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Simple Monetary Policymaking without the Output Gap

by

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Simple Monetary Policymaking without the Output Gap*

Kai Leitemo♣ and Ingunn Lønning

Norges Bank

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Abstract

The performance of a simple monetary policy rule, which does not rely on explicit information about the output gap but instead uses the change in the rate of inflation as a proxy for the output gap, is explored in a simple model of the US economy. The rule is found to outperform an optimised Taylor rule under a reasonable specification of real-time output-gap uncertainty. The relative performance improves if the inflation process is more backward-looking, if demand or cost-push shocks are less prevalent, and if the output gap has a stronger effect on inflation.

Keywords: Monetary policy, simple rules, uncertain output gap, Taylor rules, inflation-only rule.

JEL code: E58, E52, and E47.

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1. Introduction

Important theoretical as well as empirical contributions to macroeconomics assert that the output gap, defined as the difference between actual and potential output, is the key determinant of future domestic inflation. For a central bank that aims at stabilising inflation, information about the output gap may thus be useful. As Svensson (1997) shows, due to the effect of the output gap on inflation, optimal policy implies a monetary policy response to the output gap. In addition, the central bank may want to stabilise the output gap per se. Consequently, precise output gap data are of potentially great importance to the policymaker.

However, as the output gap is not readily observable, and as methods that extract information about its two components yield imprecise estimates, the computed output gap measure is associated with uncertainty in various forms. The first release of data regarding *actual* output is preliminary and associated with considerable measurement error. Consequently, the numbers are revised over time. An even more important source of uncertainty, however, is the estimate of *potential* output,[1] where history shows that final revised figures can differ substantially from the *real-time* estimate, that is, the output gap estimate that was available to the policymaker at the time of decision-making. In addition, there are several different approaches to *modelling* potential output, so that final figures will depend on the method being used. Orphanides (2001) demonstrates how policy recommendations based on real-time data for the output gap differ considerably from those obtained with revised data. Taken to the extreme, policy decisions may be judged erroneous based on ex-post data when, in fact, they may have been well suited to the situation given the information available at the time the decisions were made.

Taylor (1999) points out that monetary policy in the 1970s would have performed better, and that the Great Inflation may have been avoided, if the policymaker had followed a simple interest rate rule that includes a response to the output gap, as proposed in Taylor (1993). Orphanides (2000) shows, however, that monetary policy in the 1970s actually was close to the policy prescribed by the Taylor rule when real-time output gap data are used. Hence, the Taylor rule may have been a *cause* of the Great Inflation rather than a promising cure. Thus, a simple monetary policy rule based on the output gap may be little robust to the uncertainty in output gap figures. We ask in this paper whether an alternative policy rule that does not rely on the size of the output gap will be able to outperform the Taylor rule when the historical level of uncertainty is accounted for.

1.1 The real-time estimates of the output gap are distorted

[1] See, e.g., Holden and Nymoen (2002) for a discussion of the problems associated with the method employed by the OECD in estimating potential output.

As pointed out above, the measurement of the output gap is plagued by a number of problems. We shall not discuss the pros and cons of the different methods of extracting information about the output gap,[2] but rather point to the existing evidence that historical real-time estimates of the output gap tend to be quite distorted. Orphanides (1998) studies the difference between the estimates of the output gap available in real time and the 1994 estimates for the output gap for the period 1980 – 1992 on US data. He finds that the average output gap was –3.99 per cent of GDP in the real-time data while only –1.64 per cent in the final figures. In addition, the variance of the real-time output gap was considerably larger than the variance of the output gap based on final figures. In a similar study for the UK, Nelson and Nikolov (2001) find that over the period 1965 Q1 – 1995 Q4, the average real-time estimate of the output gap is –4.78 per cent while the final average estimate is 0.06 per cent. The standard deviation of the real-time output gap measurement error is 3.48 per cent for the entire period, but has decreased somewhat over time.

1.2 Approaches to dealing with output-gap uncertainty

Studies concerning the issue of how to deal with output gap uncertainty using simple policy rules have proceeded along two lines. One asks how output gap uncertainty should influence the way policy responds to the output gap. The other asks what alternative indicator could substitute for the output gap in the policy rule.

Along the first line several studies show that the central bank in its policy should attach less weight to a variable the more uncertain it is. See, for instance, Smets (1999) and Rudebusch (2001). This is the case if the observed uncertain variable enters the policy function directly. If, on the other hand, we use an optimal estimate of the uncertain variable, certainty equivalence holds so that optimal policy should react as if a variable was observed with certainty. See, for instance, Svensson and Woodford (1999) and Orphanides (1998) for a discussion of the distinction between the two cases.[3]

Another strand of this literature looks at non-linear policy rules in the face of uncertainty about NAIRU, the labour market equivalent of the output gap. The idea is that monetary policy should be careful when there is uncertainty as to whether unemployment is above or below NAIRU. The policymaker should then become more aggressive when unemployment decreases (increases) to the

[2] A common approach to estimating potential output is to find trend output by using purely statistical methods, as done for instance by Taylor (1993). Other approaches include estimation of the output gap via estimation of the unemployment gap. See Orphanides (2001) for a discussion of these two methods and the resulting difference in final output gap figures.

3 See also Ehrmann and Smets (2001) for an application on a model of the euro area.

extent that the policymaker becomes more confident that unemployment is below (above) NAIRU (Meyer et al., 2001).

Along the second line, several studies (McCallum 1998, Orphanides 1999) have suggested some form of nominal income targeting. A rule that responds to nominal income growth does not rely on information about the output gap as it responds only to the sum of real output growth and inflation. Rudebusch (2000) shows, however, that only for large output gap uncertainty and for particular model formulations does nominal income targeting improve the performance of the Taylor rule. A simple rule for nominal income targeting is also less robust to model uncertainty.

Orphanides *et al.* (2000) suggest that the output gap in the Taylor rule should be replaced by growth in the output gap as this could potentially reduce the effect of an uncertain real-time estimate of the output gap. They find that such a rule may outperform the Taylor rule if output gap uncertainty is relatively high compared to historical uncertainty. The benefit from reducing the impact of output gap uncertainty must be weighed against the cost of not directly responding to the determinant of inflation.

1.3 Our approach: a rule without the output gap

Much along the approach of Orphanides *et al.*, this paper suggests a simple rule that substitutes the output gap for the change in the rate of inflation. The motivation for the substitution is simple and follows from the inflation accelerationist argument: if output is above potential, inflation will gradually increase. Thus, the change in the rate of inflation will be a proxy for the output gap. Our motivation hence rests on a relatively backward-looking view of the Phillips curve.

To foreshadow some of the results, we find that the proposed rule may outperform the Taylor rule for baseline level of uncertainty given that the policymaker attaches only a small loss to changes in the interest rate. The result is, however, independent of the weight attached to output-gap variability relative to inflation variability.

The paper proceeds by presenting the New Keynesian model framework and the Rudebusch (2000) empirical specification of this model, which we will use as our simulation model. We continue by giving a more detailed discussion of and motivation for the proposed rule, contrasting it to the Taylor rule. In Section 3, the model is simulated to compare welfare losses of using either policy rule under different assumptions about the degree of uncertainty and structure of the economy. Section 4 concludes.

2. The model

2.1 The theoretical model

Our choice of macroeconomic framework is that of the new Keynesian tradition with nominal rigidities. See Gali *et al.* (1999) and Woodford (2002) for a detailed presentation.

We consider a closed-economy model with only a single consumption good. The first-order Euler condition for optimal consumer behaviour implies a traditional smoothed consumption profile. Demand moves in the same direction as expected future demand, and depends, due to intertemporal substitution effects, on the real interest rate. The equilibrium real interest rate, r^*, is the interest rate consistent with product market equilibrium. The first-order condition in terms of the output gap may be written as

$$y_t = \mu_y E_t y_{t+1} + \left(1-\mu_y\right) y_{t-1} - \beta_r (i_t - E_t \pi_{t+1} - r^*) + \eta_t, \tag{1}$$

where y_t is the output gap, $E_t y_{t+1}$ is the expected output gap at time $t+1$ given the information available at time t, i_t is the nominal interest rate, $E_t \pi_{t+1}$ is the inflation rate at time $t+1$ given the information available at time t, r^* is the equilibrium real interest rate, and η_t is a stochastic error term, representing demand shocks. The presence of a backward-looking term in the Euler equation, that is, $\mu_y < 1$, can be justified by for instance habit formation, where the utility of current consumption depends on previous consumption levels, see Fuhrer (2000) and McCallum (2001).

