting rules. I also conduct a form of risk assessment by evaluating the consequences for macroeconomic outcomes of basing policy on incorrect parameter values. I show how conclusions about the consequences of this form of parameter misspecification depend on whether all the implications of the misspecification—on structural equations, on objectives, and on the nature of economic disturbances—are fully accounted for.

The model employed in the analysis draws on the recent extension of the basic new Keynesian model by Benigno and Woodford (2004), an extension that explicitly incorporates the case of a distorted steady-state. Cost shocks, normally treated as exogenous in the literature on monetary policy, arise endogenously due to stochastic fluctuations in the wedge between the efficient level of output and the flexible-price equilibrium level of output. Two aspects of the model will be the primary foci of the analysis: the degree of structural inflation inertia and the degree of nominal price

[3]Levin and Williams also consider robust min–max policies.

stickiness. Both have generated much empirical debate and also appear to be important for the evaluation of alternative policies. One of the earliest criticisms of forward-looking models of inflation was that they were incapable of matching the highly serially correlated nature of actual inflation processes (Nelson, 1998). While the persistence displayed by inflation could result from serially correlated inflation shocks or from the behavior of monetary policy (Goodfriend and King, 2001), there is great uncertainty about the respective roles of forward and backward elements in the inflation process. For example, Rudebusch (2002) estimates the weight on lagged inflation to be over twice that on expected future inflation, while Galí and Gertler (1999) find essentially the reverse. This uncertainty about the degree of structural inflation inertia is unfortunate, since the existing literature has identified it as one of the most critical factors affecting the evaluation of alternative policies.[4]

The degree of nominal price rigidity, like the degree of structural inflation inertia, is also an issue around which there is great uncertainty. Early structural estimates of forward-looking new Keynesian Phillips curves obtained values for the average period between price adjustments that were very long, on the order of a year or more (Galí and Gertler, 1999; Sbordone, 2002; Dennis, 2003). This is much longer than is consistent with microevidence (Bils and Klenow, 2002).[5]

In the next section, the basic model is set out and the optimal targeting rule that minimizes the expected present discounted value of a second-order approximation to the welfare of the representative household is derived. The way in which this objective function depends on the model's structural parameters is discussed. Section 3 then considers the case in which the central bank's model of the economy is correct, but policy is based on the wrong objectives. The purpose of this section is to investigate how conclusions reached in standard models with exogenous objectives might need to be altered once model consistent objectives are employed. Section 4 examines the robustness of the optimal targeting rule to parameter misspecification, focusing on how assessments of robustness are affected by the endogeneity of the objective function. Conclusions are summarized in the final section.

2. The basic model and optimal targeting rules

The basic model has been described as either new Keynesian or new synthesis (Goodfriend and King, 1997; Rotemberg and Woodford, 1997; Yun, 1996; McCallum and Nelson, 1999; Walsh, 2003a; Woodford, 2003), and the specific version employed here borrows from Benigno and Woodford (2004). They provide a detailed discussion of the underlying assumptions of the model; consequently, the presentation here is kept quite brief.

[4]See, for example, Rudebusch (2002), Levin and Williams (2003a), and Walsh (2003b).

[5]Christiano et al. (2005) and Eichenbaum and Fischer (2004) have extended the basic new Keynesian Phillips curve to allow for structural inflation inertia, the use of lagged information, and variable rates of capital utilization, and they obtained estimates closer to the microevidence on how long prices remain unchanged.

Define $x \equiv \hat{Y}_t - \hat{Y}_t^n$ as the gap between actual output $\hat{Y}_t$ and the flexible-price equilibrium output level $\hat{Y}_t^n$ (all expressed as log deviations from the steady-state). The Euler condition from the representative household's consumption decision can be represented as

$$x_t = E_t x_{t+1} - \left(\frac{1}{\sigma}\right)(i_t - E_t \pi_{t+1} - r_t^n), \tag{1}$$

where i is the nominal interest rate and r^n is the Wicksellian real rate of interest. This equilibrium real interest rate is equal to

$$r_t^n \equiv \sigma\{E_t(\hat{Y}_{t+1}^n - \hat{Y}_t^n) - (1 - s_C)E_t(\hat{G}_{t+1} - \hat{G}_t)\},$$

where $\hat{G}_t$ is the log deviation of government consumption from its steady-state value and s_C is the steady-state ratio of consumption to output. The parameter σ is equal to the representative household's coefficient of relative risk aversion divided by s_C, the steady-state ratio of consumption to income.

Benigno and Woodford (2004) show that equilibrium output with flexible prices depends positively on government spending through a standard neo-classical labor supply response, negatively on a distortionary income tax rate, and positively on aggregate productivity. If a_t is the aggregate productivity shock, τ_t is the income tax shock, and $\bar{\tau}$ is the steady-state tax rate,

$$\hat{Y}_t^n = \frac{\sigma\hat{G}_t + \phi(1 + v)a_t - [\bar{\tau}/(1 - \bar{\tau})]\tau_t}{\omega + \sigma},$$

where v is inverse of the wage elasticity of labor supply, ϕ is the elasticity of firm output with respect to labor input, and $\omega = \phi(1 + v) - 1 > 0$ is the inverse of the elasticity of firm marginal cost with respect to output.

Inflation adjustment is based on the assumption that each period a fixed fraction $1 - \alpha$ of randomly chosen firms optimally adjust their price while the remaining firms simply index their price to a fraction γ of last period's inflation rate. As Woodford (2003) shows, this assumption yields an aggregate inflation equation of the form

$$\pi_t - \gamma\pi_{t-1} = \beta(E_t\pi_{t+1} - \gamma\pi_t) + \kappa x_t. \tag{2}$$

The parameter γ measures the degree of structural inflation inertia, β is the discount rate, and the output elasticity of inflation, κ, is given by

$$\kappa = \frac{(1 - \alpha)(1 - \alpha\beta)}{\alpha(1 + \theta\omega)}(\omega + \sigma),$$

where θ is the demand elasticity faced by individual firms.

