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

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Abstract

In the New Keynesian framework, the public's expectation about the future path of monetary policy is an important determinant of current economic conditions. This paper examines the impact of unobservable shifts in the central bank's output gap target on inflation and output dynamics. I show that when the degree of persistence of a shock is private information of the central bank, and policy is discretionary in nature, it is optimal for the central bank *not* to reveal the future expected path of the output gap target. Perfect transparency unambiguously increases inflation and output volatility and thus lowers welfare.

Keywords: Monetary policy; Transparency; Discretion

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.[1] 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

[1] The 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 a 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.

The theoretical literature has provided ambiguous conclusions about the desirability of transparency. A common theme across studies, however, is that increased transparency improves the public's understanding of the central bank's objectives and actions.[2] As a result, transparency renders expectations more responsive to current policy actions. The transparency literature has highlighted two channels through which the increased responsiveness of expectations impacts welfare. First, if monetary policy only affects the real economy through unanticipated policy actions, then increased transparency may reduce the effectiveness of monetary policy as it can no longer surprise the public. Thus, publishing economic forecasts makes it harder for monetary policy to mitigate real shocks and would therefore be welfare reducing. This argument, of course, hinges on the assumption that the central bank has some degree of informational advantage about real shocks and that anticipated policy has no real impact.[3] Second, increased responsiveness of expectations may induce reputational effects which discourage the central bank from engaging in inflationary policy. If agents understand the incentives that the central bank is faced with, then inflation expectations rise when the marginal cost of expansionary policy is perceived as low, preventing these inflationary actions to be realized in the first place.[4] Publishing forecasts would thus impose an external disciplinary mechanism on the central bank which would have welfare improving effects. These reputational effects do not generally depend on whether anticipated policy has a real effect on the real economy. Nonetheless, the bulk of the transparency literature typically makes use of a Lucas-type supply curve and abstracts from the forward-looking nature of expectations as exhibited

[2]See Carpenter (2004) for a comprehensive review of the theoretical literature on policy transparency.

[3]See Cukierman and Meltzer (1986) and Geraats (2007)

[4]See Faust and Svensson (2001), Jensen (2002) and Geraats (2005) for models emphasizing the reputational effects of transparency.

by the stylized New Keynesian Phillips curve.[5]

The purpose of this paper is to take a new look at the desirability of transparency with an emphasis on forward-looking expectations.[6] Consistent with the core of the transparency literature, I examine the case where the preferences of the central bank are time-varying and unobservable to the public. In particular, I assume that the central bank's output gap target is subject to temporary and persistent shifts. In a perfectly transparent policy regime, the central bank reveals the true nature of the preference shock to the public. In practice, this can be done by publishing forecasts of the instrument rate or the goal variables (e.g., inflation and output gap) from which the public can infer the true nature of the preference shock. Under imperfect transparency, however, the public must form an optimal forecast of the output gap target. I show that, when expectations are forward-looking and monetary policy is discretionary in nature, it is optimal for the central bank *not* to reveal the future expected path of the output gap target. In fact, imperfect transparency lowers both inflation and output gap volatility and hence raises welfare.

The key to this result is the impact that future expected policy has on inflation expectations. Under perfect transparency, the cost of expansionary policy, in terms of higher inflation, is always lower when the preference shock is transitory than when it is persistent. This is because inflation expectations are more responsive to persistent shocks than to transitory policy shocks. Under imperfect transparency, however, agents assign some probability that a shock is temporary when the shock in reality is persistent and vice versa. Thus, imperfect transparency *reduces* the responsiveness of expectations when the output gap shock is persistent but *increases* the responsiveness of expectations when the shock is transitory. Thus, lack of transparency increases the cost of achieving an overoptimistic output gap target when the perceived trade-off between inflation and output is low (i.e., when the shock is transitory) but decreases the cost when the trade-off between inflation and output is high (i.e., when the shock is persistent). As a result, imperfect transparency lowers both inflation and output gap volatility by the smoothing inflation and output gap dynamics.

