Imperfect Transparency and Shifts in the Central Bank’s Output Gap Target

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Abstract

Despite a significant increase in transparency in recent years, most central banks remain reluctant to reveal their future intended course of policy. This paper analyzes the case where the central bank’s projected path of the output gap target is private information. It is assumed that the target is subject to temporary and persistent shocks motivated either by measurement errors of potential output or as a result of political pressure. Under imperfect transparency, the public cannot observe the true degree of persistence of a shock to the target and must learn by observing past data. In this setting, the paper shows that the economic consequences of imperfect transparency critically depend on whether monetary policy is characterized by discretion or commitment. Indeed, under discretion, imperfect transparency reduces inflation and output gap variability and thus increases welfare. Under commitment, the effect of imperfect transparency on inflation and output variability is ambiguous. Welfare, however, unambiguously declines.

Keywords: Monetary policy; Transparency; Discretion; Commitment

JEL classification: E5; E52; E61

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1 Introduction

Traditionally, central bankers have been very reluctant to disclose their objectives or intended future actions. Indeed, the U.S. Federal Reserve did not make it a practice to officially announce its instrument target until February 1994, and post-meeting statements were not released until May 1999. The economic reasoning for this secrecy has been less than obvious. One common argument in favor of imperfect transparency is that it shields the monetary authorities from political oversight, thus protecting the central bank’s independence. This reasoning has become increasingly less convincing. Blinder (1998) effectively argues that improved transparency is likely to reduce political influence over monetary policy since it increases accountability and thereby enhances public support for central bank independence. Additionally, with the rise of the New Keynesian synthesis, which emphasizes the importance of forward-looking expectations in price-setting behavior, there has been an increasing realization that transparency can potentially anchor inflation expectations and improve the trade-off between inflation and output variability (e.g., Woodford 2004).

Inflation targeting central banks have generally been the strongest advocates for increased transparency. By announcing an explicit inflation target and publishing periodic inflation-reports, which provide a basis for monetary policy decisions, inflation targeting central banks hope to provide enough transparency to stabilize inflation expectations around the target. Although such practice is likely to increase both accountability and the public’s understanding of the objectives of monetary policy, there are still measures that can be taken to further enhance transparency about future policy actions. The most obvious measure would be to publish the intended future path of the policy instrument. Yet, very few central banks are willing to provide such degree of transparency. Theoretically, of course, central banks need not go as far as publishing the projected path of the policy instrument. If the public knows the targeting rule used by the monetary authorities when setting the instrument, all that is really needed for the public to infer future policy actions is either: (i) complete transparency regarding the bank’s belief about the future path of variables used as inputs in the decision process, or (ii) a projection of the future path of target variables such as output and inflation based on the intended future path of the policy instrument. Although most inflation targeting central banks do publish inflation forecasts, these forecasts are typically not based on the intended future path of policy. Instead, they are either based on market expectations

1The Federal Reserve Bank of New Zealand, the Bank of Norway, and most recently the Swedish Central Bank (Riksbanken) publish the projected path of the policy instrument.
of the policy instrument or simply derived under the assumption of a constant instrument rate. Thus, even inflation targeting central banks seem to be reluctant to embrace perfect transparency.

Whether a central bank should go as far as displaying the future projected path of the instrument rate is currently an widely debated subject. Mishkin (2004) argues that too much transparency can be counterproductive as far as it complicates communication with the public and distracts from the central bank’s long-run goals of low and stable inflation. Goodhart (2005) also points out that committing to a future path of the policy instrument can be interpreted as unconditional, thus constraining desired policy flexibility in the future. Svensson (2006) and Woodford (2004), on the other hand, argue that if the purpose of transparency is to increase the predictability of monetary policy, then revealing future policy intentions should be preferable.

This paper attempts to shed light on the desirability of transparency.\textsuperscript{2} In particular, I examine how uncertainty about future monetary policy in a world of forward looking rational agents affects inflation and output gap volatility and consequently, overall welfare. The source of uncertainty is due to temporary and persistent shifts in the central bank’s output gap target. These shifts can be motivated either by measurement errors of potential output or as a result of political pressure. I assume that the public can contemporaneously observe changes in the output target, but unless the central bank discloses the exact nature of these changes (i.e., whether the change in the output target is likely to be persistent or transitory), private agents cannot accurately predict the future path of monetary policy. I show that the economic consequences of imperfect transparency in such an environment critically depend on whether optimal monetary policy is characterized by discretion or commitment.

Under discretion, imperfect transparency mitigates the overall impact that shifts in the output gap target has on inflation expectations and therefore decreases inflation and output gap variability and increases welfare. Under commitment, however, the impact of imperfect transparency is less obvious. Indeed, optimal policy under commitment is \textit{history dependent} and displays intrinsic inertia. When the target is hit by a persistent shock, the mitigating impact that imperfect transparency has on inflation expectations causes a stronger policy response which is prolonged by the policy inertia. Since agents are forward-looking this prolonged policy response can destabilize inflation expectations and cause an increase in both inflation and output variability. The effect on inflation and output variability under commitment is therefore ambiguous. Welfare, however,

\textsuperscript{2}Thus, it does not address the feasibility of implementing transparency in practice. See Cukierman (2005) for a discussion of desirability versus feasibility of transparency.
unambiguously declines under imperfect transparency and commitment.

These results indicate that a central bank operating under discretion has an incentive to be opaque about future policy actions while the opposite is true for central banks operating under commitment. Indeed, simulations indicate that the welfare improvements due to imperfect transparency under discretion are larger than the welfare losses under commitment. Thus, central bankers who take the discretionary approach have a greater incentive to oppose transparency than central bankers advocating commitment have to improve transparency.

The paper is structured as follows. Section 2 briefly describes the importance of transparency when agents are forward-looking, and section 3 describes the benchmark case for optimal policy under discretion and commitment. Section 4 introduces exogenous shifts in the output gap target and its impact on optimal policy. Section 5 defines imperfect transparency and describes the nature of the learning method applied by the public. Section 6 and 7 describes the case of perfect and imperfect transparency under discretion and commitment. Section 8 presents simulations of the model, quantitatively evaluating the effects of imperfect transparency under various parameter settings. Finally, section 9 concludes.

2 The Relevance of Forward-Looking Expectations for Monetary Policy

In recent years, the New Keynesian synthesis has emerged as the main paradigm used for monetary policy (e.g., Clarida, Gali, Gertler 1999). The framework assumes a monopolistic competition environment where optimizing firms are unable to continuously adjust their prices as economic conditions changes. The aggregate supply curve or the so-called New Keynesian Phillips curve can then be shown to take the following form:

\[ \pi_t = \lambda x_t + \beta E_t \pi_{t+1} \]  

(1)

Expression (1) states that the current inflation rate, \( \pi_t \), is determined by the output gap, \( x_t \), and expected future inflation, \( E_t \pi_{t+1} \). The output gap is proportional to the real marginal cost faced by firms and is therefore positively related to inflation. Also, a higher future expected price level forces firms to revise their current prices upwards since they may be unable to adjust prices in the future. Thus, an increase in expected inflation causes today’s inflation rate to rise. This

\[^3\]The output gap is defined as the difference between output and its flexible-price level or potential level.
suggests that there are two channels through which monetary policy can influence the current rate of inflation. First, the implied price inertia enables the central bank to manipulate the real interest rate through changes in the nominal interest rate. The real interest rate in turn affects the output gap. Hence, by adjusting the real interest rate the monetary authorities can affect the output gap and maneuver the inflation rate. Second, monetary policy can have an indirect effect on inflation through inflation expectations. To see this, iterate equation (1) forward to the infinite future.

\[ \pi_t = E_t \sum_{i=0}^{\infty} \beta^i \lambda x_{t+i} \]  

Expression (2) illustrates the impact that the expected future stream of output gaps has on the current inflation level. If the output gap is expected to rise in the future, some firms would raise their prices today since they may be unable to do so in the future. This would cause current inflation to rise. Similarly, a future expected contraction of the economy would lower inflation today. Given that monetary policy can affect the output gap, expression (2) shows that not only does current monetary policy matter, but so does the public’s perception of future policy. Hence, the forward-looking property of the New Keynesian Phillips curve is not only an important channel for monetary policy but also essential for the impact of policy transparency. For example, a persistent shift in the central bank’s output target would have a greater impact on inflation expectations and thereby on current inflation than a temporary shift. Imperfect transparency regarding the future course of monetary policy can therefore have a direct impact on the current economic environment and the effectiveness of monetary policy.

3 Optimal Monetary Policy under Discretion and Commitment

In keeping with the mainstream literature, I assume that the social welfare function is quadratic in inflation and the output gap.\(^5\)

\[ W = -\frac{1}{2} E_t \sum_{i=0}^{\infty} \beta^i (\pi_{t+i}^2 + \alpha x_{t+i}^2) \]  

\(^4\)The importance of this traditional effect of monetary policy on inflation is measured by the slope coefficient \(\lambda\). Lambda partially reflects the fraction of the firms that can adjust their prices in response to changes in the current output gap. A low value of lambda reflects a low level of price-flexibility, while a high value indicates the opposite.

\(^5\)Woodford and Rotemberg (1997) show that the aggregate welfare level in an economy based on utility maximizing agents is well approximated by expression (3). However, it is also common to simply assume a quadratic welfare function similar to (3) without a micro-foundation.
Welfare is negatively related to inflation and output gap variability and the parameter $\alpha$ represents the relative weight assigned to output volatility. Ideally, the objective function of the central bank should coincide with the social welfare function. That is, monetary authorities should minimize inflation and output gap variability in accordance with the relative weight $\alpha$. Optimal monetary policy is thus defined as the state-contingent action plan which maximizes the objective function (3) subject to the aggregate supply relationship (1). This state-contingent plan can be derived as:

$$x_{t+i} = -\frac{\lambda}{\alpha} \pi_{t+i} \quad for \quad i = 0$$

$$x_{t+i} = x_{t+i-1} - \frac{\lambda}{\alpha} \pi_{t+i} \quad for \quad i \geq 1$$

Equation (4) describes the optimal targeting rule in period $t$ while equation (5) describes the optimal rule for subsequent periods. Accordingly, if inflation increases, the central bank should decrease its current output target and gradually bring the target back in line with potential output. This suggests that optimal policy displays a certain degree of intrinsic inertia. The problem, however, is that this state-contingent action plan is time-inconsistent. A central bank that re-optimizes the objective function each period will always follow (4) and never implement (5). To address this problem, Woodford (1999) suggests that the central bank should pre-commit itself to the targeting rule described by (5) and simply disregard (4) as an initial condition implemented in the distant past. He appropriately labels this strategy as the timeless perspective approach to optimal policy. Interestingly, Giannoni and Woodford (2003) show that such a strategy can be achieved through a credible commitment to an optimal target criterion. They argue that inflation targeting regimes can be viewed as examples of such a commitment.