2.1. Endogenous policy objectives

Woodford (2003) has stressed that in models based on well defined optimization problems for the agents in the model, one should view the maximization of the welfare of the representative agent as the appropriate objective of policy. Benigno and Woodford (2004) have extended Woodford's earlier work to deal with cases in which distortions generate a gap between the economy's steady-state and the Pareto optimal steady-state equilibrium. In the model that leads to (1) and (2), they show that the second-order approximation to the welfare of the representative household is equal to

$$W_t = -\frac{1}{2}\Omega E_t \sum_{i=0}^{\infty} \beta^i [(\pi_{t+i} - \gamma\pi_{t+i-1})^2 + \lambda(\hat{Y}_{t+i} - Y^*_{t+i})^2] + T_{t_0}, \tag{3}$$

where Y^*_t is the first-best, efficient level of output (expressed as a log deviation around the steady-state) and T_{t_0} is a transitory component that depends on expectations of future outcomes as of time t_0. Additional terms independent of policy have been ignored. In this approximation to social welfare, the (distorted) steady-state around which welfare is approximated is the steady-state consistent with the optimal policy from a timeless perspective. The past commitments under this policy are reflected in T_{t_0}. Thus, (3) gives a correct second-order approximation to social welfare for initial expectations consistent with the commitments that constrain a policy maker implementing the policy that is optimal from the timeless perspective. Because it reflects these past commitments, T_{t_0} is predetermined at time t_0.

Benigno and Woodford (2004) show that the first-best output level is given by

$$Y^*_t = w_1 \hat{Y}^n_t - w_2 \hat{G}_t + w_3 \hat{\tau}_t,$$

where

$$w_1 = \frac{\omega + \sigma + \Phi(1-\sigma)}{\xi},$$

$$w_2 = \frac{\Phi\sigma s_c^{-1}}{(\omega+\sigma)\xi},$$

$$w_3 = \frac{\bar{\tau}}{(1-\bar{\tau})\xi},$$

and

$$\Phi = 1 - \frac{\theta - 1}{\theta}(1-\bar{\tau}) < 1,$$

where $\xi \equiv (\omega + \sigma) + \Phi(1-\sigma) - \Phi\sigma(s_c^{-1} - 1)/(\omega + \sigma)$. The parameter Φ is a measure of the steady-state distortions in the economy. These arise from two sources: the presence of imperfect competition (reflected in θ) and taxes. If Φ is zero (as is often assumed), $w_1 = 1$ and the efficient level of output moves one-for-one with the flexible-price output level.

Define the first term in (3) as the social loss:

$$\mathscr{L}^{\mathrm{sl}}_t = \frac{1}{2}\Omega E_t \sum_{i=0}^{\infty} \beta^i [(\pi_{t+i} - \gamma\pi_{t+i-1})^2 + \lambda(\hat{Y}_{t+i} - Y^*_{t+i})^2]. \tag{4}$$

This loss function will be used to evaluate alternative policies. It corresponds to the type of quadratic loss function commonly employed in the literature to rank policies in ignoring the effects of any past commitments captured in (3) by T_{t_0}. Unlike the standard quadratic loss function, however, the parameters in (4) are not exogenous to the structural equations of the model but in fact depend on the structure of the model. Specifically, the leading coefficient, Ω is given by

$$\Omega = \frac{\bar{Y} u_{\mathrm{c}} \theta}{\kappa}[\omega + \sigma + \Phi(1 - \sigma)],$$

where $\bar{Y}$ is steady-state output and u_{c} is the marginal utility of consumption evaluated at the steady-state, while the weight placed on the welfare gap relative to inflation, λ, is given by

$$\lambda = \frac{\kappa}{\theta}\left[\frac{\omega + \sigma + \Phi(1 - \sigma) - \Phi\sigma(s_{\mathrm{c}}^{-1} - 1)/(\omega + \sigma)}{\omega + \sigma + \Phi(1 - \sigma)}\right] = \frac{\kappa}{w_1 \theta}. \tag{5}$$

The two parameters of primary interest, γ measuring the degree of structural inflation inertia and α measuring the degree of price rigidity, have different effects on the loss function. The value of γ affects the social loss function, but only in terms of the definition of the quasi-difference of inflation whose volatility is associated with a welfare loss. The relative weight placed on objectives, λ, is independent of the degree of structural inflation inertia. The degree of nominal price stickiness, α, affects both Ω and λ through its effect on κ, the output gap elasticity of inflation. Greater price rigidity (an increase in α) reduces κ and lowers the relative weight the central bank should put on stabilizing the output gap measure. With a higher α, it becomes more important to stabilize the quasi-difference of inflation.

It is convenient to re-express the model in terms of the gap between output and the efficient output level, since this is the gap variable that appears in the loss function (4). Let $\tilde{x}_t \equiv \hat{Y}_t - Y_t^*$ be this welfare gap, and define $\mu_t \equiv Y_t^* - \hat{Y}_t^n$ as the gap between the efficient output level and the flexible-price level. Then $x_t = \tilde{x}_t + \mu_t$, and the model can be written in terms of the welfare gap $\tilde{x}_t$ as

$$\tilde{x}_t = E_t \tilde{x}_{t+1} - \left(\frac{1}{\sigma}\right)(i_t - E_t \pi_{t+1} - \tilde{r}_t^n) \tag{6}$$

and

$$\pi_t - \gamma \pi_{t-1} = \beta(E_t \pi_{t+1} - \gamma \pi_t) + \kappa \tilde{x}_t + \kappa \mu_t, \tag{7}$$

where the real interest rate variable $\tilde{r}$ is now defined as

$$\tilde{r}_t^n \equiv \sigma\{E_t(Y_{t+1}^* - Y_t^*) - (1 - s_{\mathrm{C}})E_t(\hat{G}_{t+1} - \hat{G}_t)\}. \tag{8}$$

Note that the "cost shock" $\kappa \mu_t$ in (7) arises from any stochastic variation in the wedge between the efficient level of output and the flexible-price output level. When $\Phi > 0$, μ_t fluctuates in response to movements in the flex-price output level, government spending, and taxes. The standard deviation of the cost shock is proportional to κ; increases in price rigidity that reduce the output gap elasticity of inflation also reduce the volatility of cost shocks. Demand shocks, represented by $\tilde{r}_t^n$ are potentially correlated with the cost shocks.[6]

The loss function (4) is model consistent—it is based on a second-order approximation to the welfare of the represent agent in the model that gave rise to the structural equations (6) and (7)—and I will refer to it as the social loss function. However, given the structural equations (6) and (7), the vast majority of researchers have assumed that policy objectives can be represented by a loss function of the form

$$\mathscr{L}_t^{\text{std}} = \frac{1}{2}\bar{\Omega}E_t\sum_{i=0}^{\infty}\beta^i(\pi_{t+i}^2 + \bar{\lambda}y_{t+i}^2), \tag{9}$$

where y is an output gap measure. In this standard specification, $\bar{\Omega}$ and $\bar{\lambda}$ are exogenous parameters, treated as independent of the specification of the structural equations of the model. Critically, this loss function is treated as fixed as other aspects of the structural model are varied.[7] For example, Levin and Williams (2003a) employ such a loss function to evaluate the consequences of employing a policy that is optimal for one model when the economy is characterized by a difference economic model.[8] Angeloni et al. (2003) investigate the implications of misspecifying the degree of structural inflation inertia, with outcomes all evaluated using a fixed objective function. A similar exercise is conducted by Walsh (2003c).