Furthermore, although the central bank is assumed to not explicitly care about interest rate stability, the model suggests that interest rate volatility also decreases under imperfect transparency.

[5] One notable exception is Jensen (2002) who use a two-period New Keynesian Phillips curve.

[6] The fundamental reason for using the New Keynesian Phillips curve is twofold. First, it provides a more realistic depiction of the transmission mechanism of monetary policy by allowing both current and future policy actions to affect real activity. Second, underpinning the discussion on the publication of forecasts is the presumption that the central bank can affect current expectations by revealing expected future actions. A Lucas-type Phillips curve only allows for current actions to matter in the formation of today's expectations.

Finally, in the last section, I provide an alternative interpretation of the output gap shifts as exogenous measurement errors of the central bank's estimate of potential output.

2 The Relevance of Forward-Looking Expectations for Monetary Policy Transparency

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 change. The aggregate supply curve or the so-called New Keynesian Phillips curve can then be shown to take the following form:

$$\pi_t = \lambda x_t + \beta E_t^p \pi_{t+1} \tag{1}$$

where E_t^p denotes the expectations operator with respect to the information set of the private sector.[7] Expression (1) states that the current inflation rate, π_t, is determined by the output gap, x_t, and expected future inflation, $E_t^p \pi_{t+1}$.[8] 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 suggests that there are two channels through which monetary policy 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.[9] Second, monetary policy has an indirect effect on inflation through inflation expectations. To see this, iterate equation (1) forward to the infinite future.

$$\pi_t = E_t^p \sum_{i=0}^{\infty} \beta^i \lambda x_{t+i} \tag{2}$$

[7] The superscript p indicates that the information set available to price-setters may differ from the full information set as would be the case under imperfect transparency.

[8] The output gap is defined as the difference between output and its flexible-price level or potential level.

[9] The importance of this traditional effect of monetary policy on inflation is measured by the slope coefficient λ. 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 λ reflects a low level of price-flexibility, while a high value indicates the opposite.

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 Asymmetric Information about Policy Preferences

Most of the transparency literature focuses on a situation where the preferences of the monetary authorities are not fully known to the public. To this purpose, consider the following formulation of the central bank's objective function:

$$U = -\frac{1}{2} E_t \sum_{i=0}^{\infty} \beta^i \left[(\pi_{t+i} - \pi^*)^2 + \alpha \left(x_{t+i} - \tau \right)^2 \right] \tag{3}$$

That is, the monetary authorities try to stabilize inflation and the output gap around some predetermined targets π^*, and τ respectively. The relative weight that the central bank assigns to output gap stability is represented by the parameter α. The exact nature of the source of the asymmetric information between the central bank and the public varies across studies. For instance, in their seminal work on optimal transparency, Cukierman and Meltzer (1986) assume that the preference parameter α is time-varying and unobservable to the public. They argue that such shifts represent changing sentiments of the monetary authorities due to pressure from politicians, interest groups or the general electorate. Faust and Svensson (2001 and 2002) and Jensen (2002), assume a stochastic output gap target, τ, that is unobservable to the public. They suggest that shifts in the output gap target arise due to the manner in which the structure of the central bank aggregates heterogeneous societal preferences. For instance, changes in the composition of the policymaking board with heterogenous preferences could shift the output target.[10] Geraats (2005), focuses on shifts in the inflation target and argues that despite the increased tendencies of central banks to announce inflation targets, these targets are usually specified as ranges and thus allows for shift in the target.