The new Keynesian consensus on price dynamics can be expressed by a generalised Phillips curve of the form

$$\pi_t = \mu_\pi E_t \pi_{t+1} + (1-\mu_\pi)\pi_{t-1} + \alpha_y y_t + \varepsilon_t, \tag{2}$$

where $E_t \pi_{t+1}$ is the expected rate of inflation at time $t+1$ given the information available at time t, and ε_t is a stochastic error term, normally referred to as a cost-push shock. Although it would be reasonable to describe (2) as a consensus for price dynamics in the New Keynesian tradition, a consensus on the true value of μ_π has not yet been reached. The literature offers estimates in the whole range between zero (see, e.g. Rudebusch and Svensson (1999)) and unity (see, e.g. Gali (2000)).

The pure New Keynesian Phillips curve derived from microfoundations asserts that $\mu_\pi = 1$. This result can be derived within a model of staggered price setting with model-consistent expectations, as in Calvo (1983). It is then assumed that the output gap relates linearly to marginal costs, which affect price setting.[4] Due to staggered price setting, price setters must act in a forward-looking manner, anticipating future marginal costs. Thus, this specification implies that inflation is not only determined by the present output gap, but also expected future output gaps. A forward-looking specification allows the inflation rate to jump when new information about marginal costs arrives that leads agents to revise their expectations.

With $\mu_\pi = 0$, the specification collapses into the traditional accelerationist Phillips curve and past inflation rates and hence past output gaps are determinants of inflation. From the point of view of optimising behaviour, it is difficult to find a rationale for backward-looking price setting. However, Roberts (1995, 1997) and Gali and Gertler (1999) point out that the existence of rule-of-thumb or non-rational price setters may introduce backward-looking terms in the Phillips curve. Fuhrer (1997) finds that a value of $\mu_\pi = 0.2$ describes US inflation dynamics well but cannot rule out a value of zero. Based on various empirical studies Rudebusch (2000) suggests a value of μ_π between 0 and 0.6. Estrella and Fuhrer (2001) discuss the dynamics implied by a purely forward-looking model and argue that such dynamics are unrealistic.

2.2 The monetary policy rule

The model is closed with a description of interest rate setting. It is useful to start with the description of the Taylor (1993) rule.[5] This rule is given by

$$i_t = r^* + \bar{\pi}_t + g_\pi^T\left(\bar{\pi}_t - \pi^*\right) + g_y^T y_t, \qquad (3)$$

where $\bar{\pi}_t = \frac{1}{4}\sum_{i=0}^{3}\pi_{t-i}$ is the four-quarter inflation rate, r^* and π^* are the equilibrium real interest rate and the inflation target, respectively. We normalise the equilibrium real interest rate and the inflation target to zero. Acknowledging that the policymaker needs to use the real-time estimate of the output gap, the Taylor rule can be expressed as

[4] A reasonable interpretation is that the output gap is a representation of the squeeze on available resources, and indirectly the level of marginal costs faced by the price setters. There are other variables that will represent the level of marginal costs. For instance, Gordon (1997) finds that lagged values of the unemployment gap, the deviation of unemployment from NAIRU, i.e. the labour market equivalent of the output gap, are significant determinants of inflation.

$$i_t = g_\pi^T \pi_t + g_y^T \hat{y}_{t|t}, \tag{4}$$

where the real-time estimate is given by

$$\hat{y}_{t|t} = y_t + n_t, \tag{5}$$

y_t is the final estimate of the output gap, $\hat{y}_{t|t+i}$ is the period $t+i$ estimate of the output gap in period t, and n_t is the measurement error.

Inserting for $\hat{y}_{t|t}$ in the Taylor rule we get

$$i_t = g_\pi^T \pi_t + g_y^T y_t + g_y^T n_t. \tag{6}$$

We propose a similar rule that substitutes the real-time estimate of the output gap with the change in the rate of inflation. With normalisation of the equilibrium real interest rate and the inflation target to zero, the rule is given by

$$i_t = g_\pi^{io} \pi_t + g_{\Delta\pi}^{io} (\pi_t - \pi_{t-1}). \tag{7}$$

Our motivation for this rule is given directly by the Phillips curve. To see this, we rearrange the Phillips curve in (2):

$$\pi_t - \pi_{t-1} = \mu_\pi (E_t \pi_{t+1} - \pi_{t-1}) + \alpha_y y_t + \varepsilon_t. \tag{8}$$

As we see, the change in the inflation rate is related to the output gap, the expectations of future inflation and the white-noise cost-push shock. The change in the rate of inflation can be seen as a (imperfect) proxy or indicator for the output gap.[6] In the backward-looking case ($\mu_\pi = 0$), this indicator will be proportional (up to a white-noise error) to the true output gap and has the advantage of being more readily observable than the output gap. By inserting for the inflation difference from

[5] See Svensson (1997) for a theoretical motivation for the Taylor rule in a model setting similar to the one in this paper.

[6] It can be shown that the change in the inflation rate would be the optimal indicator of the output gap in the case when the policymaker has access to information only regarding the inflation time series and the Phillips curve is entirely backward-looking.

equation (8) in the inflation-only rule, we can find an expression that is comparable with the Taylor rule in (6):

$$i_t = g_{\pi}^{io}\pi_t + g_{\Delta\pi}^{io}\alpha_y y_t + g_{\Delta\pi}^{io}\mu_{\pi}(E_t\pi_{t+1} - \pi_{t-1}) + g_{\Delta\pi}^{io}\varepsilon_t. \quad (9)$$

We see that both reaction functions include a response to inflation and the true output gap. In the Taylor rule, the interest rate will in addition respond to the measurement error, which may bring policy prescriptions far away from the true Taylor rule recommendation. The inflation-only rule implies, on the other hand, that the interest rate will respond more aggressively to cost-push shocks as well as to the difference between expected next-period inflation and last-period inflation in the case of forward-looking price setting. Hence, a forward-looking term in the Phillips curve distorts the expected proportionality between the indicator and the output gap.[7] However, this distortion may not be serious given that the reaction coefficient is appropriately adjusted. Reacting to supply shocks, however, destabilises output. Thus, to the extent that the central bank also is concerned about variability in output, reacting to supply shocks may lower welfare. The implicit response to future inflation, however, may have a stabilising effect on output to the extent that future inflation reflects the state of the output gap instead of lagged inflation.

In this paper we try to weigh the pros and cons of the new rule in an empirical model and identify under what conditions the relative benefits of responding to the change in the rate of inflation instead of the real-time output gap estimate outweigh the costs. Our analysis may be seen as a test of the efficiency of a monetary policy that systematically uses this approach for policymaking in an environment of output gap uncertainty.[8]

2.3 The empirical specification

[7] An approach to correct for this would be to extract information regarding private sector inflation expectations in real-time. Such a procedure would undoubtedly introduce inflation expectations measurement errors (albeit not systematic?). An interesting topic for future research would be to include such information in our proposed rule and see if it can improve the outcome. We are grateful to Henrik Jensen for pointing this out.

[8] Looking at the change in the rate of inflation as a proxy for the output gap is not a new idea, however. For example, as US unemployment fell in the last part of the 1990s, unemployment was first believed to have fallen below NAIRU, which indicates that there would be a positive output gap. However, when inflation did not increase, the lower unemployment rate was interpreted as a fall in the NAIRU. Thus, the lack of increase in the inflation rate was interpreted as a sign that the output gap had not increased.