Optimal monetary policy can hence either be characterized by discretion or by commitment. In the former case, the central bank makes no pre-commitment about future policy and re-optimizes its objective function each period. The optimal target rule is then described by (4) for all periods. If current inflation increases, the monetary authorities should contract output, and if it falls, they should expand output. The drawback with this policy approach is that it forgoes the opportunity to manipulate inflation expectations. Under commitment, however, the monetary authorities take advantage of the forward-looking nature of inflation expectations through the introduction of policy inertia. By committing to keep output below its potential level even after an inflationary shock has dissipated, the central bank lowers the expected sum of future output gaps, which lowers inflation expectations and improves the short-run trade-off between inflation and the output gap.
When combining the optimal targeting rules under either discretion or commitment together with the Phillips curve, they predict the same policy outcome. That is, in order to minimize inflation and output gap variability the central bank should simply keep output at its potential level at all times. Such a strategy would ensure that both the output gap and inflation are zero. This result is altered in a more realistic setting where a cost-push shock is added to the New Keynesian Phillips curve. Unlike demand shocks, which cause inflation and output to move in the same direction, supply shocks cause inflation and output to move in opposite directions. While demand shocks can and should be completely reversed under optimal policy, the response to supply shocks depends on the relative aversion to inflation and output variability. As Clarida, Gali and Gertler (1999) show, in such a case it matters whether monetary policy is conducted under discretion or commitment. In fact, discretionary policy is likely to lead to a stabilization bias where output volatility is too low and inflation volatility is too high. Under commitment the central bank is able to manipulate expectations and improve the trade-off between inflation and output gap variability. Commitment is therefore welfare superior to discretion.\footnote{Jensen and McCallum (2002) points out that the timless approach is not generally optimal within the class of rules characterized by (5). Jensen (2001) has shown that a slight modification of (5) does perform better.}

The focus of this paper, however, is different. Instead of concentrating on cost-push shocks, I turn the attention to unwanted shifts in the output target. Although I abstract from supply shocks in the analysis, the inclusion of such shocks does not alter the results with respect to the impact of imperfect transparency under discretion or commitment. Their inclusion would only affect the welfare implication of commitment relative to discretion.

4 Shifts in the Output Gap Target and Optimal Policy

The targeting rules in the previous section were derived under the assumptions that the monetary authorities had perfect information regarding the structure of the economy and that the decision process was insulated from outside pressure. These assumptions may be too restrictive in reality. Cukierman (2005), for instance, argues that the output target “may fluctuate due to changes in the composition of the policymaking board, changes in the intensity of political pressure and changes in the bank’s evaluation of unobservable economic fundamentals like potential output.” For example, a temporary increase in productivity would cause potential output to rise. The appropriate response by the central bank is then to adjust its output target upwards. However, this might be easier
said than done since potential output and productivity shocks are notoriously difficult to estimate.
If the central bank overestimates (underestimates) potential output, the output target will be too
high (low) and monetary policy too expansionary (contractionary). The output target may also
shift for political reasons. The government can put pressure on the central bank to either directly
stimulate the economy, or to not completely eliminate planned fiscal expansionary measures. In
this case, the output target would vary over time according to the political business cycle.

Let $\tau_t$ denote the measurement error of potential output in period $t$. That is, $\tau_t = \hat{y}_{tcb} - \hat{y}_t$,
where $\hat{y}_t$ denotes potential output and $\hat{y}_{tcb}$ denotes the central bank’s best estimate of potential out-
put. An increase (decrease) in $\tau_t$ would accordingly represent an overestimation (underestimation)
of potential output. Conversely, if the output target is subject to shifts due to political pressure,
then $\tau_t$ can be interpreted as the central bank’s output gap target i.e., $\tau_t = y_{t}^T - \hat{y}_t$, where $y_{t}^T$ is
the central bank’s desired output target. A shift in $y_{t}^T$, given potential output, represents a change
in the intensity of political pressure and leads to a change in the output gap target. This suggests
that the central bank’s estimate or desired level of the current output gap, denoted by $x_{tcb}$, can be
expressed as:

$$x_{tcb} = y_t - y_{tcb} = x_t - \tau_t$$

(6)

An important difference between these two interpretations of $\tau_t$ is the impact they have on
the central bank’s maximization problem. The political pressure story is fairly straightforward. All
we need to do is substitute $x_{tcb}$ for $x_t$ in equations (4) and (5). However, as Svensson and Woodford
(2002, 2003) show, when the central bank has to estimate potential output and if forward-looking
variables, such as inflation, are used to derive this estimate, then the certainty equivalence principle
may not hold. That is, it may not be possible to simply substitute the true value of potential output
with its optimal estimate into the first-order conditions (4) and (5). The problem is that policy
today depends on estimates of potential output, which depends on inflation, which in turn depends on expectations about policy. Thus, a simultaneity problem arises that the central bank must
solve. Furthermore, the so-called separation principle (i.e., the separation between the estimation
of potential output and the optimization problem itself) may also fail.

In this paper, I avoid such complications by assuming that the optimal estimate of potential
output is pre-determined and does not depend on any forward-looking indicators or current policy
actions (see appendix A). Thus, both the certainty equivalence and the separation principle hold.
Consequently, the first-order conditions remain the same whether shifts in the output gap target
are interpreted as measurement errors of potential output or as a result of political pressure. In
both cases we can substitute \( x^b_t \) for \( x_t \) in equations (4) and (5). Thus, the optimal targeting rules under discretion and commitment, respectively, are as follows:

\[
x_t - \tau_t = -\frac{\lambda}{\alpha} \pi_t, \quad (7)
\]

\[
(x_t - \tau_t) = (x_{t-1} - \tau_{t-1}) - \frac{\lambda}{\alpha} \pi_t. \quad (8)
\]

Equations (7) and (8) both indicate that an increase in the output gap target, \( \tau_t \), would cause an expansion of output (given inflation). However, under commitment, a shift in the output gap target would have a lasting effect on output dynamics.

Finally, to complete the model we need to specify the dynamics of the output gap target. Let \( \tau_t \) be described by the following stochastic process:

\[
\tau_t = \varepsilon_t + w_t \tag{9}
\]

\[
\varepsilon_t = \rho \varepsilon_{t-1} + \eta_t \tag{10}
\]

where \( w_t \) and \( \eta_t \) are i.i.d random variables with mean zero and variances \( \sigma^2_w \) and \( \sigma^2_{\eta} \), respectively. The stochastic variable \( \varepsilon_t \) has an unconditional mean of zero and represents a persistent force that pushes the central bank’s output gap target away from its long-run mean, while \( w_t \) represents a temporary shock to the output gap target. The parameter \( \rho \) measures the degree of persistency in the stochastic variable \( \varepsilon_t \). Appendix A presents a more detailed model for the interpretation of \( \tau_t \) as a measurement error of potential output.\(^7\)

\(^7\) Alternatively, we could consider a more general set up:

\[
\tau_t = \mu \varepsilon_t + w
\]

\[
(\varepsilon_t - k) = \rho (\varepsilon_{t-1} - k) + \eta_t
\]

In this case, the stochastic variable \( \varepsilon_t \) has an unconditional mean of \( k \). The parameter \( \mu \) measures the impact that the persistent shock has on the output gap target. In line with the motivation above, the persistent shock can be interpreted as a measure of the political business cycle, and the parameter \( \mu \) can be viewed as a measure of central bank autonomy. The lower the value of \( \mu \), the less influence the government has on monetary policy. The qualitative nature of the results derived in proceeding sections still holds.

\(^8\) Appendix A derives equation (9) and (10) based on the assumption that neither the public nor the central bank can perfectly differentiate between permanent and transitory productivity shocks. The measurement error, \( \tau_t \), is then interpreted as the difference between the central bank’s and the public’s estimate of potential output.

In order to introduce persistent differences between the central bank’s and the public’s estimate of potential output, I assume that the signals that the central bank receives regarding the productivity shocks are different but of the same quality as those received by the public.
5 Imperfect Transparency and the Optimal Filtering Problem

Suppose now that the monetary authorities are not perfectly transparent with respect to the projected path of the output gap target. In particular, the private agents can observe a shift in the central bank’s current output gap target but are unsure whether the shift is going to be temporary or persistent. Since it is essential for firms to predict the future course of monetary policy, they must estimate the persistent and temporary components of the observed output gap target. Notice from (9) and (10) that since agents observe \( \tau_t \) directly, current and past values of inflation and output do not provide any extra information about the nature of the shock. This simplifies matters considerably. The only information needed for an optimal estimate of the components of the target is the history of observed output gap targets (which are exogenously determined). Furthermore, this implies that the central bank cannot affect the public’s estimation of its output gap target and must treat the estimation error as an exogenous shock process.