This paper is consistent with Faust and Svensson (2001 and 2002) and Jensen (2002) in assuming that the output gap target may fluctuate over time. Given the recent development of publicly announced inflation targets and that central bankers tend to be much more comfortable expressing their views on inflation goals rather than output or unemployment goals, I find such an assumption more realistic than allowing for shifts in the inflation target.[11] Consequently, I assume that the central bank maximizes the following objective function:

$$U = -\frac{1}{2} E_t \sum_{i=0}^{\infty} \beta^i \left[\pi_{t+i}^2 + \alpha \left(x_{t+i} - \tau_{t+i} \right)^2 \right] \tag{4}$$

The time-varying output gap target, τ_t , is determined by the following stochastic process:

$$\tau_t = \varepsilon_t + w_t \tag{5}$$

$$\varepsilon_t = \rho \varepsilon_{t-1} + \eta_t \tag{6}$$

The random variables w_t and η_t are i.i.d. with mean zero and variances σ_w^2 and σ_η^2, respectively. The stochastic variable ε_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 transitory shock to the output gap target. The parameter ρ measures the degree of persistency in the stochastic variable ε_t. The unconditional expected output target is zero, indicating that there is no permanent desire to reach an overoptimistic output level.

4 Optimal Monetary Policy

Optimal monetary policy can either be characterized by discretion or commitment. In the former case, the central bank makes no pre-commitment about future policy and re-optimizes its objective

[10] Cukierman (2005) also 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." The notion that shifts in the output gap target could reflect measurment errors is addressed in section 9.

[11] See Mishkin (2004), Cukierman (2005) and Cukierman (2002) for a discussion of the reluctance of central bankers to talk about the output gap target.

function period by period taking the start-up conditions in each period as given. Under commitment, on the other hand, the monetary authorities take advantage of the forward-looking nature of inflation expectations through the introduction of policy inertia. In the proceeding analysis, I abstract from discussing optimal policy under commitment and focus on discretionary policy. This seems reasonable for at least a couple of reasons. First, to successfully affect inflation expectations, the commitment to a future path of policy must be credible. Policy transparency would thus appear to be a prerequisite for such a strategy. Second, since policy under commitment is the welfare maximizing policy, introducing imperfect transparency simply adds another constraint to the central bank's optimization problem. Thus, imperfect transparency must unambiguously reduce welfare under commitment.[12]

Hence, under discretion, the monetary authorities maximize (4) subject to (1) taking inflation expectations as given. It is straightforward to derive the optimal targeting rule under discretion as:

$$x_t = \tau_t - \frac{\lambda}{\alpha}\pi_t \tag{7}$$

Equation (7) reflects the "leaning against the wind" policy where the monetary authorities respond to a rise in inflation by contracting the economy and thus, mitigate the inflationary pressure. Additionally, shifts in the preferences of the central bank as represented by, τ_t, affect policy independent of inflation dynamics. For instance, a rise in the output gap target, given inflation, induces the monetary authorities to expand the economy.

5 Imperfect Transparency and the Optimal Filtering Problem

Suppose now that τ_t is private information of the central bank. Note that since the current inflation rate and output gap are observable, the public can perfectly infer the current output gap target, τ_t from (7). However, the public cannot identify whether a change in the preferences of the central bank is persistent or transitory. Since it is essential for firms to predict the future course of monetary policy, they must estimate the persistent and transitory component of the output target. Using (6) as the transition equation and (5) as the measurement equation, the optimal estimate of the persistent component, using the Kalman filter can be derived as:

$$E_t^p \varepsilon_t = E_{t-1}^p \varepsilon_t + K\left(\tau_t - E_{t-1}^p \tau_t\right) \tag{8}$$

[12] I would like to thank two anonymous referees for bringing these two points to my attention.

The parameter K 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, the so-called constant gain coefficient, can be obtained as:

$$K = \frac{-\Psi - \left(1-\rho^2\right) + \sqrt{\left(\Psi + \left(1-\rho^2\right)\right)^2 + 4\rho^2\Psi}}{2\rho^2} \tag{9}$$

where $0 \leq K \leq 1$ and $\Psi = \sigma_\eta^2/\sigma_w^2$.[13] It will be convenient to let ϕ_t denote the estimation error of ε_t at time t (i.e., $\phi_t = \varepsilon_t - E_t^p \varepsilon_t$). Expression (8) can then be rewritten in the following manner:

$$\phi_t = (1-K)\left(\rho\phi_{t-1} + \eta_t\right) - K w_t \tag{10}$$

Equation (10) 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 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