For the simulations we use an empirical version of the model on quarterly data. Following Rudebusch (2000) we specify the Phillips curve as

$$\pi_t = \mu_\pi E_{t-1}\bar{\pi}_{t+3} + (1-\mu_\pi)(\alpha_{\pi 1}\pi_{t-1} + \alpha_{\pi 2}\pi_{t-2} + \alpha_{\pi 3}\pi_{t-3} + \alpha_{\pi 4}\pi_{t-4}) + \alpha_y y_{t-1} + \varepsilon_t, \tag{10}$$

Rudebusch estimates this Phillips curve on US data and finds coefficient values of $\mu_\pi = .29$, $\alpha_{\pi 1} = .67$, $\alpha_{\pi 2} = -.14$, $\alpha_{\pi 3} = .40$, $\alpha_{\pi 4} = .07$ and $\alpha_y = .13$. The standard error is $\sigma_\varepsilon = 1.012$.

For the empirical aggregate demand equation, Rudebusch (2000, Appendix A) suggests:

$$y_t = \mu_y E_{t-1} y_{t+1} + \left(1-\mu_y\right)\left(\mu_1 y_{t-1} + \mu_2 y_{t-2}\right) - \beta_r (i_{t-1} - E_{t-1}\bar{\pi}_{t+3} - r^*) + \eta_t. \tag{11}$$

Based on a combination of his own estimates and figures appearing in other works (Fuhrer, 2000), Rudebusch suggests plausible coefficient values for the US economy, with μ_1 =1.15, μ_2 = -.27, β_r =.09 and μ_y approximately equal to .3. The standard error is estimated at $\sigma_\eta = .833$. The output gap in the Phillips curve and the interest rate in the demand equation are both lagged one period. The information set is also lagged one period and output and inflation are both regarded as predetermined variables. This captures the empirically sluggish effect of monetary policy. Acknowledging uncertainty associated with the coefficient estimates, we perform some robustness checks of the monetary policy rules to changes in the various coefficient values.

With regard to the policy rule, using the empirical version of the Phillips curve, the equivalent measure of the inflation differential is given by

$$\pi_t - \tilde{\pi}_{t-1} = \mu_\pi (E_{t-1}\bar{\pi}_{t+3} - \tilde{\pi}_{t-1}) + \alpha_y y_{t-1} + \varepsilon_t, \tag{12}$$

where $\tilde{\pi}_{t-1} = \alpha_{\pi 1}\pi_{t-1} + \alpha_{\pi 2}\pi_{t-2} + \alpha_{\pi 3}\pi_{t-3} + \alpha_{\pi 4}\pi_{t-4}$.

We note two differences compared with the expression for the inflation differential given by the theoretical model in equation (8). The output gap is now lagged one period. This means that the observation of the inflation differential will lag output by one period. This time lag will increase the distortion in using the inflation differential as an indicator for monetary policy, as the interest rate, by reacting to the inflation differential, will react to the lagged output gap.

Second, the inflation differential is now expressed as the difference between contemporary inflation and a weighed sum of inflation rates in the previous four quarters, where the weights are the estimated parameters in the Phillips curve relationship. Inserting for the empirical inflation differential from equation (12) into the inflation-only rule, the specification of the rule used in the simulation of the model is given by

$$i_t = g_{\pi}^{io}\pi_t + g_{\Delta\pi}^{io}\alpha_y y_{t-1} + g_{\Delta\pi}^{io}\mu_{\pi}(E_t\pi_{t+1} - \tilde{\pi}_{t-1}) + g_{\Delta\pi}^{io}\varepsilon_t. \tag{13}$$

2.4 Assumptions about the mismeasurement of the output gap

In order to compare the performance of the two rules under uncertainty we need to make some assumptions about the form and size of the measurement error in the output gap. The real-time estimate of the output gap at time *t* is given by (5). Orphanides *et al.* (2000) suggest that the measurement error in the output gap can be approximated by a first-order autoregressive process,

$$n_t = \rho_n n_{t-1} + \xi_t. \tag{14}$$

This stochastic process captures the potential persistence in the measurement error: some part of the mismeasurement of the output gap in the present quarter is expected to be carried over into the next quarter's estimate. Orphanides *et al.* (2000) provide estimates of the parameters in (14) for three different periods covering 1966-1994. These estimates are reported in Table 1

.

Table 1. Alternative Measurement Error Processes. Assumed model: $n_t = \rho_n n_{t-1} + \xi_t$.

Time period	$\hat{\rho}_n$	Sd (ξ) (in percent)
Baseline case – output gap revisions 1980:Q1 – 1994:Q4	0.84	0.97
Worst case – output gap revisions 1966:Q2 – 1994:Q4	0.96	1.09
Best case – capacity utilisation revisions 1980:Q1 – 1994:Q4[9]	0.80	0.51

We adopt the baseline case figures as our baseline and will refer to the two other cases either as levels of "low" and "high" uncertainty or as best or worst-case levels of uncertainty.

[9] Orphanides et al. find that revisions in measures of capacity utilisation in manufacturing have been smaller over the actual period and use these figures to give a possible measure of a future "best case" output gap uncertainty.

3 Analysis of the rules

We now turn to the analysis of how useful the change-in-inflation indicator is relative to an imperfect measure of the output gap. We do this by comparing the unconditional standard deviation of the goal (targeting) variables under the two policy rules, with varying assumptions about the degree of output-gap mismeasurement involved. Section 3.1 discusses the central bank's objectives. Section 3.2 evaluates the relative usefulness of the indicators included in the rules under varying configurations of output-gap uncertainty. Section 3.3 discusses how different coefficient configurations affect the relative performance of the two rules and identifies the conditions under which the inflation-only rule works better. Finally, Section 3.4 discusses the robustness of the two rules to other types of uncertainty.

3.1 Central bank preferences

We assume that the central bank has a conventional quadratic loss function with periodic loss given by

$$L_t = (1-\lambda)(\bar{\pi}_t - \pi^*)^2 + \lambda y_t^2 + \nu (i_t - i_{t-1})^2 . \tag{15}$$

where $\bar{\pi}_t$ is the four-quarter inflation rate. The central bank minimises the unconditionally expected loss, i.e.,

$$\min_{i_t} EL_t \tag{16}$$

subject to either the Taylor rule (4) or the inflation-only rule (13) strategies and the model, taking into account that the estimate of the output gap is imperfect. As baseline values of the parameters in the loss function, we set $\lambda = .5$ and $\nu = .01$. The reason why we attach only a small parameter to the interest rate smoothing term in the loss function is that interest rate smoothing does not affect consumer welfare under conventional assumptions. We nevertheless attach some weight to this term, in order to allow the optimal coefficients in the rules to have reasonable magnitudes.[10]

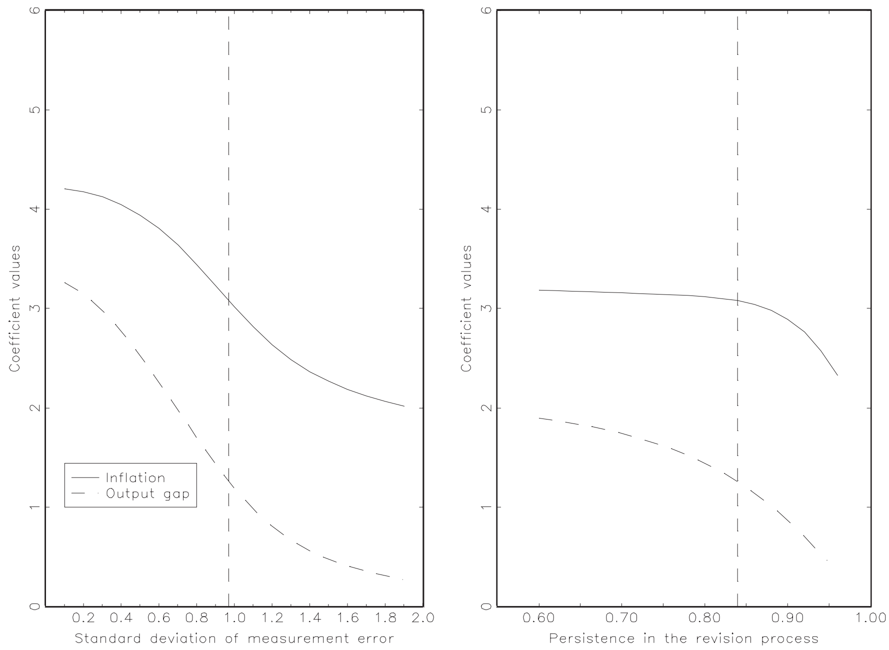
[10] There are, however, reasons to expect that monetary policy rules with large coefficients may be in danger of prescribing a negative nominal interest rate. Given the zero bound on interest rates, hitting this bound increases the likelihood of getting stuck in a liquidity trap. A concern for interest-rate smoothing may be a proxy for the policymaker's wish to avoid this trap. It could, however, be argued that in this case, interest rate stabilisation around the equilibrium rate might serve as a better approximation. That is, $(i_t - i^*)^2$ should enter the loss function instead of $(i_t - i_{t-1})^2$.