The optimal estimate of the persistent component, using the Kalman filter can be derived as:

\[
E^p_t \varepsilon_t = E^p_{t-1} \varepsilon_t + K_t \left( \tau_t - E^p_{t-1} \tau_t \right)
\]

where \( E^p_t \) denotes the expectations operator with respect to the information set of the private sector. The parameter \( K_t \) represents the weight or importance that agents assign to new information (i.e., the realized forecast error of the output gap target) in updating their previous estimate. The weight \( K_t \), the so-called constant gain coefficient, can be obtained as:

\[
K_t = \frac{-\Psi - (1 - \rho^2) + \sqrt{(\Psi + (1 - \rho^2))^2 + 4\rho^2 \Psi}}{2\rho^2}
\]

where \( 0 \leq K \leq 1 \) and \( \Psi = \sigma^2_{\eta_t}/\sigma_{\varepsilon_t}^2 \). It will be convenient to let \( \phi_t \) denote the estimation error of \( \varepsilon_t \) at time \( t \) (i.e., \( \phi_t = \varepsilon_t - E^p_{t-1} \varepsilon_t \)). Expression (11) can then be rewritten in the following manner:

\[
\phi_t = (1 - K) (\rho \phi_{t-1} + \eta_t) - Kw_t
\]

Equation (13) states that the estimation error of the persistent component follows an autoregressive process of order one. The volatility of the estimation error is the degree of uncertainty to which imperfect transparency gives rise. Such implied uncertainty about the output gap process may at first seem undesirable. However, as we will see, the overall effect of imperfect transparency

\[9\text{See Appendix F for a derivation of the constant gain coefficient.}\]
on the dynamics of inflation and output depends on the correlation between the temporary and persistent components of the output gap target and the estimation error.

6 Inflation and Output Gap Dynamics under Perfect Transparency

Under perfect transparency there is no asymmetric information between the public and the central bank. That is, the central bank conveys the exact composition of the output gap target to the public. As a result, $\phi_t = 0$ for all $t$.

6.1 Discretion

Using the Phillips curve together with the optimal targeting rule under discretion (7), the following expressions for the equilibrium inflation and output gap can be obtained:

$$\pi_t = q\alpha \lambda \varepsilon_t + \theta\alpha \lambda w_t$$

$$x_t = (1 - q\lambda^2) \varepsilon_t + (1 - \theta\lambda^2) w_t$$

where $q = (\lambda^2 + \alpha (1 - \beta\rho))^{-1}$ and $\theta = (\lambda^2 + \alpha)^{-1}$. Unsurprisingly, a positive shock to the output gap target causes output to rise above its potential level and pushes inflation above zero. The central bank reacts to the inflationary pressure by holding back the real expansion which prevents the output gap target to be reached. Furthermore, since $q > \theta$, a persistent shock has a relatively greater impact on inflation than a temporary shock. The opposite is true for the output gap. The reason is that a persistent shock causes the output gap to be positive for a longer period of time than a temporary shock. Due to the forward-looking nature of the Phillips curve, inflation expectations must therefore rise by more in response to a persistent shock than to a temporary shock and cause a greater increase in the current inflation rate. The greater inflationary pressure under a persistent shock forces the central bank to be less expansionary. Figures 1(a) and 1(b) display the dynamics of inflation and the output gap in response to a unit shock to the persistent and temporary components of the output gap target, respectively. The discretionary case is represented by the solid line and the output gap target is marked by the thin dotted line. The figures confirm that the immediate inflation (output) response is greater (smaller) when the shock is persistent in nature.

Using the set-up in the previous footnote, the long run inflation level is above its socially optimal level and equal to $\omega \mu k / \lambda$. The bias is negatively related to the degree of price flexibility since the pass-through of current expansionary policy to inflation is higher.
6.2 Commitment

Using the Phillips curve together with the targeting rule under commitment (8), the following expressions for the equilibrium inflation and output gap can be obtained:

\[
\pi_t = \frac{\alpha}{\lambda} (1 - b_x) (x_{t-1} - \tau_{t-1}) + q^c \alpha \lambda \varepsilon_t + \theta^c \alpha \lambda w_t \tag{16}
\]

\[
x_t = b_x (x_{t-1} - \tau_{t-1}) + (1 - q^c \lambda^2) \varepsilon_t + (1 - \theta^c \lambda^2) w_t \tag{17}
\]

where \( q^c = (\lambda^2 / (1 - b_x) + \alpha \beta (1 - \rho))^{-1} \) and \( \theta^c = (\lambda^2 / (1 - b_x) + \alpha \beta)^{-1} \).\(^{11}\) Similar to the discretionary case, a positive shock to the target leads to an inflationary real expansion. Again, the monetary authorities respond to the inflationary pressure by increasing the output gap by less than the increase in the output gap target. Under commitment, however, the central bank also pre-commits to keeping the output gap below the target for a prolonged period of time. This intrinsic policy inertia is represented by the lagged differential between the gap and the target in equations (16) and (17). If this commitment is credible, current inflation expectations will be lower than in the discretionary case and thus, improving the short-run trade off between inflation and output.

The immediate inflationary impact of an upward shift in the output gap target is therefore lower under commitment relative to discretion while the opposite is true for its expansionary impact. This can be seen by comparing equations (14) and (15) with equations (16) and (17) noting that \( \theta^c < \theta \) and \( q^c < q \).\(^{12}\) The dashed lines in figures 1(a) and 1(b) show the dynamics of inflation and output gap under commitment when the target is subject to a persistent and a temporary unit shock, respectively. The figures show that the immediate output gap (inflation) response due to a shift in the output target is greater (smaller) under commitment than discretion. Eventually, however, the output gap under commitment is lower than under discretion. Thus, the discounted sum of future output gaps is lower under commitment which mitigates the effect of the shock on inflation expectations.

\(^{11}\) The parameter \( b_x \) is defined as the solution to the quadratic equation \( \alpha \beta b_x^2 = (\alpha (1 + \beta) + \lambda^2) b_x - \alpha \) which is smaller than one.

\(^{12}\) This hold assuming that the discount factor is close enough to unity.
7 Inflation and Output Gap Dynamics under Imperfect Transparency

Under imperfect transparency the public must estimate the persistent and transitory components of the output gap target. The estimation error of the persistent component is no longer zero but follows the autoregressive process described in (13).

7.1 Discretion

By combining the Phillips curve (1) with the optimal targeting rule under discretion (7) and (13), we can derive the following expressions for the equilibrium inflation and output gap under imperfect transparency:

\[
\pi_t = q \alpha \lambda \varepsilon_t + \theta \alpha \lambda w_t - (q - \theta) \alpha \lambda \phi_t \\
x_t = (1 - q \lambda^2) \varepsilon_t + (1 - \theta \lambda^2) w_t + (q - \theta) \lambda^2 \phi_t
\]  

Expressions (18) and (19) show that the only difference between perfect and imperfect transparency is the added estimation error term. Similar to the case of perfect transparency, an increase in the output gap target raises both inflation and output. However, the implied positive correlation between the estimation error, \(\phi_t\), and the persistent component, \(\varepsilon_t\), dampens the inflationary effect of a persistent shock while it amplifies its expansionary impact. On the other hand, the negative correlation between \(\phi_t\) and \(w_t\) dampens the expansionary effect of a temporary shock while it amplifies its inflationary impact.

Figure 2 illustrates the difference between perfect and imperfect transparency. Figure 2(a) shows the dynamics of a one unit shock to the persistent component of the output gap target on inflation and the output gap. The solid lines represent the case of perfect transparency while the dashed line represents the case of imperfect transparency. When the shock is persistent, the inflation level and output gap are persistently above their long-run levels, only to slowly return to their initial values. This is true under both imperfect and perfect transparency. However, under the former, agents assign some weight to the event that the shock is temporary. This leads to a dampened effect on inflation expectations and on the inflationary impact of the shock. In other words, the public underestimates the persistent component, \(\varepsilon_t\), leading to an increase in \(\phi_t\) which has a negative impact on inflation. Lower inflation expectations improve the perceived short-run trade-off between inflation and output, and the central bank can now afford to be more...
expansionary than under perfect transparency. The output gap will therefore increase more in response to a persistent shock under imperfect transparency than under perfect transparency.

Figure 2(b) shows the dynamics of a one unit shock to the temporary component of the output gap target. Under perfect transparency (solid line), the transitory shock does not impact inflation expectations since it quickly dies out. Consequently, inflation and output increase in the first period only to return to long-run values in the following period. Under the case of imperfect transparency (dashed lines), the public puts some weight on the event that the shock to the output gap target is persistent and hence, adjusts their inflation expectations upward. Inflation, therefore, responds more forcefully under imperfect transparency. The increase in inflation expectations also makes it more costly to raise current output compared to the case of perfect transparency. Thus, monetary policy is less expansionary under imperfect than perfect transparency when the shock to the output target is transitory.

The effect on the unconditional variability of inflation and output gap is not immediately apparent from figure 2. Imperfect transparency reduces inflation volatility and increases output gap variability with respect to persistent shocks, but it has the opposite effect with respect to transitory shocks. Recall, however, that under perfect transparency, a persistent shock has a greater impact on inflation than a temporary shock while a temporary shock has a greater impact on output than a persistent shock. Imperfect transparency thus smooths these tendencies and stabilizes expectations. Both inflation and output gap volatility must therefore be lower under imperfect transparency. As shown in Appendix D, the difference between inflation and output gap volatility under imperfect transparency (IT) and perfect transparency (PT) can be derived as:

\[
\sigma_{\pi,IT}^2 - \sigma_{\pi,PT}^2 = -(q - \theta)^2 \alpha^2 \lambda^2 K \sigma_w^2
\]

\[
\sigma_{x,IT}^2 - \sigma_{x,PT}^2 = -(q - \theta)^2 \lambda^4 K \sigma_w^2
\]

**Result 1:** When the central bank’s output gap target is subject to persistent and temporary shifts and optimal monetary policy is discretionary in nature, imperfect transparency reduces inflation and output gap variability.

The welfare implications of imperfect transparency are thus straightforward. Since both inflation and output gap volatility decreases, it must be true that overall welfare is improved. Throughout the paper, when evaluating the welfare effects of transparency, I will assume that the
discount factor is equal to unity. This does not only make the calculation more manageable, but is also probably a good approximation when time period intervals are short.\textsuperscript{13} Under this assumption, the welfare function defined by (3) is simply the weighted sum of the unconditional inflation and output gap volatility.