The loss function in (4) contrasts with (9) in three ways. First, social loss depends on the volatility of a particular quasi-difference of the inflation rate rather than on inflation volatility itself. Second, the appropriate output gap measure is defined specifically in terms of the distortions that underlie the economic model. And third, the relative weight placed on the two objectives and the leading coefficient Ω in (4) are functions of the model's structural parameters.

In what follows, one of the objectives will be to investigate how policy conclusions depend on whether a standard loss function such as (9) is used to evaluate outcomes or whether outcomes are evaluated using the social loss function (4).

2.2. Targeting rules

The model consisting of Eqs. (6)–(8) plus the definition of μ_t will constitute the central bank's reference model. The best way to model policy is a topic of much debate (e.g., Svensson, 2003, 2004a,b; McCallum and Nelson, 2004a,b). I focus here on targeting rules of the type analyzed by Svensson and Woodford (2005), and Svensson (2003, 2004a). These correspond to the robustly optimal rules analyzed by Giannoni and Woodford (2003). Targeting rules are derived from the first-order

[6]It is common to treat demand and cost shock disturbances as if they were independent. Neglecting their correlation may be important when evaluating optimal simple rules.

[7]As noted above, Erceg et al. (2000), Levin and Williams (2003b), Kimura and Kurozumi (2003), Steinsson (2003), and Amato and Laubach (2003) are among the exceptions.

[8]In common with many other authors, they also include an interest rate smoothing objective, again with an exogenous weight on this objective. In his comments on the Levin and Williams paper, Ireland (2003) notes that using a common loss function across alternative structural models may be inconsistent.

conditions of the central bank's decision problem and are represented as a linear relationship among endogenous variables. They thus represent an equilibrium condition among the target variables that the central bank commits to maintain.

Suppose the central bank chooses policy to minimizes the social loss function (4) subject to (6) and (7). Letting $z_t \equiv \pi_t - \gamma\pi_{t-1}$, this problem can be written as[9]

$$\min \frac{1}{2}\Omega E_t \sum_{i=0}^{\infty} \beta^i (z_{t+i}^2 + \lambda \tilde{x}_{t+i}^2)$$

subject to

$$z_t = \beta E_t z_{t+1} + \kappa \tilde{x}_t + \kappa \mu_t. \tag{10}$$

This is isomorphic to a standard policy problem with the exception that the variable z replaces inflation in both the objective function and the inflation adjustment equation. The *optimal* targeting rule from a timeless perspective can be expressed in terms of z and the structural parameters as

$$z_t = -\left(\frac{\lambda}{\kappa}\right)(\tilde{x}_t - \tilde{x}_{t-1}) = -(w_1\theta)^{-1}(\tilde{x}_t - \tilde{x}_{t-1}). \tag{11}$$

Expressed in terms of inflation, the optimal targeting rule is

$$\pi_t - \gamma\pi_{t-1} = -(w_1\theta)^{-1}(\tilde{x}_t - \tilde{x}_{t-1}). \tag{12}$$

The equilibrium behavior of z and $\tilde{x}$ are obtained by jointly solving (10) and (11) under rational expectations.[10] The behavior of z and $\tilde{x}$, and therefore social welfare, are not affected by the value of γ.[11] The equilibrium behavior of the rate of inflation does depend on γ, as does the behavior of the nominal rate of interest, but the behavior of these two variables is irrelevant for social welfare.

This result illustrates clearly the effects of endogenous objectives. In standard analysis, the loss function is treated as exogenous while aspects of the structural equations are altered. With that approach, policy performance deteriorates as the structural inflation process becomes more inertial. In addition, as Levin and Williams (2003a) demonstrate, policy rules designed for forward-looking models perform poorly when structural equations are characterized by more inertial behavior. However, when evaluating using a loss function that reflects the way the

[9]The leading coefficient Ω will not affect the central bank's first-order conditions nor the resulting targeting rule. However, as Levin and Williams (2003b) emphasize, it can be important for evaluating loss as a function of the model's structural parameters since Ω is a function of these parameters. Under uncertainty about the parameter values, the optimal Bayesian policy will be affected by the manner in which, for example, variations in Ω are correlated with variations in λ (see Levin and Williams, 2003b).

[10]The actually implementation of policy requires that the central bank determine the nominal interest rate consistent with (11). As discussed in Svensson (2004b), this will involve the bank constructing forecasts and setting its interest rate instrument so that the equilibrium consistent with those forecasts satisfies (11). Since my interest is primarily on how the evaluation of targeting rules is affected by whether model consistent objectives or exogenous objectives are used, I will simply assume that the central bank is able to credibly commit to maintaining (11).

[11]Recall that we are considering the case in which the central bank knows the value of γ so that it bases policy on the correct definition of the variable z.

inflation process affects welfare, one finds that loss no longer depends on the degree of structural inflation inertia.[12]

Allowing for endogenous objectives also alters the role of the other parameter of interest, α. Levin and Williams (2003b), Kurozumi (2003), and Aoki and Nikolov (2004) have made the point that the policy rule (11) is independent of α. However, the output gap elasticity of inflation (κ) does depend on α, and variations in κ affect the variance of the disturbance term in the inflation equation. Thus, equilibrium inflation and the output gap are affected by α, even though the optimal targeting rule is not.