By combining the Phillips curve (1) with the optimal targeting rule under discretion (7) and the measurement error (10), the following expressions for the equilibrium inflation and output gap under imperfect transparency can be derived (see appendix B):

$$\pi_t = q\alpha\lambda\varepsilon_t + \theta\alpha\lambda w_t - (q-\theta)\,\alpha\lambda\phi_t \tag{11}$$

$$x_t = \left(1 - q\lambda^2\right)\varepsilon_t + \left(1 - \theta\lambda^2\right) w_t + (q-\theta)\,\lambda^2\phi_t \tag{12}$$

where $q = \left(\lambda^2 + \alpha\left(1-\beta\rho\right)\right)^{-1}$and $\theta = \left(\lambda^2 + \alpha\right)^{-1}$. Inflation and output gap dynamics under perfect transparency are thus described by (11) and (12) with $\phi_t = 0$ for all t.

Let us first consider the case of perfect transparency. 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 from being reached (i.e., $\left(1-q\lambda^2\right) < 0$, and $\left(1-\theta\lambda^2\right) < 0$). Furthermore, since $q > \theta$, a persistent shock has a relatively greater impact on inflation than a

[13] See Appendix A for a derivation of the constant gain coefficient.

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 rise by more in response to a persistent shock than to a temporary shock and hence cause a greater increase in the current inflation rate. However, the greater inflationary pressure under a persistent shock forces the central bank to be less expansionary.

Now consider the case of imperfect transparency. That is, when the public has to estimate the persistent and temporary component of the output gap. 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, ϕ_t, and the persistent component, ε_t, dampens the inflationary effect of a persistent shock while it amplifies its expansionary impact. On the other hand, the negative correlation between ϕ_t and w_t dampens the expansionary effect of a temporary shock while it amplifies its inflationary impact.

Figures 1(a) and 1(b) illustrate the difference between perfect and imperfect transparency. Figure 1(a) shows the dynamics of a one unit shock to the persistent component of the output gap target on inflation and the output gap while figure 1(b) shows the dynamics of a one unit shock to the temporary component. The solid lines represent the case of perfect transparency while the dashed line represents the case of imperfect transparency.

As expected, 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. Under perfect transparency, however, the immediate inflation (output) response is greater (smaller) when the shock is persistent in nature. This pattern is not prevalent under imperfect transparency. In fact, the immediate inflation and output response appears to be fairly similar under a persistent and a temporary shock. What is the intuition behind this result? First, consider a persistent shock to the output gap. In this case 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, ε_t, leading to an increase in ϕ_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. Now consider a temporary shock. Under perfect transparency, 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, the public puts some weight on the event that the shock to the output gap target is persistent and hence, adjusts its 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 figures 1(a) and (b). Imperfect transparency reduces inflation volatility and increases output gap variability with respect to persistent shocks, but 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. In fact, as shown in appendix C, the difference between inflation and output gap volatility under imperfect transparency (IT) and perfect transparency (PT) can be expressed as:

$$\sigma^2_{\pi,IT} - \sigma^2_{\pi,PT} = -\left(q-\theta\right)^2 \alpha^2 \lambda^2 K \sigma^2_w \tag{13}$$

$$\sigma^2_{x,IT} - \sigma^2_{x,PT} = -\left(q-\theta\right)^2 \lambda^4 K \sigma^2_w \tag{14}$$

Proposition 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.*

7 Welfare Implications of Transparency

To evaluate the welfare effects of transparency it is necessary to specify a social welfare function. In most of the transparency literature the welfare function is assumed to differ from the objective function of the central bank at least in the short-run.[14] Faust and Svensson (2001), for instance,