\textbf{Result 2:} When the central bank’s output gap target is subject to persistent and temporary shifts and optimal monetary policy is discretionary in nature, imperfect transparency improves overall welfare. The welfare improvement can be derived as:

\[
W_{IT} - W_{PT} = \frac{1}{2} \frac{(q - \theta)}{\theta} \lambda^2 \alpha K \sigma_w^2
\]  

(22)

The above analysis indicates that imperfect transparency can potentially protect the central bank from undesirable outcomes due to political pressure. By not revealing the future course of monetary policy, the central bank can hide the true nature of the government’s influence. The lack of transparency causes inflation expectations to rise when the perceived trade-off between inflation and output is low (i.e., when the shock is transitory) increasing the cost of giving in to political pressure in terms of increased inflationary pressure. On the other hand, it causes inflation expectations to fall when the trade-off is high (i.e., when the shock is persistent) making it less costly to give in to political pressure. The smoothing effect that imperfect transparency has on inflation expectations lowers the average impact of political pressure and thus, increases welfare.

Alternatively, imperfect transparency can be beneficial when the central bank is uncertain about its estimate of potential output. If the central bank publishes its projection of potential output, then persistent measurement errors induce large movements in inflation expectations while temporary errors have no impact on inflation expectations. This means that the central bank will be more (less) aggressive in pursuing its estimate of potential output in the case of a temporary (persistent) measurement error. On the other hand, if the central bank is secretive about its projections, inflation expectations will be less volatile and will smooth the central bank’s aggressiveness to close a mis-measured output gap, thereby reducing inflation and output volatility and increasing welfare. At first, this interpretation seems to hinge on the assumption that the public knows the true level of potential output. However, as appendix A shows, this result holds even under a more general scenario where the public also has imperfect information about the potential output level.

\textsuperscript{13}Note that as the discount factor gets closer to zero, the state-contingent action plan converges to the discretionary case. Assuming $\beta = 1$ also eliminates the long-run trade off between inflation and output gap that the Phillips curve otherwise gives rise to.
What matters is the relative measurement error of potential output between the central bank and the public.\textsuperscript{14}

7.2 Commitment

Under commitment, the monetary authorities no longer take expectations as given when setting optimal policy. Instead, they try to manipulate expectations in order to achieve a more favorable short-run trade-off between inflation and output. The equilibrium inflation and output gap under commitment and imperfect transparency can be derived as:

\[ \pi_t = \frac{\alpha}{\lambda} (1 - b_x) (x_{t-1} - \tau_{t-1}) + q^c \alpha \lambda \varepsilon_t + \theta^c \alpha \lambda w_t - (q^c - \theta^c) \alpha \lambda \phi_t \] (23)

\[ x_t = b_x (x_{t-1} - \tau_{t-1}) + (1 - q^c \lambda^2) \varepsilon_t + (1 - \theta^c \lambda^2) w_t + (q^c - \theta^c) \lambda^2 \phi_t \] (24)

Again, the difference between perfect and imperfect transparency is the added estimation error term. In contrast to discretion, however, the estimation error will now not only be correlated with the components of the current output gap target, but it will also affect inflation and output dynamics through the policy inertia that is introduced under commitment.

Figure 3 shows the effects of a unit shock to the persistent and temporary components of the target under perfect and imperfect transparency. Similar to the discretionary case, figure 3(a) shows that a persistent shock to the target has a greater (smaller) immediate impact on the output gap (inflation) under imperfect transparency. However, in subsequent periods both inflation and the output gap tend to be higher under imperfect transparency. As figure 3(b) indicates, the exact opposite seems to be true of a positive temporary shock. Consequently, the overall effect of imperfect transparency on the unconditional inflation/output volatility appears to be ambiguous.

Indeed, equations (23) and (24) indicate that imperfect transparency has two opposing effects on both inflation and output volatility. To see this, first recall that a persistent shock to the target has a greater immediate impact on inflation than a temporary shock while the reverse is true for the output gap (i.e., \( q^c > \theta^c \)). This is because inflation expectations increase by more when the shock to the target is persistent as opposed to transitory. Thus, just as in the case of discretion, imperfect transparency should have a smoothing effect on inflation expectations and reduce inflation and output gap variability.

\textsuperscript{14}Furthermore, expression (22) indicates that (i) a high relative weight on output gap volatility in the welfare function (i.e., a high \( \alpha \)), implies greater welfare benefits from imperfect transparency and (ii) a high degree of prices stickiness, i.e., a low value of \( \lambda \) implies lower welfare benefits from imperfect transparency under discretion.
The second effect of imperfect transparency arises because of policy inertia. The inertial policy response to a shock always amplifies the consequences of a persistent shift in the target relative to that of a temporary shift. Consequently, we only need to examine how imperfect transparency affects the interaction between policy inertia and the persistent component of the output gap target. Since an increase in the target never leads to an equal increase in the output gap, due to the increased inflationary pressure, the covariance between $\varepsilon_t$ and $x_{t-1} - \tau_{t-1}$ must be negative. This negative correlation has mitigating impact on inflation and output volatility. Under imperfect transparency, however, the inflationary pressure is lower and the central bank is able to push the output gap closer to the target. This decreases the negative covariance between $\varepsilon_t$ and $x_{t-1} - \tau_{t-1}$, increasing inflation and output gap volatility. In other words, under imperfect transparency, a persistent shift in the target causes a larger output gap response which is prolonged by the intrinsic inertia in policy. This has a destabilizing effect on inflation expectations resulting in an increase in the variability of inflation and output gap.

Consequently, the overall impact of imperfect transparency on inflation and output gap variability is ambiguous. It depends on which of the two opposing effects is greater. In fact, inflation volatility is more likely to increase under imperfect transparency if $\rho$ is high, while the opposite is true for output gap volatility. Appendix E derives the following expressions for the change in inflation and output gap volatility under commitment:

\[
\sigma_{\pi, IT}^2 - \sigma_{\pi, PT}^2 = 2\left(\theta^c - \frac{1 - \rho}{1 - \rho b_x}q^c\right)\left(\frac{q^c - \theta^c}{1 + b_x}\right)\alpha^2 \lambda^2 K \sigma_w^2
\]

\[
\sigma_{x, IT}^2 - \sigma_{x, PT}^2 = 2\left(\rho b_x \frac{1 - q^c \lambda^2 - b_x^2}{1 - \rho b_x}\right) - (q^c - \theta^c) \lambda^2 \left(\frac{q^c - \theta^c}{1 + b_x^2}\right)\lambda^2 K \sigma_w^2
\]

Some algebraic manipulation delivers the following condition under which imperfect transparency increases inflation variability:

\[
\rho > 1 - \frac{\lambda^2}{\alpha \beta b_x}
\]

Similarly, equation (26) implies that overall output volatility increases under imperfect transparency.

---

15The reason for this is partly because an increase in $\rho$ causes a shock to the target to have a greater impact on inflation expectations and thus, on inflation. Of course, a greater immediate impact on inflation discourages the central bank from expanding (or contracting) economic activity, producing a muted output gap response to the shock. Imperfect transparency thus causes a relatively greater reversal for this immediate impact when $\rho$ is high. The relatively greater increase in the output gap combined with the intrinsic policy inertia raises the persistence level in inflation and therefore, its unconditional volatility.
if the following condition holds:

$$\rho < \frac{\beta \lambda^2 - 2b_x (1 - \beta) \left( \alpha \beta (1 - b_x) + \lambda^2 \right)}{b_x \lambda^2 - 2b_x (1 - b_x) \left( \alpha \beta (1 - b_x) + \lambda^2 \right)}$$  \hspace{1cm} (28)$$

Indeed, as long as the discount factor, $\beta$, is greater than $b_x$, the right hand of expression (28) is always greater than one. That is, output gap volatility most likely increases under imperfect transparency.

**Result 3:** When the central bank’s output gap target is subject to persistent and temporary shifts and optimal monetary policy is characterized by commitment, then imperfect transparency has an ambiguous effect on inflation and output gap variability. Inflation volatility increases under imperfect transparency if condition (27) holds and increases output volatility if condition (28) holds.

Since the effect of imperfect transparency on inflation and output gap volatility is ambiguous, the welfare implication is less straightforward. However, assuming that the discount factor is equal to one, the welfare differential between perfect and imperfect transparency can be derived as:

$$W_{IT} - W_{PT} = -\frac{1}{2} \left( 2\rho b_x^2 + (1 - \rho b_x) \left( \frac{q^c - \theta^c}{1 - b_x} \right) \left( \frac{1}{1 - \rho b_x} \right) \left( \frac{q^c - \theta^c}{1 + b_x} \right) \alpha \lambda^2 K \sigma_w^2 \right)$$  \hspace{1cm} (29)$$

Expression (29) shows that imperfect transparency always reduces welfare under commitment. At first, this might seem to be an obvious result since introducing imperfect transparency simply adds an extra constraint to the optimization problem. However, as McCallum and Jensen (2002), point out, the "timeless perspective" approach represented by equation (5) is not generally optimal.\(^{16}\) Hence, it is necessary to establish that imperfect transparency cannot improve welfare under commitment. Furthermore, equation (29) ensures that inflation and output gap variability can never both decrease under imperfect transparency. Thus, we have the following result.

**Result 4:** When the central bank’s output gap target is subject to persistent and temporary shifts and optimal monetary policy is characterized by commitment, then imperfect transparency reduces overall welfare.

This suggests that a central bank that uses commitment in order to manipulate expectations should commit to full transparency and reveal intended future policy actions. By doing

\(^{16}\)It is obviously not optimal conditioned on the initial period. However, Jensen (2001) also shows that it is not optimal within the class of rules of the same form.
so, the monetary authorities allow expectations to immediately adjust and accurately reflect any measurement errors in potential output or political influence over monetary policy. The central bank can then effectively deal with any inflationary or deflationary impact that these unwanted shifts in the output target may give rise to.\textsuperscript{17}

8 Sensitivity Analysis

Although the results presented above indicate that imperfect transparency improves welfare under discretion and deteriorate welfare under commitment, it may be of interest to evaluate the magnitude of these effects. Tables 1-4 show the effects of imperfect transparency on inflation and output gap variability as well as on welfare for a variety of parameter settings. The basic parameter values used for the simulations are in line with estimates taken from the empirical literature on the New-Keynesian Phillips curve (e.g., MacCullum and Nelson, 2004). The tables confirm that, under discretion, imperfect transparency decreases inflation and output gap volatility and thus, increases welfare. Under commitment, on the other hand, imperfect transparency increases output gap volatility but has an ambiguous effect on inflation variability (see table 1). Welfare, however, always decreases.