When the central bank minimizes the standard loss function (9), the targeting rule that characterizes optimal policy differs from (11). Assume that the same output gap appears in both. That is, $y_t \equiv \tilde{x}_t$.[13] Then, the first-order conditions for the optimal commitment (timeless perspective) policy that minimizes (9) subject to (6) are

$$\pi_t + (1 + \beta\gamma)\phi_t - \phi_{t-1} - \beta\gamma E_t \phi_{t+1} = 0$$

and

$$\bar{\lambda}\tilde{x}_t - \kappa\phi_t = 0,$$

where ϕ is the Lagrangian multiplier on the inflation adjustment equation. Combining these to eliminate the Lagrangian multiplier yields the targeting rule

$$\pi_t = -\left(\frac{\bar{\lambda}}{\kappa}\right)(\tilde{x}_t - \tilde{x}_{t-1}) + \beta\gamma\left(\frac{\bar{\lambda}}{\kappa}\right)(E_t\tilde{x}_{t+1} - \tilde{x}_t). \tag{13}$$

I will refer to targeting rules such as (13) that maximizes a loss function other than the social welfare function as ad hoc targeting rules.

The optimal targeting rule (12) can be compared to the ad hoc rule given in (13). When $\gamma = 0$ (no structural inflation inertia), (13) reduces to the optimal targeting rule (12). When $\gamma > 0$, the rules differ in three ways. First, the rule that minimizes social loss is backward looking in the sense that, given the change in the welfare gap, current inflation is a function of lagged inflation. This dependency arises because the central bank should reduce volatility in $\pi_t - \gamma\pi_{t-1}$, not π_t. Second, a policy designed to reduce the volatility of inflation is forward looking in that the ad hoc targeting rule depends on the expected future change in the output gap measure. This aspect of the rule arises because current inflation affects future inflation when $\gamma > 0$. And third, the coefficient on the output gap change terms in (12) is independent of κ, while it is decreasing in κ in (13).

[12] Of course, this result is specific to the way inflation inertia has been modeled here. Steinsson (2003) and Amato and Laubach (2003) show how the approximation to the loss function is affected by alternative approaches to introducing inertia.

[13] I am ignoring the important issues involved in measuring the appropriate output gap. See Orphanides (2003a,b) and Orphanides and Williams (2002).

Table 1
Calibrated parameters

Structural parameters		Implied values	
α	0.66	κ	0.024
β	0.99	λ	0.048
γ	0.50	ω	1.235
σ	0.16	w_1	1.0062
ϕ	1.5	w_2	0.0311
θ	7.88	w_3	0.1503
sc	0.8	ξ	1.6633
η	0.49		
$\bar{\tau}$	0.2		
Innovations			
σ_a	0.007	ρ_a	0.95
σ_G	0.0108	ρ_G	0.99
σ_τ	0.024	ρ_τ	0.80

3. Right parameters, wrong objectives

In this section, I investigate the implications of ignoring the endogeneity of objectives when the true structural model is known. To do so, I examine the consequences for social loss if the central bank uses an ad hoc targeting rule that is optimal for the standard loss function (9) when social loss is actually represented by (4).

This exercise parallels the more common investigation of robustness in which a rule that is optimal for one model, based on an exogenous loss function, is employed in a different model, with the outcomes evaluated according to the fixed, exogenous loss function. In contrast, I assume the model is constant (and known) and evaluate policies that are optimal for one loss function when social welfare is actually measured by a different loss function.

Suppose the central bank implements the ad hoc targeting rule (13) that minimizes the standard loss function given by (9). This corresponds to the case of using the correct model but failing to use model consistent objectives. To explore this case, I solve a calibrated version of the model. The baseline parameter values are taken from Giannoni and Woodford (2003) and Woodford (2003) and are based on the work of Rotemberg and Woodford (1997). The values are reported in Table 1.[14] Parameter values not taken from Woodford's work are the standard deviations and serial correlation properties of the shocks. In most studies of policy in new Keynesian models, the standard deviations of the cost shock (the disturbance in the inflation equation) and the natural real rate of interest (the disturbance in the IS equation) are taken directly from empirical estimates and are commonly assumed to be uncorrelated. In the present model, the underlying primitives are the standard

[14]All values are based on the structural equations expressed in terms of inflation and interest rates at quarterly rates. Following Woodford, the value of λ reported in the table is for the loss function expressed in terms of inflation at annual rates.

deviations (and serially correlations) of the productivity, government spending, and tax shocks. For the productivity shocks a_t, I drawn on standard values from the real business cycle literature and set $\sigma_a = 0.007$ and $\rho_a = 0.95$. The values for the government spending and tax shocks are obtained from estimating AR(1) processes for detrended log fiscal variables, using the data on tax revenue and government consumption from Blanchard and Perotti (2002). Current and lagged detrended log real GDP is included in the tax equation to account for the procyclicality of tax revenues. Both fiscal processes are highly serially correlated.

3.1. Structural inflation inertia

Let $\mathscr{L}^{\mathrm{sl}}(\mathrm{sl})$ denote the value of the social loss function when the central bank implements the target rule optimal for $\mathscr{L}^{\mathrm{sl}}$, and let $\mathscr{L}^{\mathrm{sl}}(\mathrm{std})$ denote social loss when the ad hoc rule optimal for the standard loss function is used instead. Finally, let $\mathscr{L}^{\mathrm{std}}(\mathrm{std})$ denote the value of the standard loss function when the central bank implements the target rule optimal for the standard loss. Table 2 reports $\mathscr{L}^{\mathrm{sl}}(\mathrm{sl})$, $\mathscr{L}^{\mathrm{sl}}(\mathrm{std})$, and $\mathscr{L}^{\mathrm{std}}(\mathrm{std})$ for various values of structural inflation inertia. Table 3 reports the standard deviations of the output gap, the quasi-difference of inflation $z_t = \pi_t - \gamma\pi_{t-1}$, and the inflation rate. Results are given for $\bar{\lambda} = \lambda = 0.048$, the value of λ implied by the benchmark parameter values, and for $\bar{\lambda} = 1$, a standard choice in the literature.