3.2 The usefulness of the indicators depending on the degree of output gap uncertainty

Figure 1 plots the optimised coefficients in a Taylor rule at different levels of output-gap uncertainty, represented both by different levels of persistence in the mismeasurement and in shock variability. A number of interesting observations can be made.

First, as also found elsewhere (see Smets (1999) and Rudebusch (2001)), the optimal coefficient on the output gap in the Taylor rule decreases as the actual level of output gap uncertainty increases. The intuition for this result is straightforward: as the reliability of an indicator is reduced, one should place less emphasis on the information it conveys. Second, this result is independent of whether the increased uncertainty comes in the form of higher persistence or higher shock variability.

Figure 1. Optimised coefficients in the Taylor rule.



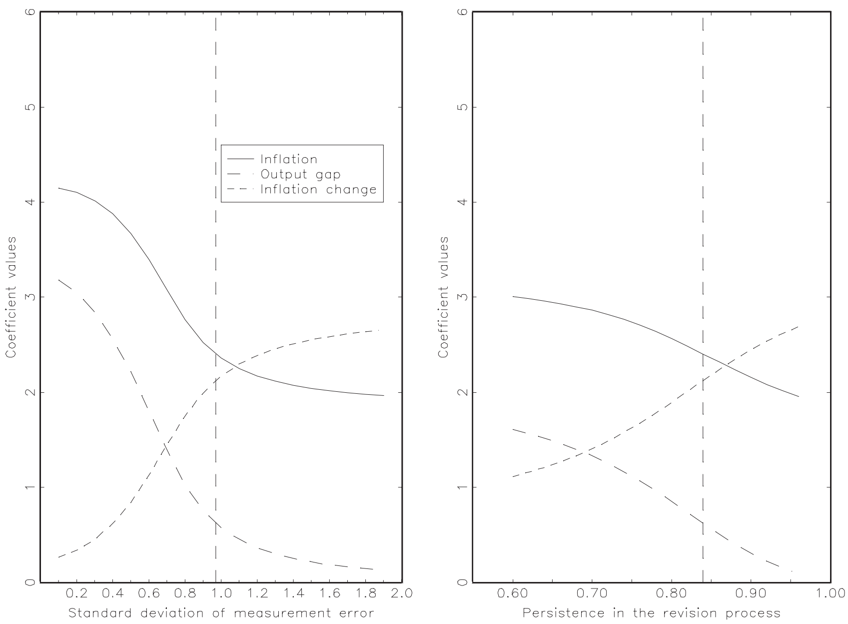
Third, the no-uncertainty coefficient levels are much larger than coefficients obtained from the empirical estimation of Taylor rules on the US economy (see, e.g. Taylor (1993,1999) and Judd and Rudebusch (1998)). However, as output-gap uncertainty increases towards a more realistic level, the optimised coefficients get closer to their associated empirical counterparts, suggesting that taking into account output-gap uncertainty is an important element of policymaking. Fourth, the coefficient on inflation is also reduced accordingly. This result is robust to reasonable changes in the parameters in the loss function.[11]

The optimised coefficients in the inflation-only rule will of course be independent of the level of output-gap uncertainty, as the rule does not use the output gap as an indicator. However, in order to illustrate the efficiency of the 'change in inflation' as an indicator-variable, it is possible to consider a rule that encompasses all indicators used in both rules. We can then study the relative value of the indicators by considering their coefficient in this rule. This encompassing rule is given by

$$i_t = g_\pi \left(\bar{\pi}_t - \pi^* \right) + g_y y_t + g_{\Delta\pi} \left(\pi_t - \tilde{\pi}_{t-1} \right). \tag{17}$$

Figure 2 plots the optimised coefficients in this rule.

Figure 2. The optimised coefficients in the encompassing rule.



In the encompassing rule, the coefficient on the output gap declines as output-gap uncertainty increases. The optimal coefficient on the inflation differential is zero when there is no output-gap uncertainty, which implies that the encompassing rule is a Taylor rule. As output-gap uncertainty increases, the indicator's efficiency improves relative to the real-time estimate of the output gap. In the

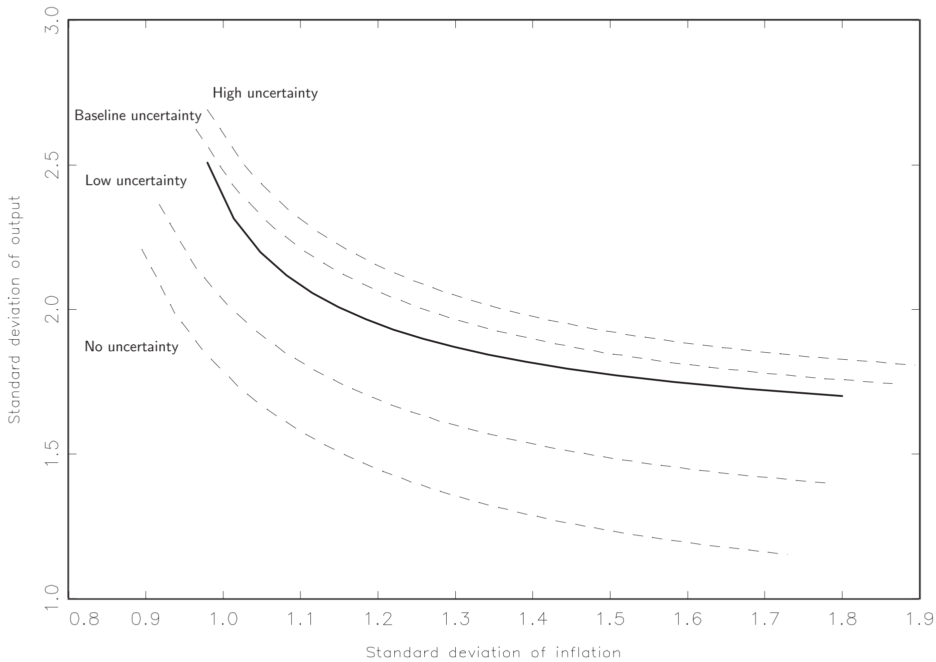
[11] Tables A1-A2 in the appendix show the performance and the optimal coefficients in both the optimal Taylor rules and the inflation-only rule under different assumptions about the (by the policymaker) perceived and the actual degree of output-gap uncertainty.

limit, the coefficient on the output gap is zero, and the encompassing rule is the inflation-only rule. For baseline output-gap uncertainty, the optimal encompassing rule attaches some weight to both indicators of inflationary pressures, although the coefficient on the output gap is relatively small compared with the no-uncertainty case.

3.3 Welfare loss and relative efficiency of the two policy rules

We now turn to consider the relative loss and the relative variability of the goal variables from using the two different rules. First, we consider the efficiency frontiers of the two rules. The frontiers trace out the minimum variability of the goal variables as the relative weight on the output gap (λ) increases from .1 to .9 in the loss function (15). Figure 3 shows the efficiency frontier for the inflation-only rule as the solid line. The dashed lines are the efficiency frontiers for the Taylor rule given different levels of output-gap uncertainty.

Figure 3. Efficiency frontiers for the inflation-only rule and the Taylor rule (dashed lines) under different levels of output-gap uncertainty.



Note: Standard deviations in per cent.