Table 1(a) displays the effects of changes in the persistence measure $\rho$. Not surprisingly, the welfare improvements of imperfect transparency under discretion increase with $\rho$. Indeed, imperfect transparency increases welfare by over 10% when $\rho = 0.9$ while only by 2% when $\rho = 0.5$. Thus, the more persistent the shifts in the output gap target, the lower is the incentive for the central bank to increase policy transparency. Table 1(b) shows that the opposite is true under commitment. Also, consistent with the theoretical results in section 7, imperfect transparency lowers inflation volatility when persistence is low ($\rho = 0.5$ and $\rho = 0.75$) but increases inflation variability when it is high ($\rho = 0.9$). Table 2 illustrates the effects of changes in the relative variance of the shock to the persistent and temporary components. As $\psi$ increases (due to an increase in $\sigma_\eta^2$), the welfare effects of imperfect transparency tend to decline under discretion (from 13.75% down to 8.32%) while they stay fairly constant under commitment.

\textsuperscript{17}Appendix A shows that this conclusion changes if both the public and the central bank have to learn about shifts in potential output. If the problem is perfectly symmetric, i.e., the signals received by the public and the central bank regarding the level of potential output are of equal quality, then transparency is likely to have no welfare effects under commitment. However, it is never the case that imperfect transparency is welfare improving when the the central bank operates under commitment.
Table 3 illustrates the sensitivity of the welfare effect of imperfect transparency to the slope of the Phillips curve, $\lambda$. As the level of price flexibility increases, the Phillips curve becomes steeper and the welfare effects of imperfect transparency are magnified under both discretion and commitment. This is due to the fact that current shifts in the output gap target now become even more important to inflation dynamics. Finally, table 4 shows the sensitivity of the theoretical results with respect to the relative weight on the output gap objective in the welfare function, $\alpha$. The more the public cares about output volatility relative to inflation volatility, the greater are the welfare effects of imperfect transparency under discretion. The welfare effects due to an increase in $\alpha$ under commitment appear to be small and non-monotonic.

A couple of interesting conclusions can be drawn from these simulations. First, a central bank that operates under discretion is going to be more opposed to transparency the more persistent the political pressure (or measurement errors) and the more the public cares about output fluctuations relative to inflation variability. Second, imperfect transparency tends to increase welfare by more under discretion than it decreases welfare under commitment. Indeed, while the welfare improvements under discretion vary between 1.48% to as much as 13.74%, the reductions in welfare under commitment lie between 0.73% and 6.89%.

9 Conclusion

The New Keynesian framework emphasizes the role of forward-looking rational expectations in the price setting behavior of firms. The future expected course of monetary policy can therefore be an important influence on current economic conditions. Since policy transparency improves the predictability of future monetary policy it plays an important part in the design of a comprehensive monetary policy strategy. In this paper, I examine the impact of imperfect transparency on inflation and output gap variability when undesirable shifts (from a welfare perspective) in the central bank’s output gap target occur. These shifts can be motivated either by imperfect information about potential output or as a result of political pressure. A positive persistent shock to the target expands the economy and increases the inflationary pressure by raising inflation expectations. The increase in inflation expectations worsens the short-run trade-off between inflation and output. A temporary shock to the target has no effect on inflation expectations and thus, does not affect the short-run trade-off between inflation and output. Consequently, a persistent shock is relatively more inflationary than a temporary shock while a transitory shock is relatively more expansionary.
than a persistent shock.

I show that imperfect transparency mitigates the impact on inflation expectations in response to a persistent shock (reducing the inflationary pressure) while it amplifies the impact on inflation expectations in response to a transitory shock (reducing its expansionary/contractionary impact). This causes an overall reduction in inflation and output gap variability and raises welfare. However, when policy displays inertia (i.e., the central bank pre-commits to only gradually bringing output back in line with its potential level even after the shock has dissipated), the impact of a persistent shock is amplified relative to the impact of a temporary shock. Since imperfect transparency causes a persistent shock to have a greater impact on the output gap, it tends to have a destabilizing effect on inflation expectations which may lead to both an increase in inflation and output gap variability. Indeed, I show that welfare is always reduced under imperfect transparency and commitment. Thus, the desirability of perfect transparency depends on whether optimal monetary policy is characterized by discretion or commitment. If the latter is an accurate depiction of inflation targeting, as argued by Giannoni and Woodford (2003), the above analysis might shed some light on why inflation targeting central banks promote a higher degree of policy transparency.

References


Appendices

A Measurement Errors and Potential Output

This appendix introduces a model of partial information regarding potential output. In the set-up, the central bank and the public receive noisy signals about productivity shocks and must assess whether these shocks are temporary or persistent. I assume that the central bank receives different signals than the public. This assures that there are persistent differences in the central bank’s and the public’s opinions about the level of potential output. Although the signals are different they are assumed to be of the same quality. Importantly, the signals that the central bank and the public receive are assumed to be independent of current and past values of output and inflation. Thus, since no endogenous indicators are used in estimating potential output and productivity shocks are assumed to be exogenous, the certainty equivalence and the separation principle hold.

A.1 The Central Bank’s Estimate of the Output Gap

The output gap, \( x_t \), is equal to the difference between the output, \( y_t \), and its potential level, \( \tilde{y}_t \), i.e.,

\[
x_t = y_t - \tilde{y}_t
\]  

(A.1)

Assume that potential output can be decomposed into two components:

\[
\tilde{y}_t = a_{pt} + a_{Tt}
\]  

(A.2)

\[
a_{pt} = \kappa a_{pt-1} + v_t
\]  

(A.3)

where \( a_{pt} \) and \( a_{Tt} \) represent persistent and temporary productivity shocks. Suppose the central bank cannot observe either of these two components directly, but that it receive noisy signals from the data. Let \( s_{pt}^{cb} \) and \( s_{Tt}^{cb} \) be the signals that the central bank receives for the persistent and temporary components, respectively i.e.,

\[
s_{pt}^{cb} = a_{pt} + \chi_{t}^{cb}
\]  

(A.4)

\[
s_{Tt}^{cb} = a_{Tt} + w_t^{cb}
\]  

(A.5)

where \( \chi_{t}^{cb} \) and \( w_t^{cb} \) are independent random variables with fixed variances and means of zero. Using the Kalman filter approach, the optimal estimate of the persistent component \( a_p \) at time \( t \) is:

\[
E_t^{cb} a_{pt} = E_{t-1}^{cb} a_{pt} + G \left( s_{pt}^{cb} - E_{t-1}^{cp} s_{pt}^{cb} \right)
\]  

(A.6)
where $G$ is the constant gain coefficient. Let $\varepsilon_t^{cb}$ be the central bank’s measurement error of the persistent component defined as $\varepsilon_t^{cb} = E_t^{cb} a_{pt} - a_{pt}$. Using (A.6), it is straightforward to show that the measurement error of the persistent component follows the following AR(1) process:

$$\varepsilon_t^{cb} = \rho \varepsilon_t^{cb} + \eta_t^{cb} \tag{A.7}$$

where $\eta_t^{cb} = G \chi_t^{cb} - (1 - G) v_t$ and $\rho = (1 - G) \kappa$. The measurement error for the temporary component, $E_t^{cb} a_{Tt} - a_{Tt}$, is simply equal to $w_t^{cb}$. The measurement error of potential output, denoted by $\tau_t^{cb}$, is thus equal to:

$$\tau_t^{cb} = \gamma_t^{cb} = \gamma_t = \left( E_t^{cb} a_{pt} - a_{pt} \right) + \left( E_t^{cb} a_{Tt} - a_{Tt} \right) = \varepsilon_t^{cb} + w_t^{cb} \tag{A.8}$$

The central bank’s estimated output gap can then be written as:

$$x_t^{cb} = y_t - \hat{y}_t = x_t - \tau_t^{cb} \tag{A.9}$$

### A.2 Public’s Estimate of the Output Gap

Suppose that private agents in the economy are facing a similar problem in terms of estimating potential output, but that they receive different signals. Thus, the set up is almost identical to the central bank:

$$s_{pt}^p = a_{pt} + \chi_t^p \tag{A.10}$$

$$s_{Tt}^p = a_{Tt} + w_t^p \tag{A.11}$$

The noise variables $\chi_t^p$ and $w_t^p$ are independent from $\chi_t^{cb}$ and $w_t^{cb}$, but they have the same mean and variance. That is, the quality of the signals facing the private sector and the central bank is the same. Thus, in a similar fashion to the bank’s problem, the measurement error of the public’s estimate of potential output can be described by the following system of equations:

$$\tau_t^p = \gamma_t^p - \hat{y}_t = \varepsilon_t^p + w_t^p \tag{A.12}$$

$$\varepsilon_t^p = \rho \varepsilon_t^p + \eta_t^p \tag{A.13}$$

$$\eta_t^p = G \chi_t^p - (1 - G) v_t \tag{A.14}$$
The public can directly observe the policy instrument $y_t$. Thus, the public’s estimated output gap can then be written as

$$x_t^p = y_t - \hat{y}_t^p = x_t - \tau_t^p$$  \hspace{1cm} (A.15)

Notice that in the short-run there may be persistent deviations between the market’s and the central bank’s expectations about future output gap dynamics. These differences are due to the exogenous noise variables. Hence, it is assumed that the central bank relies on its own estimate of potential output when setting monetary policy while the firms rely on their own estimate when setting prices. Thus, neither the central bank nor the public uses each others estimates to improve their estimations of the productivity shock. I avoid such complications since I am only interested in creating a wedge between the public’s and the central bank’s belief about the true nature of the economy.