Recall that under the optimal targeting rule, social loss is independent of γ. For $\bar{\lambda} = \lambda = 0.048$, columns 5 and 6 of Table 2 show that loss using the ad hoc targeting rule (13), the rule optimized for the standard loss function, increases modestly as structural inflation inertia increases, whether social loss or the standard loss function is used to evaluation the outcomes. When $\bar{\lambda} = 1$, however, conclusions using the standard loss become quite misleading. While the absolute level of $L^{\mathrm{std}}(\mathrm{std})$ depends on the choice of the scale factor $\bar{\Omega}$, the key point is that a central bank using rule (13) and the standard loss function would conclude that performance deteriorates significantly as γ increases. This is consistent with the general conclusion that more

Table 2
Effects of structural inflation inertia γ

1 γ	2 λ	3 $\bar{\lambda}$[a]	4 $L^{\mathrm{sl}}(sl)$	5 $L^{\mathrm{sl}}(\mathrm{std})$	6 $L^{\mathrm{std}}(\mathrm{std})$
0.1	0.048	0.048	10.96	10.99	11.27
0.3	0.048	0.048	10.96	11.23	11.96
0.7	0.048	0.048	10.96	12.34	13.38
1.0	0.048	0.048	10.96	13.30	14.21
0.1	0.048	1	10.96	30.93	73.72
0.3	0.048	1	10.96	25.17	87.05
0.7	0.048	1	10.96	15.11	131.50
1.0	0.048	1	10.96	12.23	175.70

[a]For $\bar{\lambda} = 1$, $\bar{\Omega}$ set to benchmark value.

Table 3
Standard deviation (%)

sl				std ($\bar{\lambda} = 1$)		
γ	$\sigma_{\tilde{x}}$	σ_z	σ_π	$\sigma_{\tilde{x}}$	σ_z	σ_π
0.1	2.71	1.40	1.48	1.52	4.43	4.69
0.3	2.71	1.40	1.70	1.64	3.83	4.97
0.7	2.71	1.40	2.59	2.06	2.64	5.39
1.0	2.71	1.40	5.40	2.51	1.91	5.06

backward-looking models are harder to control. But when the same outcomes are evaluating using the social loss function (column 5), the conclusion is the exact opposite; loss declines with inflation inertia. Table 3 shows the reason for this reversal. Under the optimal targeting rule, the variability of $\tilde{x}$ and z are independent of γ. Under the ad hoc targeting rule designed for the standard loss function, both $\tilde{x}$ and π become more variable as γ increases. That is why using the standard loss function suggests outcomes deteriorate with γ. However, as Table 3 reveals, z actually becomes less volatile as γ increases, and social loss depends on the volatility of z, not on the variability of inflation. The volatility of inflation rises as γ increases from zero to one, but this is irrelevant for social loss.

3.2. Nominal rigidity

The parameter α plays two roles in the standard analysis of targeting rules. First, it affects the output gap elasticity of inflation κ. Second, by affecting κ, it also alters the coefficient that appears in the targeting rule (12). When the endogeneity of objectives is recognized, however, λ is also affected by α, and the ratio λ/κ that appears in the targeting rule is actually independent of α. This last point, emphasized by Levin and Williams (2003b) in the case of an optimal non-inertial commitment policy, implies that uncertainty about the degree of nominal price stickiness does not affect policy behavior under the optimal commitment targeting rule.[15]

Thus, when the central bank treats the reference model as given, the optimal targeting rule it should follow is independent of the degree of nominal rigidity. Greater price stickiness reduces κ, requiring larger output gap movements to control inflation. But an increase in α also makes it more important to stabilize inflation, reducing the weight λ on the output gap term in the loss function. These two effects cancel out, leaving the targeting rule independent of α. Equilibrium outcomes still depend on α through its impact on the slope of the Phillips curve and the size of “cost shocks” in the inflation equation, since the standard deviation of these shocks is proportional to κ.

Table 4 reports outcomes under the optimal and ad hoc targeting rules for various values of α. Also shown are the implied values of κ and λ associated with the

[15]See also Kurozumi (2003) and Aoki and Nikolov (2004).

Table 4
Effects of nominal price rigidity (α)

1 α	2 κ	3 λ	4 $\bar{\lambda}$[a]	5 L^{sl}(sl)	6 L^{sl}(std)	7 L^{std}(std)
0.2	0.43	0.863	0.863	17.67	19.01	19.01
0.4	0.12	0.244	0.244	15.47	17.47	17.45
0.7	0.02	0.035	0.035	10.01	10.42	12.06
0.9	0.00	0.003	0.003	3.87	4.97	13.11
0.2	0.43	0.863	1	17.67	17.82	367.08
0.4	0.12	0.244	1	15.47	16.92	274.76
0.7	0.02	0.035	1	10.01	19.38	82.24
0.9	0.00	0.003	1	3.87	21.33	8.26

[a]For $\bar{\lambda} = 1$, $\bar{\Omega}$ set to benchmark value.

Table 5
Standard deviations (%), effects of nominal rigidity (α)

sl				std ($\bar{\lambda} = 1$)		
α	$\sigma_{\tilde{x}}$	σ_z	σ_π	$\sigma_{\tilde{x}}$	σ_z	σ_π
0.2	3.80	3.73	4.30	3.81	3.78	3.76
0.4	3.43	2.20	3.41	3.13	4.42	5.61
0.7	2.56	1.21	1.78	1.62	2.88	4.77
0.9	1.57	0.28	0.47	0.65	1.07	2.08

different values of α. Comparing columns 5 and 6 in the top half of the table shows that basing policy on the standard loss function with $\bar{\lambda} = \lambda$ leads to little deterioration in social welfare. Generally similar conclusions obtain when outcomes are evaluating using the standard loss function (col. 7). Results differ when $\bar{\lambda} = 1$, as seen in the bottom half of Table 4. Now, performance would appear to improve dramatically under the ad hoc rule (13) as α increases when the standard loss is used (col. 7), while in fact, as column 6 shows, social loss actually increases with α.

Table 5 shows how the standard deviations of $\tilde{x}$, z, and π vary with α. Interestingly, volatility decreases under either targeting rule as prices become stickier. This contrasts with the usual finding that volatility increases with greater price rigidity, and it highlights another important implication of a model that endogenizes the disturbance term that appears in the inflation-adjustment equation. According to (7), this disturbance term is equal to $\kappa\mu_t$, where μ_t is a function of the exogenous productivity and fiscal shocks. This shock to the wedge between the flexible-price output level and the efficient output level are the basic cause of policy trade-offs in this model. The standard deviation of the cost shock is proportional to κ. Thus, as α increases and κ declines, the source of policy trade-offs becomes less important. In the limit, as the variance of this shock goes to zero, the socially optimal

Table 6
Standard deviations (%) holding variance of cost shock fixed

sl				std ($\bar{\lambda}=1$)		
α	$\sigma_{\tilde{x}}$	σ_z	σ_π	$\sigma_{\tilde{x}}$	σ_z	σ_π
0.2	0.21	0.21	0.24	0.21	0.21	0.21
0.4	0.68	0.53	0.67	0.42	0.87	1.11
0.7	3.47	1.64	2.42	2.20	3.91	6.47
0.9	23.08	4.13	6.93	9.56	15.84	30.70

policy ensures $\tilde{x}_t = z_t = 0$. Even under the rule optimal for the standard loss function, the volatility of the output gap and inflation decline significantly with α due to the declining variance of the cost shock.