The efficiency frontiers suggest that the inflation-only rule is inefficient compared with the Taylor rule for any choice of λ in a situation where there is little or no uncertainty about the output gap. This is what we should expect from the exercise in the previous section, as the coefficient on inflation change is virtually zero when output-gap uncertainty is low. However, as the level of output-gap uncertainty reaches our best estimate of the true uncertainty, the Taylor rule delivers higher variability both in output and inflation for any choice of relative weight.

What affects the relative efficiency of the rules?

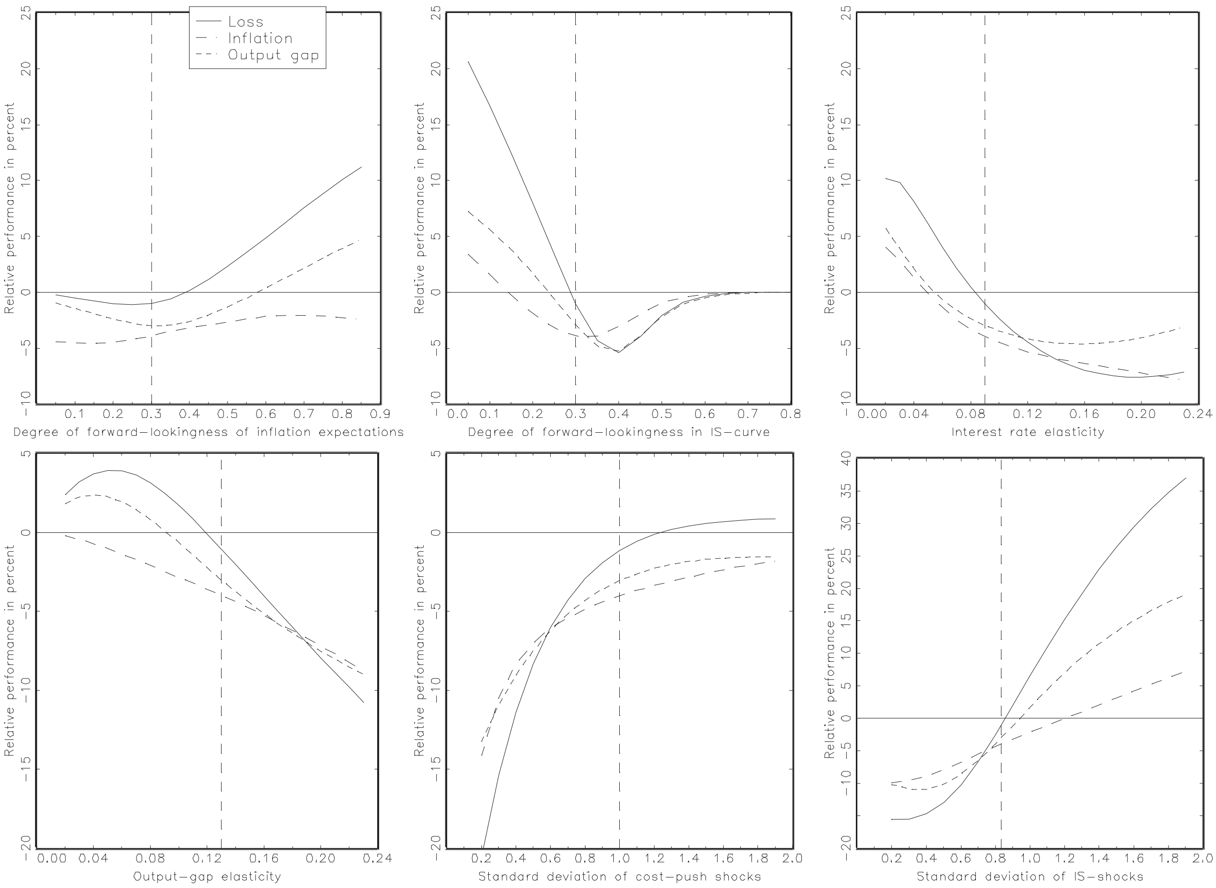
In this section we try to identify what structural conditions should be present, in addition to uncertainty, for the inflation-only rule to have good properties relative to the Taylor rule. We do this by varying key coefficients in the model and then compute the relative loss and standard deviations of inflation and output of the two rules. We assume that the policymaker knows the model and optimises the respective rules subject to this information. Figures A1 and A2 in the Appendix show the resulting optimised coefficient values. We assume a baseline level of uncertainty in the output gap.

Figure 4 shows the performance, both in terms of relative loss and relative standard deviations of inflation and output, from using the inflation-only rule compared with the Taylor rule. Observations above zero indicate a higher loss or more variability produced by the inflation-only rule. Although the Taylor rule has the upper edge in many situations, the inflation-only rule is the better performer in a wide range of settings. In no situation, perhaps with the exception of variability in demand shocks, do the rules perform very differently.

The total relative loss is in most situations higher than the relative standard deviations of output and inflation. This is due to the larger variability in the interest rate when following the inflation-only rule.

The inflation-only rule performs on par with the Taylor rule when inflation expectations are sufficiently backward-looking. The relative performance of the rule deteriorates as inflation expectations become increasingly forward-looking. As illustrated in the introduction, when inflation expectations are completely backward-looking, the change in inflation reflects the output gap and a transitory cost-push shock. The change in inflation is then a better indicator of the output gap, compared with a situation where movements in inflation also reflect movements in expected future inflation.

Figure 4. Relative loss and standard deviations of inflation and output under different coefficient configurations. Optimised rules when the policymaker knows the underlying model coefficients.



The inflation-only rule performs worse when aggregate demand is more backward-looking. The inflation-only rule starts to respond to aggregate demand shocks only when they have materialised into an increase in inflation. This lagged response is more serious when demand is backward-looking since demand then reacts more sluggishly to the interest rate, worsening the effects of the lagged response in the inflation-only rule. This also explains why a higher prevalence of demand shocks worsens the relative performance of the inflation-only rule. On the other hand, if demand is more forward-looking, agents react quickly to expected *future* interest rates. Rational agents will understand that future interest rates will increase to the extent that the present output gap contributes to future inflation. The increase in expected future interest rates has a contractionary effect on demand. In this sense, the inflation-only rule makes good use of the interest-rate expectations channel. When the IS-curve becomes fully forward-looking, however, the output gap will no longer include any usable information for the policymaker. The forward solution of the IS-curve is then given by