A.3 Firms’ Price Setting Behavior

The aggregate supply curve under imperfect information regarding potential output can be written as:

$$\pi_t = \lambda (y_t - \hat{y}_t^p) + \beta E_t \pi_{t+1}$$  \hspace{1cm} (A.16)

This price setting rule reflects both the public’s own estimate of current and future potential output levels (through $\hat{y}_t^p$) and the central bank’s estimate of current and future potential output levels (through its effect on the policy instrument $y$).

A.4 Targeting Rules under Discretion and Commitment

Since the certainty equivalence principle holds, the targeting rules under discretion and the timeless perspective can be derived as:

$$x_t^{cb} = -\frac{\lambda}{\alpha} \pi_t$$  \hspace{1cm} (A.17)

and

$$x_t^{cb} = x_{t-1}^{cb} - \frac{\lambda}{\alpha} \pi_t$$  \hspace{1cm} (A.18)

The central bank responds to the private sector’s estimate of the output gap as far as it affects inflation. There is nothing the monetary authorities can do to affect the difference in opinions over the output gap, since the difference is exogenously determined by the noise variables.
A.5 Imperfect Transparency

When the central bank does not disclose its projected path of potential output, the public have to form beliefs about the bank’s estimates. Since the public believe that its estimate of the output gap, $x_t^p$, is correct, they treat the realized difference between $x_t^p$ and $x_t^{cb}$ as the central bank’s measurement error of potential output (i.e., $E_t^p \tau_t^{cb} = x_t^p - x_t^{cb}$). For example, if $x_t^p < x_t^{cb}$, then $\tilde{y}_t^{cb} < \tilde{y}_t^p$ (given $y_t$). That is, the firms believe that the monetary authorities’ estimate of potential output is too low. Since price setting today also depends on future expected monetary policy, the market would like to know whether this difference of “opinion” is going to be persistent or not. The problem is that this is hard to figure out if the central bank does not disclose its projected output gap estimate (which in turn of course reveals its future policy actions). Hence, the public has to try to estimate the path of the central bank’s future measurement errors.

Let $\tau_t$ be the difference between the government’s and the public’s measurement error of potential output:

$$\tau_t = \tau_t^{cb} - \tau_t^p$$

(A.19)

Note that $\tau_t$ is also equal to the public’s estimate of the central bank’s measurement error of the output gap, i.e., $E_t^p \tau_t^{cb} = x_t^p - x_t^{cb} = \tau_t^{cb} - \tau_t^p$. Also, I adopt the following notation.

$$\varepsilon_t = \varepsilon_t^{cb} - \varepsilon_t^p$$

(A.20)

$$w_t = w_t^{cb} - w_t^p$$

(A.21)

$$\eta_t = \eta_t^{cb} - \eta_t^p = G \left( \chi_t^{cb} - \chi_t^p \right)$$

(A.22)

The public’s estimate of the central bank’s measurement error can thus be described by the following process:

$$\tau_t = \varepsilon_t + w_t$$

(A.23)

$$\varepsilon_t = \rho \varepsilon_{t-1} + \eta_t$$

(A.24)

Note that equations (A.23) and (A.24) correspond to (9) and (10) when the public has full information about potential output, i.e., when $\tau_t^p = 0$.

Since the private agents cannot distinguish between $\varepsilon_t$ or $w_t$, they create an optimal estimate of $\varepsilon_t$, i.e.,

$$E_t^p \varepsilon_t = E_{t-1}^p \varepsilon_t + K \left( \tau_t - E_{t-1}^p \tau_t \right)$$

(A.25)
where $K$ is the constant gain coefficient as defined by (12). Let $\phi_t$ denote the estimation error of $\varepsilon_t$ at time $t$ (i.e., $\phi_t = \varepsilon_t - \mathbb{E}_t^p \varepsilon_t$). Expression (A.25) can then be rewritten in the following manner:

$$\phi_t = (1 - K) (\rho \phi_{t-1} + \eta_t) - Kw_t$$  \hspace{1cm}  (A.26)

### A.6 Derivation of the Constant Gain Coefficient $K$

The estimation error of the persistent component, $\phi_t$, cannot be correlated with the observed output gap target, $\tau_t$, at time $t$. That is,

$$\text{Cov}(\tau_t, \phi_t) = \text{Cov}(\varepsilon_t + w_t, \phi_t) = \text{Cov}(\varepsilon_t, \phi_t) + \text{Cov}(w_t, \phi_t) = 0$$  \hspace{1cm}  (A.27)

First, derive an expression for $\text{Cov}(\varepsilon_t, \phi_t)$ using equation (A.26),

$$\text{Cov}(\varepsilon_t, \phi_t) = \rho^2 (1 - K) \text{Cov}(\varepsilon_{t-1}, \phi_{t-1}) + (1 - K) \sigma_\eta^2$$  \hspace{1cm}  (A.28)

Noting that $\rho^2 (1 - K) < 1$, iterating (A.28) backward gives us:

$$\text{Cov}(\varepsilon_t, \phi_t) = \left[ 1 + \sum_{i=1}^{\infty} (\rho^2 (1 - K))^i \right] (1 - K) \sigma_\eta^2 = \frac{1 - K}{1 - \rho^2 (1 - K)} \sigma_\eta^2$$  \hspace{1cm}  (A.29)

Second, using (A.26), $\text{Cov}(w_t, \phi_t)$ can be derived as:

$$\text{Cov}(w_t, \phi_t) = -K \sigma_w^2$$  \hspace{1cm}  (A.30)

Combining (A.27), (A.29) and (A.30) gives us the following relationship:

$$\frac{1 - K}{1 - \rho^2 (1 - K)} \sigma_\eta^2 = K \sigma_w^2$$  \hspace{1cm}  (A.31)

Solving for $K$ we have:

$$K = \frac{-\Psi - (1 - \rho^2) + \sqrt{(\Psi + (1 - \rho^2))^2 + 4 \rho^2 \Psi}}{2 \rho^2}$$  \hspace{1cm}  (A.32)

where $0 \leq K \leq 1$ and $\Psi = \sigma_\eta^2 / \sigma_w^2$.

### B The Special Case when $\tau^p_t = 0$

Given the set-up in appendix A, we can now derive the results in the main text. Notice that when the public has full information about potential output i.e., $\tau^p_t = 0$ for all $t$, equation (A.16), (A.17), (A.18), (A.23), (A.24) and (A.26) corresponds to (1), (7), (8), (9), (10) and (13).
B.1 Equilibrium Inflation and Output Gap under Discretion

Inserting the targeting rule (7) into the New Keynesian Phillips curve (1) and rearranging the terms we have:

\[
\left(1 + \frac{\lambda^2}{\alpha}\right) (x_t - \tau_t) = \beta E_t^p (x_{t+1} - \tau_{t+1}) - \frac{\lambda^2}{\alpha} \varepsilon_t - \frac{\lambda^2}{\alpha} w_t
\]  

(B.1)

Suppose the solution to this difference equation has the following structure:

\[
(x_t - \tau_t) = c_x \varepsilon_t + d_x w_t + f_x \phi_t
\]  

(B.2)

where \( \phi_t = \varepsilon_t - E_t^p \varepsilon_t \). Since \( E_t^p \phi_{t+1} = 0, E_t^p w_{t+1} = 0 \), and \( E_t^p \varepsilon_{t+1} = \rho E_t^p \varepsilon_t \) we have:

\[
E_t^p (x_{t+1} - \tau_{t+1}) = c_x \rho E_t^p \varepsilon_t = c_x \rho \varepsilon_t - c_x \rho \phi_t
\]  

(B.3)

Substituting (B.3) into (B.1) we get:

\[
\left(1 + \frac{\lambda^2}{\alpha}\right) (x_t - \tau_t) = \beta c_x \rho \varepsilon_t - \frac{\lambda^2}{\alpha} w_t - \beta c_x \rho \phi_t
\]  

(B.4)

By comparing (B.4) and (B.2) we can solve for the coefficients \( c_x, d_x \) and \( f_x \) and get equation (19) in the text. The equilibrium expression for inflation (18) can be derived by inserting (19) into the targeting rule (7).

B.2 Inflation and Output Gap Volatility under Discretion

Applying the variance operator to equation (18) we have the following expression:

\[
\sigma_{\pi,IT}^2 = q^2 \alpha^2 \lambda^2 \frac{1}{1 - \rho^2} \sigma_{\eta}^2 + \theta^2 \alpha^2 \lambda^2 \sigma_w^2 + (q - \theta)^2 \alpha^2 \lambda^2 \sigma_{\phi}^2 - 2\alpha^2 \lambda^2 (q - \theta) q \text{Cov} (\varepsilon_t, \phi_t) - 2\alpha^2 \lambda^2 (q - \theta) \theta \text{Cov} (w_t, \phi_t)
\]  

(B.5)

Under perfect information (PT) i.e., when \( \phi_t = 0 \) we have:

\[
\sigma_{\pi,PT}^2 = q^2 \alpha^2 \lambda^2 \frac{1}{1 - \rho^2} \sigma_{\eta}^2 + \theta^2 \alpha^2 \lambda^2 \sigma_w^2 + (q - \theta)^2 \alpha^2 \lambda^2 \sigma_{\phi}^2
\]  

(B.6)

Subtracting (B.5) from (B.6) and noting that \( \text{Cov} (\varepsilon_t, \phi_t) + \text{Cov} (w_t, \phi_t) = \text{Cov} (\tau_t, \phi_t) = 0 \) we can express \( \sigma_{\pi,IT}^2 - \sigma_{\pi,PT}^2 \) as:

\[
\sigma_{\pi,IT}^2 - \sigma_{\pi,PT}^2 = (q - \theta)^2 \alpha^2 \lambda^2 \left( \sigma_{\phi}^2 + 2 \text{Cov} (w_t, \phi_t) \right)
\]  

(B.7)

From the derivation of the constant gain coefficient we have that \( \sigma_{\phi}^2 + 2 \text{Cov} (w_t, \phi_t) = -K \sigma_w^2 \).