The importance of the impact of α on the variance of $\kappa\mu_t$ is illustrated by comparing Tables 5 to 6, in which the variance of the cost shock is held fixed as α (and κ) varies. This corresponds to the standard exercise in which the variance of the cost shock is treated as an exogenous, fixed parameter. Now, volatility increases significantly as nominal rigidity increases. Under the optimal targeting rule, the relative weight placed on output gap fluctuations declines as α increases, and as a consequence, policy allows $\tilde{x}$ to become much more volatile while limiting the rise in the volatility of the inflation variable. In contrast, under the ad hoc rule designed to be optimal for the standard loss function with a fixed $\bar{\lambda}$, the central bank allows much greater inflation variability as α increases in order to limit the rise in the volatility of $\tilde{x}$.

While the results are based on a very simple model, the examples provided by γ and α illustrate how conclusions from standard models based on exogenous objectives (and ad hoc shocks) can potentially be misleading. Contrary to traditional findings, welfare is independent of the degree of structural inflation inertia, though the volatility of inflation is not. The optimal targeting rule is invariant to the degree of price rigidity because of the dependence of the weights in the loss function on the structural parameters, and policy comparisons can be affected by whether economic disturbances are treated as totally exogenous or as arising in a manner consistent with the underlying theory.

4. Right objectives, wrong parameters

The previous section investigated the consequences of minimizing the wrong loss function. It was assumed, however, that the policy maker knew the correct structural parameters. In this section, I consider the case in which the central bank employs an incorrect value for one of the model parameters in implementing the socially optimal targeting rule given by (12). The exercise is similar to previous work, for example by Angeloni et al. (2003), in assessing the consequences of basing policy on an incorrect parameter value. However, I also assess how conclusions about the effects of parameter error are influenced by the loss function used to evaluate outcomes. As in the previous section, the focus is, in turn, on structural inflation inertia and nominal price stickiness.

When the central bank has a misspecified model (whether this is reflected in its loss function or not), issues of implementation become particularly important. For example, in the ad hoc targeting rule based on $\mathscr{L}^{\mathrm{std}}$, the central bank commits to ensuring an equilibrium condition that involves the expected future output gap will hold (see (13)). In the approach to policy advocated, for example, by Svensson (2004b), the central bank would announce its projections for the output gap. However, if the central bank's model is incorrect, these projections will differ (potentially) from the public's forecasts. In this section, because I focus on the optimal targeting rule (12) in which projections do not appear, I restrict attention to the rational expectations equilibrium when the central bank credibly announces it will ensure (12) holds, ignoring the issue of how the central bank manipulates its interest rate instrument to actually achieve this outcome (see Svensson and Woodford, 2005). However, at the same time, I assume the central bank gets one of the structural parameters appearing in the rule wrong.

4.1. Structural inflation inertia

Let γ^{P} denote the central bank's perceived or estimated value of γ. Assume the central bank implements the targeting rule given by

$$\pi_t - \gamma^{\mathrm{P}}\pi_{t-1} + \left(\frac{\lambda}{\kappa}\right)\Delta\tilde{x}_t = 0. \tag{14}$$

That is, the central bank employs the correct form of the optimal targeting rule but its assumption about structural inflation inertia may differ from γ, the value that characterizes the actual inflation process. I assume the policy maker acts as if the model were known with certainty, even though some values of the parameters may be misspecified. This approach parallels that of Levin and Williams (2003a), Angeloni et al. (2003), and Adalid-Lozano et al. (2004). If the central bank's commitment to ensuring (14) holds is credible, then the rational expectations equilibrium of the economy is obtained by jointly solving (14) together with (7). I then calculate loss as a function of γ^{P} and γ as each varies from zero to one.

The effects of misspecifying the degree of structural inflation inertia in the targeting rule can be illustrated using the notion of fault tolerance introduced by Levin and Williams (2003b). They examined the effects on the objective function of varying one of the coefficients in an instrument rule. Rather than varying an instrument rule parameter, I consider variations in the central bank's estimate of a structural parameter under the assumption that, given the estimates of the parameter, policy is implemented through an optimal targeting rule. For a given value of γ in the structural inflation equation, the effect on $\mathscr{L}^{\mathrm{sl}}$ as γ^{P} varies corresponds to Levin and Williams' fault tolerance for a given model. By also

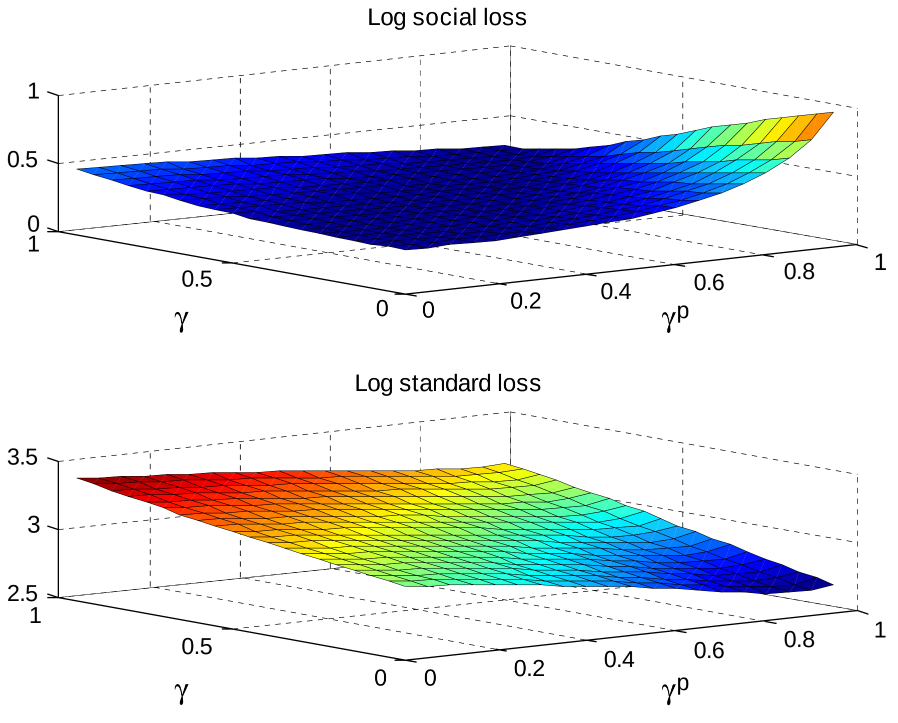

Fig. 1. Loss under targeting rule (12). The top figure is based on social loss, the bottom one on a standard loss function with $\bar{\lambda} = 1$.

varying γ, a risk surface is traced out, showing combinations of γ and γ^{P} that may produce especially bad outcomes.