$$y_{t+1} = -\beta_r \sum_{i=0}^{\infty} r_{t+i|t} + \eta_{t+1} . \qquad (18)$$

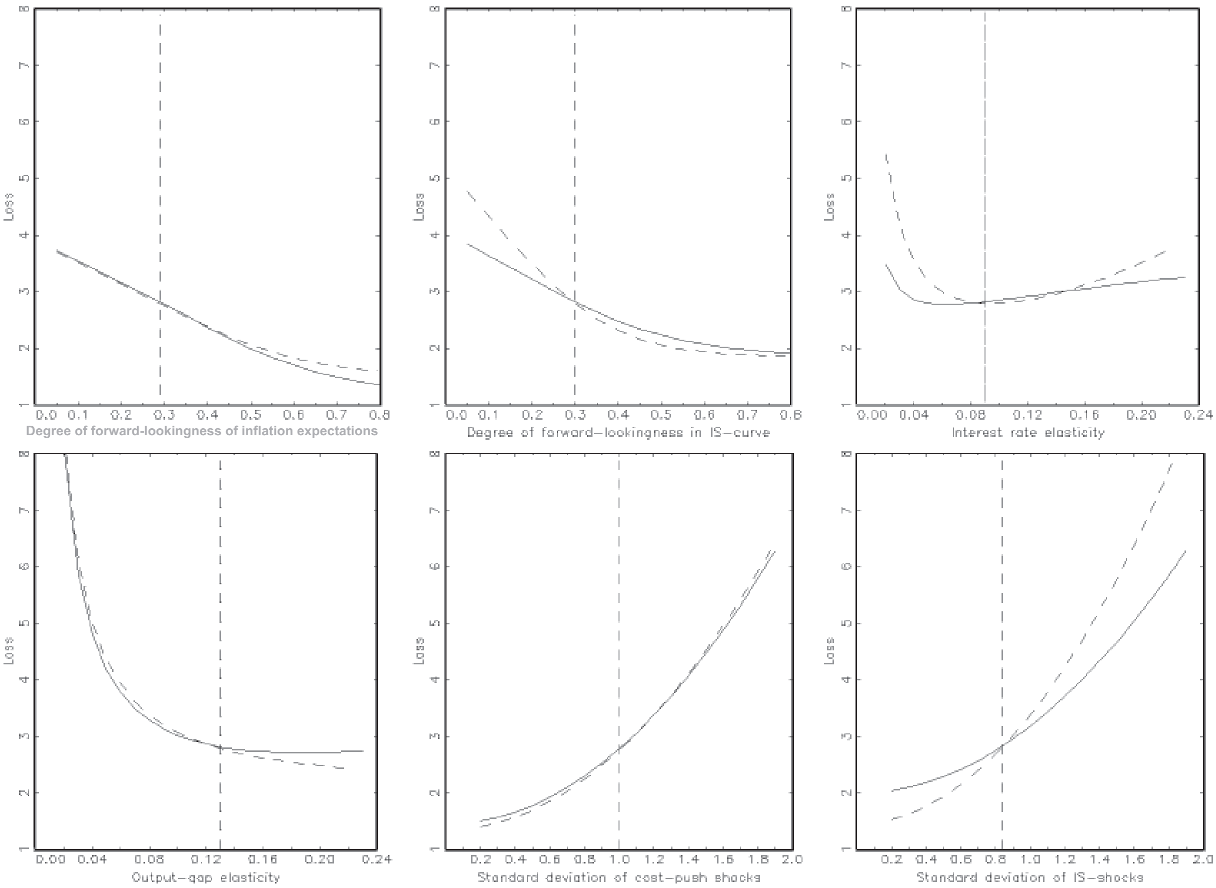
The output gap becomes a function of current and expected future real interest rates and a white-noise demand shock that cannot be stabilised due to the monetary policy control lag. The result is that the optimal Taylor rule and the inflation-only rule will prescribe the same policy recommendation, with $g_y^T = g_{\Delta\pi}^{io} = 0$. See Figures A1 and A2 in the appendix.

The inflation-only rule performs better if cost-push shocks are less prevalent: changes in the rate of inflation will then to a larger extent reflect the state of the output gap rather than cost-push shocks and stabilisation becomes more efficient. In addition, due to the more aggressive response to cost-push shocks inherent in the inflation-only rule, monetary policy will become more active as the prevalence of cost-push shocks increases, which will increase interest-rate variability, decreasing interest-rate smoothing and hence welfare loss.

The policymaker can attach more or less weight to the various components of the loss function. Tables A1 and A2 in the Appendix show how the performances of the Taylor rule and the inflation-only rule depend on the weight attached to interest rate smoothing. As the inflation-only rule requires rather active policymaking, attaching a greater weight to interest rate smoothing[12] quickly results in the Taylor rule outperforming the inflation-only rule. As also seen from Figure 4, a more powerful monetary policy, that is, a stronger ability to affect aggregate demand, improves the relative efficiency of the inflation-only rule. The reason is that the inflation-only rule in this situation does not need to be as active as before in order to stabilise inflation and output appropriately. This means that the weight attached to the interest-rate smoothing argument in the loss function will have less impact on the strategy. Finally, if the output gap exerts a strong impact on inflation, the output gap will contribute more to the change in inflation relative to other factors, and the change in inflation will be a better indicator of the output gap.

[12] Disregarding the motivation behind such a preference.

Figure 5. Loss with the Taylor rule (solid line) and the inflation-only rule (dashed line) under different coefficient configurations. Rules optimised for baseline model coefficients.



3.4 **Robustness of rules**

Coefficient uncertainty

In practise, the policymaker does not know exactly the true coefficients of the underlying model, and would like to have a strategy for monetary policy that will work well even if the coefficients deviate from the policymaker's best (baseline) guess. The ideal policy rule should therefore be robust to changes in the coefficients of the model.[13]

Figure 5 plots the losses of the baseline-optimised inflation-only rule and the baseline-optimised Taylor rule as various coefficients deviate from their baseline values. Relative robustness[14] of a rule is

[13] Söderström (2000) discusses how uncertainty about coefficient values impinges on the optimal control solution in a backward-looking model. Similar techniques for forward-looking models do not, as far as we know, yet exist.

[14] It would be tempting to define the absolute robustness of a rule to be the sensitivity of the loss to changes in the coefficients when following the rule. This would, however, not be appropriate, as the change in the loss also would reflect the change in the controllability of the model itself. However, Figure A3 in the appendix shows the

defined as the sensitivity of the loss associated with the use of this rule relative to the other when exposed to changes in the coefficient values. Relative robustness of a rule is reflected in the figure by the rule's associated line being relatively more horizontal than the other.

From the figure we see that both rules are about equally robust to changes in the degree of forward-looking inflation expectations, the output-gap elasticity and the volatility of cost-push shocks. The two rules differ, however, with respect to changes in the degree of forward-looking behaviour in demand, the volatility of demand shocks and the effectiveness of monetary policy. In all these cases, the Taylor rule is the more robust. With respect to uncertainty about the effectiveness of policy, the relative robustness of the inflation-only rule is highly asymmetric. For small increases in policy effectiveness away from the baseline value, both rules are equally robust. For decreases, however, the relative loss when following the inflation-only rule increases.

Misperceived output-gap uncertainty: uncertain output-gap uncertainty

A second important aspect of robustness is whether the optimised rules are robust to misperceptions about the true level of output-gap uncertainty. Table 2 shows the losses caused by an optimised Taylor rule under different assumptions about perceived and true uncertainty. The optimised Taylor rules are reasonably robust to overestimation of the true uncertainty involved: the perceived uncertainty needs to be far greater than the true uncertainty involved in order for the loss to deteriorate significantly, and hence favour an inflation-only rule. However, if the policymaker assumes worst case uncertainty, the inflation-only rule will always be preferred.

Table 2. Loss with the optimised Taylor rule, and the relative loss with the optimised inflation-only rule compared with the Taylor rule in parenthesis. Different assumptions about true and perceived uncertainty.

Perceived uncertainty	**True uncertainty** No	Best case (low)	Base case	Worst case (high)
No	**1.88 (148 %)**	2.19 (127 %)	3.28 (85%)	9.38 (30 %)
Best case	1.91 (146 %)	**2.16 (129 %)**	3.04 (109 %)	7.89 (35 %)
Base case	2.20 (127 %)	2.33 (120 %)	**2.82 (99 %)**	5.24 (53 %)
Worst case	3.29 (85 %)	3.31 (85 %)	3.38 (83 %)	**3.72 (75 %)**

On the other hand, underestimating the true uncertainty when it is high is considerably more problematic. Thus, the naive use of the optimised no-uncertainty Taylor rule is potentially detrimental, and may cause three times the loss compared with the inflation-only rule. Thus, in a high-uncertainty setting, it may be better to overestimate the level of uncertainty than to underestimate it when using the Taylor rule, or to adopt the inflation-only rule.

excess loss in per cent of the baseline Taylor and inflation-only rules relative to the optimised-encompassing rule for different configurations of coefficients. This approach would take into account the changes in the controllability of the model. The results do not give a different impression than those of Figure 5, however.

4 Conclusions: can we do without the output gap?

Since the output gap is considered to be the main determinant of future inflation, a central bank that aspires to stabilise inflation around some target level needs to respond appropriately to the real-time estimate of the output gap. It is therefore an important task for the bank to produce good estimates of the output gap. Empirical work shows, however, that despite the resources available at the Federal Reserve, the real-time estimate of the US output gap shows large and persistent measurement errors. Thus, interest-rate responses to the output gap may involve large and persistent policy errors. Given that most central banks do not possess the same resources as the Federal Reserve, we do not expect the US estimates to be any worse than others.

This paper has tried to shed light on the cost of disregarding direct information about the output gap under realistic assumptions about real-time output-gap uncertainty. Instead, the policymaker is assumed to use a measure of the change in the inflation rate as a proxy for inflationary pressures. We reach five main conclusions.