Inserting this expression into (B.7) gives us expression (20). It is straightforward to apply the same methodology in order to get the output gap volatility under perfect and imperfect transparency and derive (21).
B.3 Equilibrium under Commitment

Inserting the optimal targeting rule under commitment i.e., (8) into the New Keynesian Phillips curve (1) and rearranging the terms we have:

\[
1 + \beta + \frac{\lambda^2}{\alpha} (x_t - \tau_t) = \beta E_t^p (x_{t+1} - \tau_{t+1}) + (x_t - \tau_{t-1}) - \frac{\lambda^2}{\alpha} \varepsilon_t - \frac{\lambda^2}{\alpha} w_t \tag{B.8}
\]

Suppose that the solution to this difference equation has the following structure:

\[
(x_t - \tau_t) = b_x (x_{t-1} - \tau_{t-1}) + c_x \varepsilon_t + d_x w_t + f_x \phi_t \tag{B.9}
\]

where \( \phi_t = \varepsilon_t - E_t^p \varepsilon_t \). Since \( E_t^p \phi_{t+1} = 0 \), \( E_t^p w_{t+1} = 0 \), and \( E_t^p E_t^p \phi_t = \rho E_t^p \varepsilon_t \) we have:

\[
E_t^p (x_{t+1} - \tau_{t+1}) = b_x (x_t - \tau_t) + c_x \rho E_t^p \varepsilon_t = b_x (x_t - \tau_t) + c_x \rho \varepsilon_t - c_x \rho \phi_t \tag{B.10}
\]

Substituting (B.9) into (B.10) we get:

\[
E_t^p (x_{t+1} - \tau_{t+1}) = b_x^2 (x_{t-1} - \tau_{t-1}) + (b_x + \rho) c_x \varepsilon_t + b_x d_x w_t + (b_x f_x - c_x \rho) \phi_t \tag{B.11}
\]

Substituting (B.11) back in (B.8) gives us:

\[
\left( 1 + \beta + \frac{\lambda^2}{\alpha} \right) (x_t - \tau_t) = \left( \beta b_x^2 + 1 \right) (x_{t-1} - \tau_{t-1}) + \left( \beta (b_x + \rho) c_x - \frac{\lambda^2}{\alpha} \right) \varepsilon_t \tag{B.12}
\]

Comparing (B.12) and (B.9) we can solve for the coefficients \( b_x, c_x, d_x \) and \( f_x \). After some algebraic simplifications we have equation (24) in the text. Equation (23) is easily derived by using (8).

B.4 Inflation and Output Gap Volatility under Commitment

B.4.1 Inflation Volatility

By applying the variance operator to equation (23), noting that \( Cov(x_{t-1} - \tau_{t-1}, \phi_t) = 0 \) and \( Cov(\varepsilon_t, \phi_t) = -Cov(w_t, \phi_t) \), we have the following expression:

\[
\sigma_{\pi,IT}^2 = (q^c)^2 \alpha^2 \lambda^2 \frac{1}{1 - \rho^2} \sigma_y^2 + (\theta^c)^2 \alpha^2 \lambda^2 \sigma_w^2 + (q^c - \theta^c)^2 \alpha^2 \lambda^2 \left( \sigma_{\phi}^2 + 2Cov(w_t, \phi_t) \right)
+ \frac{\alpha^2}{\lambda^2} (1 - b_x)^2 Var(x_{t-1} - \tau_{t-1})
+ 2\alpha^2 q^c (1 - b_x) Cov(x_{t-1} - \tau_{t-1}, \varepsilon_t) \tag{B.13}
\]
The third term in (B.13) reflects the same benefits of imperfect transparency as under discretion. However, imperfect transparency will also have an effect on inflation volatility through $\Var(x_{t-1} - \tau_{t-1})$ and $\Cov(x_{t-1} - \tau_{t-1}, \varepsilon_t)$. We can derive the following expression for the latter:

$$\Cov(x_{t-1} - \tau_{t-1}, \varepsilon_t) = \frac{\rho}{1 - \rho b_x} \left((q^c - \theta^c)\lambda^2 \Cov(\varepsilon_t, \phi_t) - q^c \lambda^2 \Var(\varepsilon_t)\right) > 0 \quad (B.14)$$

Thus, imperfect transparency increases the covariance between the lagged gap-to-target differential and the persistent component of the target. This is because imperfect transparency has a muted effect on inflation expectations when the output gap target is hit by a persistent shock, the central bank finds it less costly to increase output and push it closer to target. Hence, imperfect transparency reduces the gap-to-target differential relative to perfect transparency. Finally,

$$\Var(x_t - \tau_t) = \frac{1}{1 - b_x^2} (q^c \lambda^2)^2 \Var(\varepsilon_t) + \frac{1}{1 - b_x^2} (\theta^c \lambda^2)^2 \sigma_w^2 \quad (B.15)$$

Expression (B.15) indicates that the volatility of the gap-to-target differential is reduced under imperfect transparency. This is due to the improved ability of the central bank to get closer to the output gap target when the shock is persistent. Given that $\sigma_\phi^2 + 2\Cov(w_t, \phi_t) = -K\sigma_w^2$ and $\Cov(w_t, \phi_t) = -K\sigma_w^2$, we can substituting (B.14) and (B.15) into (B.13) and get:

$$\sigma_{\pi, IT}^2 = \frac{2}{1 + b_x} \left(\frac{1 - \rho}{1 - \rho b_x}\right) (q^c)^2 \alpha^2 \lambda^2 \frac{1}{1 - \rho b_x} \sigma_\eta^2 + 2 \sigma_w^2 \quad (B.16)$$

The change in inflation volatility due to imperfect transparency is represented by the last term in expression (B.16). The last term is positive if:

$$\theta^c - \frac{1 - \rho}{1 - \rho b_x} q^c > 0$$

which is equivalent to:

$$\rho > 1 - \frac{\lambda^2}{\alpha \beta b_x}$$
B.4.2 Output Volatility

By applying the variance operator to equation (24), noting again that $\text{Cov}(x_{t-1} - \tau_{t-1}, \phi_t) = 0$ and $\text{Cov}(\varepsilon_t, \phi_t) = -\text{Cov}(w_t, \phi_t)$, we have the following expression for output gap volatility under imperfect transparency:

$$\sigma^2_{x,IT} = (1 - q^c \lambda^2)^2 \frac{1}{1 - \rho^2} \sigma^2_\eta + (1 - \theta^c \lambda^2)^2 \sigma^2_w$$

$$+ (q^c - \theta^c)^2 \alpha^2 \lambda^2 \left( \sigma^2_\phi + 2 \text{Cov}(w_t, \phi_t) \right)$$

$$+ b_x^2 \text{Var}(x_{t-1} - \tau_{t-1})$$

$$+ 2b_x \left( 1 - q^c \lambda^2 \right) \text{Cov}(x_{t-1} - \tau_{t-1}, \varepsilon_t)$$

Again the third term in (B.17) reflects the same benefits from imperfect transparency as under discretion. However, imperfect transparency will also have an effect on output volatility through $\text{Var}(x_{t-1} - \tau_{t-1})$ and $\text{Cov}(x_{t-1} - \tau_{t-1}, \varepsilon_t)$. Using (B.13) and (B.14), we can derive expression (26) in the main text. Expression (26) is positive if

$$2 \left( \frac{\rho b_x}{1 - \rho b_x} \right) \left( 1 - q^c \lambda^2 - b_x^2 \right) - (q^c - \theta^c) \lambda^2 > 0$$

which is equivalent to:

$$\rho < \frac{\beta \lambda^2 - 2b_x (1 - \beta) (\alpha \beta (1 - b_x) + \lambda^2)}{b_x \lambda^2 - 2b_x (1 - b_x) (\alpha \beta (1 - b_x) + \lambda^2)}$$

C The General Case

Let us now consider the more general case in which both the central bank and the public estimate potential output.

C.1 Discretion

Using the targeting rule under discretion (A.17) together with (A.16) we can derive the following equilibrium expressions for inflation and the output gap:

$$\pi_t = q\alpha \lambda \varepsilon_t + \theta \alpha \lambda w_t - (q - \theta) \alpha \lambda \phi_t$$

(C.1)

$$x_t = \tau^{cb}_t - q \lambda^2 \varepsilon_t - \theta \lambda^2 w_t + (q - \theta) \lambda^2 \phi_t$$

(C.2)

where $q = (\lambda^2 + \alpha (1 - \beta \rho))^{-1}$ and $\theta = (\lambda^2 + \alpha)^{-1}$. The only difference between these two equations and (18) and (19) is that we have $\tau^{cb}_t$ instead of $\tau_t$ in the equation (C.2). However, it can be
shown that $\text{Cov}(\tau_t^b, \phi_t) = 0$. Thus equation (20) and (21) still hold true. That is, under discretion, imperfect transparency reduces both inflation and output gap variability. It follows that welfare must also increase.