Results are illustrated in the top panel of Fig. 1. The figure shows log social loss when the targeting rule is based on γ^{P} and the actual degree of structural inflation inertia is γ.[16] The figure can be interpreted as showing how outcomes are affected if the central bank errs in over- or under-estimating γ. The figure suggests that a central bank concerned with protecting against error by following a min–max strategy should behave as if inflation is relatively non-inertial, that is, base policy on a moderate value of γ^{P}. The value of γ^{P} that minimize the maximum social loss that could arise from misspecification is 0.55. This result is in contrast to the conclusions reached by Angeloni et al. (2003), Coenen (2003), and Walsh (2003c) who all found that a robust strategy involved significantly over-estimating the degree of structural inflation inertia. However, these earlier results ignored the implications of γ for the

[16]The figures would look similar if the level of the loss were shown rather than the log level. However, in the next subsection when variations in α are considered, the range of variation in loss is much more extreme, and converting to logs makes it easier to see how the surface varies over the entire parameter space.

social loss function and evaluated outcomes using a standard, exogenous loss function.

The role played by the loss function is reveal by the bottom panel of the figure, which uses a standard loss function in inflation and output gap volatility with $\bar{\lambda} = 1$ to evaluate the outcomes for different combinations of γ and γ^{P}.[17] Here, the min–max strategy would set $\gamma^{\mathrm{P}} = 0.9$. Over-estimating structural inflation inertia appears to lead to a more robust policy, the result found in the earlier literature. The reason for this result is that the variance of the output gap increases as γ^{P} falls relative to γ. This increase in output gap volatility is very costly when $\bar{\lambda} = 1$. Not surprising, using a standard loss function but with a smaller value of $\bar{\lambda}$ consistent with the underlying model can yield very different conclusions, since the rise in output gap volatility has less weight in the loss function. If $\bar{\lambda} = 0.048$, the min–max strategy recommended by the standard loss function would base policy on the assumption of no structural inflation inertia. However, the general lesson from comparing the two panels of the figure is that employing the standard loss function can potentially provide a misleading assessment policy robustness.

4.2. Nominal price rigidity

Misspecification of the degree of nominal price rigidity has no effect on either the optimal targeting rule based on the social loss function or the ad hoc rule based on the standard loss function, as long as the endogeneity of λ is recognized. In either case, the effects of α on κ and λ leave the ratio λ/κ that appears in the targeting rules unaffected. An increase in price rigidity reduces the output gap elasticity of inflation, but it also reduces the relative weight placed on output stabilization in the social loss function. Thus, both targeting rules are robust to misspecifying the degree of nominal rigidity. However, if $\bar{\lambda}$ is treated as a fixed parameter as α varies, the targeting rule implemented by the central bank (whether minimizing social loss or the standard loss function) will be affected. For example, suppose $\bar{\lambda}$ is fixed and the central bank implements the targeting rule

$$\pi_t - \gamma\pi_{t-1} = -\left(\frac{\bar{\lambda}}{\kappa^{\mathrm{P}}}\right)(\tilde{x}_t - \tilde{x}_{t-1}), \tag{15}$$

where κ^{P} is the central bank's estimate of the output elasticity of inflation based on α^{P}. Because the central bank's rule now varies with κ^{P}, outcomes are no longer independent of the bank's estimate of α. Fig. 2 shows log social loss under policy rule (15).[18] Basing policy on an estimate of price rigidity that is too high leads to a deterioration in social welfare. Using the standard loss with $\bar{\lambda} = 1$ to evaluate outcomes yields a similar surface (not shown). Thus, unlike the example with γ, the

[17]The levels cannot be directly compared between the two panels because the leading coefficient, $\bar{\Omega}$, in the standard loss is arbitrary. For the figure, $\bar{\Omega}$ is set equal to the value of Ω in the social loss function when evaluated at the benchmark parameter values.

[18]When policy is based on the correct rule so that $\lambda^{\mathrm{P}}/\kappa^{\mathrm{P}}$ is independent of α^{P}, the surface would vary with α but not with α^{P}.

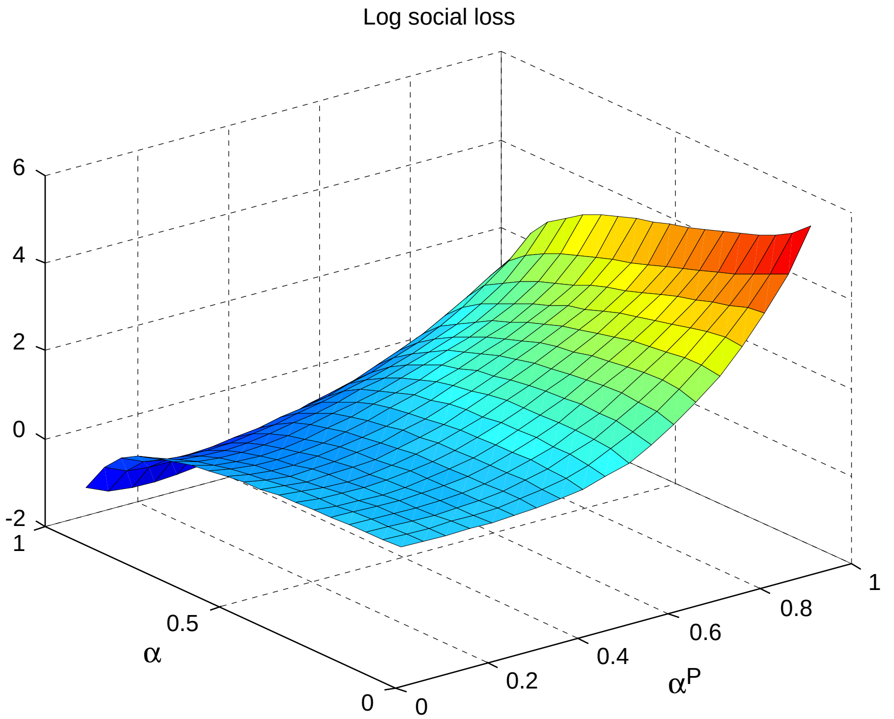

Fig. 2. Log social loss under targeting rule (15).

standard loss function does not provide a misleading qualitative assessment of outcomes under rule (15).