First, under baseline assumptions about the level of output gap uncertainty, the change-in-inflation indicator is slightly more useful than the real-time estimate of the output gap. The result is independent of the degree to which the central bank prefers inflation to output gap stability. The result hinges, however, on the degree to which the policymaker prefers interest-rate smoothing as the inflation-only rule implies a more active policy. Second, underestimation of the actual level of output gap uncertainty is potentially more serious for the Taylor rule than overestimation. The *naive policymaker,* who has considerable confidence in his output-gap estimate, may thus be better off using the inflation-only rule, which is independent of output-gap uncertainty. However, given that he does consider his estimate of the output gap to be fairly accurate, he may not be likely to do so. The *pessimistic policymaker,* who assumes a worst-case output-gap uncertainty, will, by using the Taylor rule, end up with a relative loss that is fairly robust to misperceptions about output-gap uncertainty. However, in this case the inflation-only rule will always be the preferred rule. Third, whether perceived or not, the greater the uncertainty about the output gap is, the more is to be gained by responding to the inflation differential rather than to the output gap. Fourth, we find that less variability in demand and cost-push shocks as well as greater effectiveness of monetary policy may improve the performance of the inflation-only rule relative to the Taylor rule. Fifth, we find that the inflation-only rule is marginally less robust to deviations of some of the true model coefficients from the perceived (baseline) model coefficients. That is, the inflation-only rule is somewhat less robust to coefficient uncertainty.

Since the inflation-only rule responds to the actual increase in the rate of inflation rather than the expected determinants of future inflation, it may be more robust to other models which assign a different role to the output gap in affecting future inflation. Monetary policy rules that requires a reaction to expected future inflation have been shown to be sensitive to model uncertainty (see Levin et al., 2001). Also, our output-gap uncertainty figures are based on an assumption that the final estimates of the output gap are the "true values." The uncertainty tied to the final figures may imply that the true uncertainty in the output gap is larger than what we have used in our simulation. Finally, it may be possible to filter out some of the effects of cost-push shocks on prices using judgment. All these aspects may work to increase the desirability of the inflation-only rule in practical policymaking.

Appendix A

Extra tables and figures.

Table A1.
The performance of simple rules under different assumptions about perceived and actual output-gap uncertainty.
Loss function is $L = 0.5Var[\pi] + 0.5Var[y] + 0.01Var[\Delta i]$.

Perceived uncertainty	True uncertainty	Coefficients	Sd[π]	Sd[y]	Sd[Δi]	Loss
Optimised Taylor rules						
No uncertainty		$g_\pi = 4.21,\ g_y = 3.30$				
	No		1.24	1.40	3.53	1.88
	Best case (low)		1.31	1.52	4.15	2.19
	Base case		1.60	1.85	5.41	3.28
	Worst case (high)		3.58	2.33	5.70	9.38
Baseline case		$g_\pi = 3.08,\ g_y = 1.26$				
	No		1.18	1.72	1.56	2.20
	Best case (low)		1.21	1.77	1.74	2.33
	Base case		1.35	1.93	2.12	2.82
	Worst case (high)		2.37	2.18	2.22	5.24
True uncertainty						
	Best case (low)	$g_\pi = 3.86,\ g_y = 2.57$	1.27	1.58	3.22	2.16
	Worst case (high)	$g_\pi = 2.14,\ g_y = .24$	1.53	2.25	0.96	3.72
Standard Taylor rule 1		$g_\pi = 1.5,\ g_y = .5$				
	No		1.82	1.66	0.70	3.03
	Best case (low)		1.85	1.68	0.76	3.13
	Base case		2.00	1.77	0.90	3.58
	Worst case (high)		3.55	2.06	0.95	8.45
Standard Taylor rule 2		$g_\pi = 1.5,\ g_y = 1$				
	No		2.00	1.40	1.04	2.99
	Best case (low)		2.08	1.47	1.20	3.25
	Base case		2.44	1.68	1.53	4.41
	Worst case (high)		5.91	2.30	1.63	20.16
Inflation-only rule		$g_\pi = 1.85, g_{\Delta\pi} = 2.82$	1.30	1.87	4.43	2.79

Table A2.
The performance of simple rules under different assumptions about perceived and actual output gap uncertainty.
Loss function is $L = .5Var[\pi] + 0.5Var[y] + 0.25Var[\Delta i]$.

Perceived uncertainty	True uncertainty	Coefficients	Sd[π]	Sd[y]	Sd[Δi]	Loss
Optimised Taylor rules						
No uncertainty		$g_\pi = 2.25,\ g_y = 1.06$				
	No		1.38	1.59	1.23	2.60
	Best case (low)		1.42	1.64	1.39	2.85
	Base case		1.61	1.81	1.72	3.67
	Worst case (high)		3.08	2.15	1.81	7.87
Baseline case		$g_\pi = 2.06,\ g_y = .53$				
	No		1.37	1.85	0.90	2.85
	Best case (low)		1.39	1.87	0.95	2.94
	Base case		1.47	1.94	1.08	3.26
	Worst case (high)		2.18	2.10	1.12	4.89
True uncertainty						
	Best case (low)	$g_\pi = 2.18,\ g_y = .86$	1.41	1.71	1.20	2.81
	Worst case (high)	$g_\pi = 1.92,\ g_y = .18$	1.59	2.22	0.85	3.91
Standard Taylor rule 1		$g_\pi = 1.5,\ g_y = .5$				
	No		1.82	1.66	0.70	3.14
	Best case (low)		1.85	1.68	0.76	3.27
	Base Case		2.00	1.78	0.90	3.77
	Worst case (high)		3.55	2.06	0.95	8.67
Standard Taylor rule 2		$g_\pi = 1.5,\ g_y = 1$				
	No		2.00	1.40	1.04	3.25
	Best case (low)		2.08	1.47	1.20	3.59
	Base case		2.44	1.68	1.53	4.97
	Worst case (high)		5.91	2.30	1.63	20.79
Inflation-only rule		$g_\pi = 1.64,\ g_{\Delta\pi} = .67$	1.56	2.10	1.31	3.84

Figure A 1. Optimised Taylor rule coefficients under different configurations of model parameters.