**C.2 Commitment**

Using the targeting rule under commitment (A.18) together with (A.16) we can derive the following equilibrium expressions for inflation and the output gap:

\[
\pi_t = \frac{\alpha}{\lambda} (1 - b_x) \left( x_{t-1} - \tau_{t-1}^{cb} \right) + q^c \alpha \lambda \varepsilon_t + \theta^c \alpha \lambda w_t - (q^c - \theta^c) \alpha \lambda \phi_t \tag{C.3}
\]

\[
x_t = \tau_{t-1}^{cb} + b_x \left( x_{t-1} - \tau_{t-1}^{cb} \right) - q^c \lambda^2 \varepsilon_t - \theta^c \lambda^2 w_t + (q^c - \theta^c) \lambda^2 \phi_t \tag{C.4}
\]

where $q^c = (\lambda^2 / (1 - b_x) + \alpha \beta (1 - \rho))^{-1}$ and $\theta^c = (\lambda^2 / (1 - b_x) + \alpha \beta)^{-1}$. Applying the variance operator to expressions (C.3) it is possible to derive the same expression as equation (25). However, the expression for the change in output gap volatility differs from that of (26). In fact it can be derived as:

\[
\sigma_{x,IT}^2 - \sigma_{x,PT}^2 = \left( \left( \frac{\rho b_x}{1 - \rho b_x} \right) (1 - 2q^c \lambda^2 - b_x^2) - (q^c - \theta^c) \lambda^2 \right) \left( \frac{q^c - \theta^c}{1 + b_x^2} \right) \lambda^2 K \sigma_w^2 \tag{C.5}
\]

The condition for output volatility to increase is thus different from (28) and can be derived as:

\[
\rho < \frac{\alpha \beta \lambda^2 - b_x (\alpha \beta (1 + b_x) + \lambda^2) (\alpha \beta (1 - b_x) + \lambda^2)}{b_x \alpha \beta \lambda^2 - b_x \alpha \beta (1 + b_x) (\alpha \beta (1 - b_x) + \lambda^2)} \tag{C.6}
\]

Finally, assuming a discount factor of one, the change in the welfare level due to imperfect transparency can be obtained as:

\[
W_{IT} - W_{PT} = -\frac{1}{2} \left( 1 - \rho b_x \right) \left( \frac{q^c - \theta^c}{1 - b_x} \right) \left( \frac{1}{1 - \rho b_x} \right) \left( \frac{q^c - \theta^c}{1 + b_x} \right) \alpha \lambda^2 K \sigma_w^2 \tag{C.7}
\]

However, knowing that $b_x$ is the solution to the quadratic equation $\alpha b_x^2 = (2\alpha + \lambda^2) b_x - \alpha$, it can be shown that:

\[
(1 - \rho b_x) \left( \frac{q^c - \theta^c}{1 - b_x} \right) \lambda^2 \rho b_x (1 - b_x) \tag{C.8}
\]

This indicates that there is no welfare effect (loss or gain) of imperfect transparency under commitment when both the public and the central bank have to estimate the true level of potential output.
Table 1(a): Discretion and Variations in $\rho$

<table>
<thead>
<tr>
<th>Value of $\rho$</th>
<th>0.5</th>
<th>0.75</th>
<th>0.9</th>
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<tbody>
<tr>
<td><strong>Perfect Transparency (PT)</strong></td>
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<td></td>
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<tr>
<td>Inflation Volatility (std)</td>
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<tr>
<td>Output Gap Volatility (std)</td>
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<td>1.064</td>
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<tr>
<td>Welfare Level ($\times 10^3$)</td>
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<td>-7.421</td>
<td>-23.37</td>
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<td><strong>Imperfect Transparency (IT)</strong></td>
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</tr>
<tr>
<td>Inflation Volatility (std)</td>
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<td>0.255</td>
<td>0.596</td>
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<tr>
<td>Output Gap Volatility (std)</td>
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<td>Welfare Level ($\times 10^3$)</td>
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<td>-20.96</td>
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<td><strong>Difference (IT-PT) ($\times 10^3$)</strong></td>
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<tr>
<td>Inflation Volatility (std)</td>
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<td>Change in Welfare (%)</td>
<td>1.979%</td>
<td>8.26%</td>
<td>10.32%</td>
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Table 1(b): Commitment and Variations in $\rho$

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<tbody>
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<td><strong>Perfect Transparency (PT)</strong></td>
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<tr>
<td>Inflation Volatility (std)</td>
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<td>0.134</td>
<td>0.169</td>
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<td>Output Gap Volatility (std)</td>
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<td>Welfare Level ($\times 10^3$)</td>
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<td>-5.349</td>
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<td><strong>Imperfect Transparency (IT)</strong></td>
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<tr>
<td>Inflation Volatility (std)</td>
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<td>0.173</td>
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<td>Output Gap Volatility (std)</td>
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<td>1.163</td>
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<td>Welfare Level ($\times 10^3$)</td>
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<tr>
<td>Inflation Volatility (std)</td>
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<td>Output Gap Volatility (std)</td>
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<td>Change in Welfare (%)</td>
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<td>-3.07%</td>
<td>-6.89%</td>
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1 The parameterization is as follows $\lambda = 0.1$, $\sigma_\eta^2 = 0.5$, $\sigma_w^2 = 1$, $\alpha = 0.0625$, $\beta = 1$
Table 2(a): Discretion and Variations in $\sigma^2_{\eta}/\sigma^2_{\varepsilon}$

<table>
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<th>Value of $\sigma^2_{\eta}/\sigma^2_{\varepsilon}$</th>
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<td>Inflation Volatility (std)</td>
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<td>-33.72</td>
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<td>Inflation Volatility (std)</td>
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<td>Inflation Volatility (std)</td>
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Table 2(b): Commitment and Variations in $\sigma^2_{\eta}/\sigma^2_{\varepsilon}$

<table>
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<th>0.5</th>
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<tr>
<td>Inflation Volatility (std)</td>
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1 The parameterization is as follows $\lambda = 0.1$, $\alpha = 0.0625$, $\sigma_{\omega}^2 = 1$, $\rho = 0.9$, $\beta = 1$
### Table 3(a): Discretion and Variations in $\lambda$

<table>
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<td>Inflation Volatility (std)</td>
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<td>Inflation Volatility (std)</td>
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<td>10.33%</td>
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### Table 3(b): Commitment and Variations in $\lambda$

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<th>0.1</th>
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<td><strong>Perfect Transparency (PT)</strong></td>
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<tr>
<td>Inflation Volatility (std)</td>
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<td>-10.65</td>
<td>-7.348</td>
<td>-5.349</td>
</tr>
<tr>
<td><strong>Imperfect Transparency (IT)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation Volatility (std)</td>
<td>0.094</td>
<td>0.166</td>
<td>0.173</td>
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<tr>
<td>Output Gap Volatility (std)</td>
<td>1.816</td>
<td>1.427</td>
<td>1.163</td>
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<tr>
<td>Welfare Level ($\times 10^3$)</td>
<td>-10.74</td>
<td>-7.252</td>
<td>-5.717</td>
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<tr>
<td><strong>Difference (IT-PT) ($\times 10^3$)</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Inflation Volatility (std)</td>
<td>-6.459</td>
<td>-3.229</td>
<td>4.074</td>
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<tr>
<td>Output Gap Volatility (std)</td>
<td>13.68</td>
<td>49.16</td>
<td>41.87</td>
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<tr>
<td>Welfare Level</td>
<td>-0.092</td>
<td>-0.376</td>
<td>-0.368</td>
</tr>
<tr>
<td>Change in Welfare (%)</td>
<td>-0.86%</td>
<td>-5.12%</td>
<td>-6.89%</td>
</tr>
</tbody>
</table>

---

1 The parameterization is as follows $\alpha = 0.0625$, $\sigma_n^2 = 0.5$, $\sigma_w^2 = 1$, $\rho = 0.9$, $\beta = 1$
Table 4(a): Discretion and Variations in $\alpha$ \(^1\)

<table>
<thead>
<tr>
<th></th>
<th>Value of $\alpha$</th>
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<tbody>
<tr>
<td></td>
<td>0.01</td>
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<tr>
<td><strong>Perfect Transparency (PT)</strong></td>
<td></td>
</tr>
<tr>
<td>Inflation Volatility (std)</td>
<td>0.156</td>
</tr>
<tr>
<td>Output Gap Volatility (std)</td>
<td>0.521</td>
</tr>
<tr>
<td>Welfare Level ($\times 10^3$)</td>
<td>-1.348</td>
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<tr>
<td><strong>Imperfect Transparency (IT)</strong></td>
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<tr>
<td>Inflation Volatility (std)</td>
<td>0.153</td>
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<tr>
<td>Output Gap Volatility (std)</td>
<td>0.440</td>
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<tr>
<td>Welfare Level ($\times 10^3$)</td>
<td>-1.270</td>
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<tr>
<td><strong>Difference (IT-PT) ($\times 10^3$)</strong></td>
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<tr>
<td>Inflation Volatility (std)</td>
<td>-2.534</td>
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<tr>
<td>Output Gap Volatility (std)</td>
<td>-81.45</td>
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<tr>
<td>Welfare Level</td>
<td>0.078</td>
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<td>Change in Welfare (%)</td>
<td>5.807%</td>
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Table 4(b): Commitment and Variations in $\alpha$

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<tr>
<td></td>
<td>0.01</td>
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<tr>
<td><strong>Perfect Transparency (PT)</strong></td>
<td></td>
</tr>
<tr>
<td>Inflation Volatility (std)</td>
<td>0.064</td>
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<td>Output Gap Volatility (std)</td>
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<tr>
<td>Welfare Level ($\times 10^3$)</td>
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<tr>
<td><strong>Imperfect Transparency (IT)</strong></td>
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<tr>
<td>Inflation Volatility (std)</td>
<td>0.067</td>
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<tr>
<td>Output Gap Volatility (std)</td>
<td>0.719</td>
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<tr>
<td>Welfare Level ($\times 10^3$)</td>
<td>-0.482</td>
</tr>
<tr>
<td><strong>Difference (IT-PT) ($\times 10^3$)</strong></td>
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<tr>
<td>Inflation Volatility (std)</td>
<td>3.038</td>
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<tr>
<td>Output Gap Volatility (std)</td>
<td>6.501</td>
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<tr>
<td>Welfare Level</td>
<td>-0.024</td>
</tr>
<tr>
<td>Change in Welfare (%)</td>
<td>-5.35%</td>
</tr>
</tbody>
</table>

\(^1\) The parameterization is as follows $\lambda = 0.1, \sigma^2 = 0.5, \sigma_w^2 = 1, \rho = 0.9, \beta = 1$
Figure 1 (a): Persistent Shock to the Output Gap Target

Figure 1(b): Temporary Shock to the Output Target

1 The parameterization is as follows $\alpha = 0.0625$, $\lambda = 0.1$, $\sigma_q^2 = 0.25$, $\sigma_w^2 = 1$, $\rho = 0.9$, $\beta = 1$
Figure 2(a): Transparency and a Persistent Shock to the Output Target under Discretion

Inflation

0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18

Output Gap

0  1  2  3  4  5  6  7  8  9  10  11  12  13  14  15  16  17  18

Figure 2(b): Transparency and a Temporary Shock to the Output Target under Discretion

Inflation

0  1  2  3  4  5  6  7  8  9  10

Output Gap

0  1  2  3  4  5

0  1  2  3  4  5
Figure 3(a): Persistent Shock to the Output Target under Commitment

Figure 3(b): Temporary Shock to the Output Target under Commitment