This result contrasts with the findings in Walsh (2004). There, it was found that using a standard loss function tended to exaggerate the costs of basing policy on the belief that prices were very sticky, whereas, as Fig. 2 suggests, an evaluation based on social loss shows that a policy based on a α^{P} that exceeds the actual degree of price stickiness produces the greatest loss. An important reason for the different conclusions can be traced to an aspect of the underlying model that has been neglected in previous analyses of policy rules. According to (7), the standard deviation of the cost shock is proportional to κ. Thus, as α increases and κ falls, two factors are at work in affecting social loss. First, with greater price rigidity, λ falls as the central bank should place relatively more weight on inflation stabilization. Second, the volatility of the cost shocks falls, improving the ability of monetary policy to achieve both inflation and output gap stabilization. The importance of this second channel can be assessed by holding the variance of the disturbance term in the inflation equation fixed as α (and therefore κ) varies. Fig. 3 shows the outcome of this experiment. The figure suggest that under-estimating the extent of price rigidities leads to a significant increase in the loss function, a conclusion that is contradicted by an evaluation based on the social loss function. Thus, accounting for the way

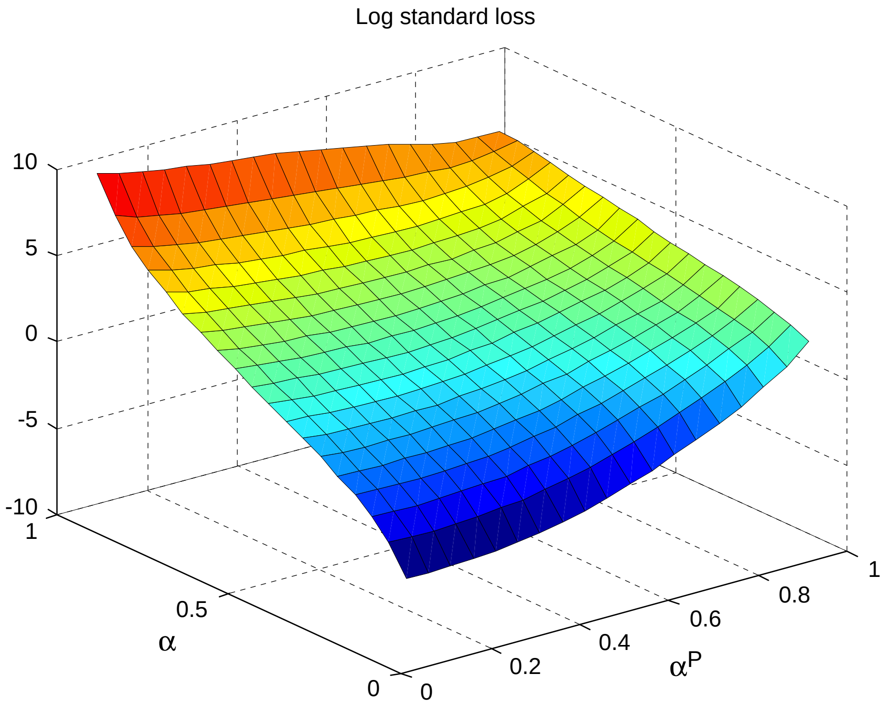

Fig. 3. Log standard loss under targeting rule (15) when the variance of "cost shock" is held fixed.

distortions affect the economy, in this case through the presence of a wedge between the flexible-price equilibrium output and the first-best output that enters as a disturbance to the inflation equation, can be important for gaining an accurate assessment of alternative policies.

5. Summary and conclusions

The standard approach to monetary policy analysis treats the objectives of policy as exogenously specified, independent of the model used to represent the economy. Economic theory, however, draws a tight link between the objectives a policy maker concerned with maximizing the welfare of the representative agent should pursue and the underlying structure of the economy. Objectives are endogenous. The purpose of this paper has been to investigate the role of endogenous objectives in the evaluation of monetary policy targeting rules. This has been done is a very simple model, but one in which the link between structural equations, social welfare, and the underlying parameters of the model is quite clear.

A variety of comparison were made that indicated the potential for conclusions based on the standard exogenous objectives common in monetary policy analysis to be misleading. Because the representation of social welfare in terms of policy objectives is model dependent, any conclusions will themselves be specific to the model employed. However, several interesting result emerge from the simple new Keynesian model used in this paper. The analysis suggested that the use of ad hoc objectives and the addition of ad hoc disturbances can significantly affect the evaluation of alternative policies. The use of the standard loss function provided misleading guidance on the effects of misspecifying structural inflation inertia, suggesting that a robust policy should assume a high degree of such inertia. In contrast, using the social loss function showed this not to be the case, even under the targeting rule that was optimal for the standard loss function. The link between the economy's distortions and the presence of a disturbance to the inflation adjustment equation also played an important role in assessing alternative targeting rules and the effects of price rigidity. Increased price rigidity reduces the output gap elasticity of inflation, but it also increases the relative weight on inflation objectives in the social loss function and reduces the important of cost shocks. Failing to incorporate these last two effects significantly affects policy evaluations.

Finally, it may be useful to note that the analysis here has not focused on policies that would be *optimal*, given parameter uncertainty. Instead, the focus was on the consequences of using incorrect parameters or objectives in designing and evaluating targeting rules. Optimal policies are unlikely to be represented as time-invariant targeting rules of the type studied in this paper. Rather, optimal policy will need to reflect the learning that occurs as the policy maker adapts to new information about the structure of the economy.[19]

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[19]See, for example, Wieland (2000).

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