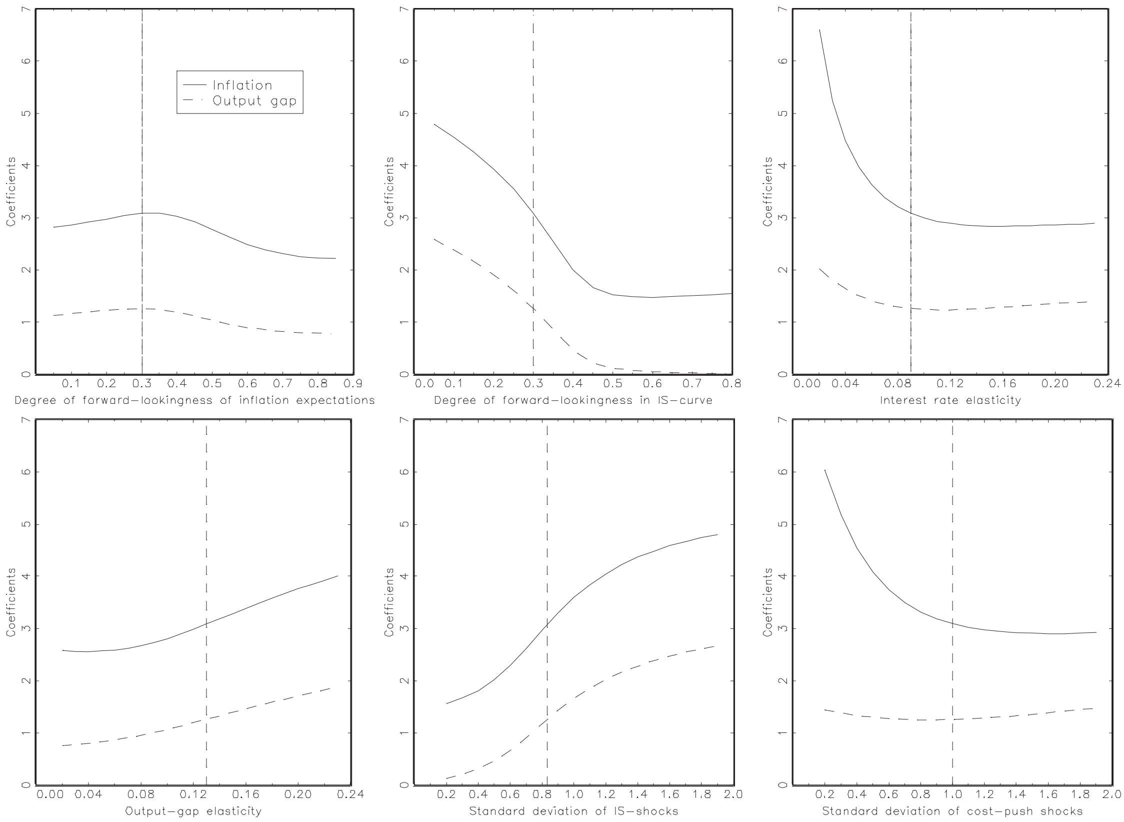


Figure A 2. Optimised inflation-only rule coefficients under different configurations of model parameters.

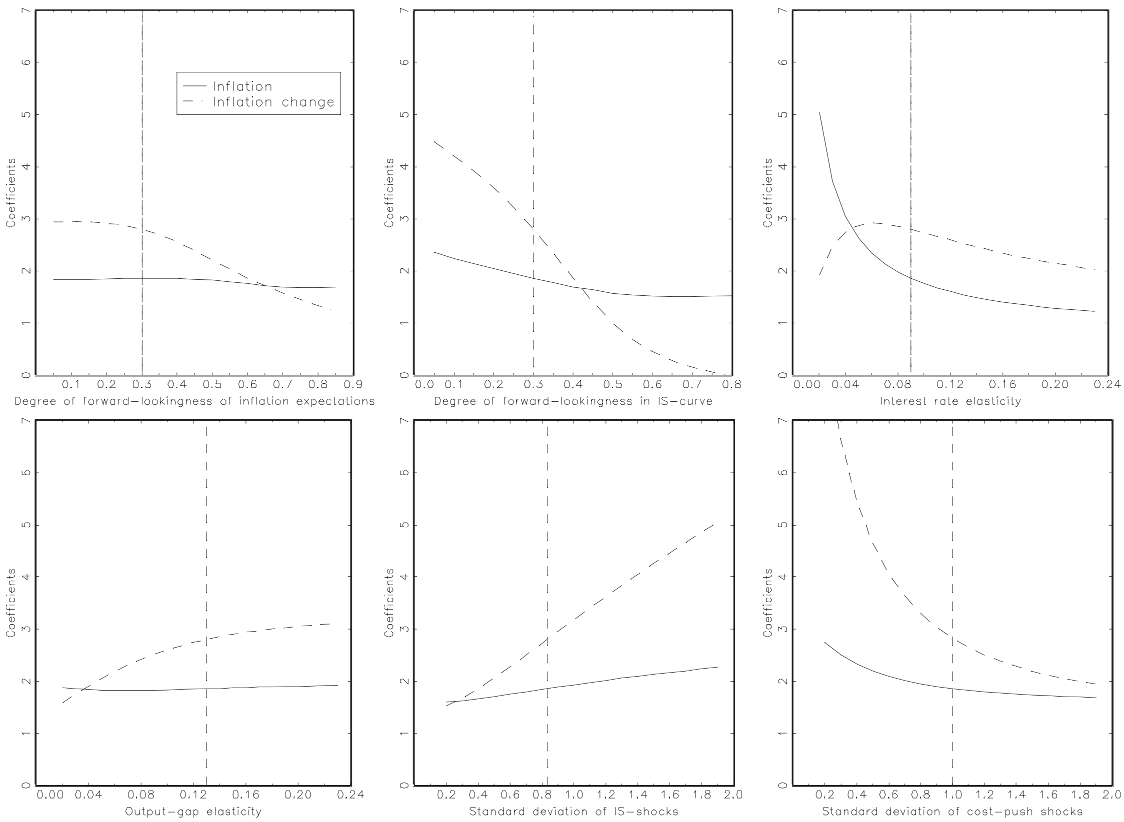
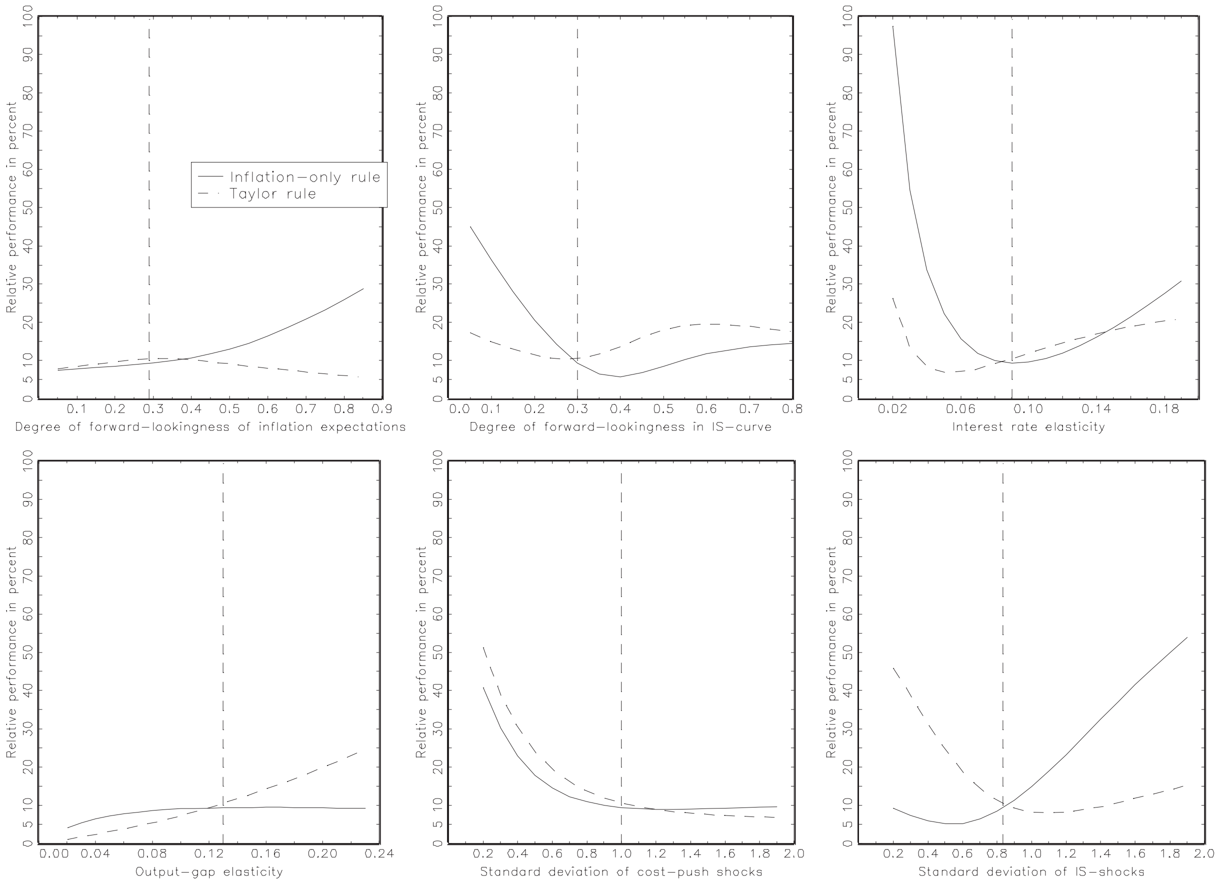


Figure A 3. Absolute robustness. Excess loss in percent with the baseline Taylor and the inflation-only rules relative to the optimised encompassing rule under different coefficient configurations.



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Kai Leitemo and Ingunn Lønning: Simple Monetary Policymaking without the Output Gap

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