[14] In the monetary policy literature, it is quite common to allow for differences between the objective function of the central bank and the social welfare function (e.g., Barro and Gordon (1983), Rogoff (1985), Walsh (1995), Svensson (1997) and Mishkin and Westelius (2007))

argue that although the preferences of the monetary authorities may differ from the public's due to some idiosyncratic preference component, they should on average be consistent with the social welfare function. Geraats (2007) partially takes the same approach by allowing the inflation and output gap target to return to their social optimal levels in the long-run, but she also allows the relative weight α to permanently deviate from the social welfare function.[15] Consistent with Faust and Svensson's (2002) argument, I define the social welfare function as:

$$W_t = -\frac{1}{2} E_t \sum_{i=0}^{\infty} \beta^i \left[\pi_{t+i}^2 + \alpha x_{t+i}^2 \right] \tag{15}$$

Given that the output gap target is on average zero, the objective function of the central bank is on average equal to (15). It is now possible to evaluate the welfare implications of imperfect transparency. Appendix D shows that the difference between the average expected welfare level under imperfect transparency (IT) and perfect transparency (PT) can be derived as:

$$W_{IT} - W_{PT} = \frac{1}{2} \frac{(q-\theta)^2}{\theta} \lambda^2 \alpha K \sigma_w^2 \tag{16}$$

Proposition 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.*

This should not be surprising given that we know that both inflation and output gap volatility is reduced under imperfect transparency. Hence, by not publishing forecasts of the output gap target, the monetary authorities avoid indirectly revealing the dynamics of any preference shifts. The lack of transparency increases the cost of achieving an overoptimistic output target when the perceived trade-off between inflation and output is low (i.e., when the shock is transitory), but decreases the cost when the trade-off between inflation and output is high (i.e., when the shock is persistent). Thus, imperfect transparency has a smoothing effect on inflation and output which reduces the welfare costs of idiosyncratic preference shocks.

Although the results presented above indicate that imperfect transparency improves welfare, it may be of interest to evaluate the magnitude of these effects. Table 1 shows 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).

[15] See section 3 in Geraats (2007).

Overall, the magnitudes for welfare improvements vary between 1.48% and 13.71% for various parameterizations, which would indicate that perfect transparency may lead to significant welfare losses. Interestingly, the welfare gains from imperfect transparency tend to be larger the less averse the public and the central bank is to inflation volatility (i.e., the larger the value of α).[16]. This is consistent with the observation that the current trend of increased transparency amongst central banks appears to have occurred simultaneously with an increased emphasis on price stability (e.g., Cukierman, 2002).[17]

8 Interest Rate Dynamics

In the preceding analysis the central bank controlled the output gap directly. In a more realistic setting, however, the central bank policy instrument is the nominal interest rate, i_t. Since the public debate around transparency has largely been focused on whether the monetary authorities should or should not publish their interest rate projection for the future, it is of interest to analyze the effect of transparency on interest rate dynamics. To do so, we can amend the model with a standard representation of the IS-curve, i.e.,

$$x_t = E_t^p x_{t+1} - \varphi \left(i_t - E_t^p \pi_{t+1} \right) \tag{17}$$

Equation (17) postulates that (i) an increase in expected future output increases today's output as individuals try to smooth consumption over time, and (ii) a higher expected real interest rate lowers today's output as individuals substitute current consumption for future consumption. The parameter φ represents the intertemporal elasticity of substitution. Rewriting (17) we have the following interest rate rule:

$$i_t = E_t^p \pi_{t+1} + \varphi^{-1} E_t^p \Delta x_{t+1} \tag{18}$$

As Svensson and Woodford (2003) point out, including (18) in the model does not change the optimal condition (7) since the central bank can perfectly control the output gap by adjusting the nominal interest rate. It is straightforward to derive expressions for $E_t^p \pi_{t+1}$ and $E_t^p \Delta x_{t+1}$ from (11) and (12), and then substitute them into (18). Appendix E show that the equilibrium interest rate can be written in the following manner:

$$i_t = A\varepsilon_t - Bw_t - (A - B)\phi_t \tag{19}$$

[16] Taking the derivative of (16) with respect to α we have $\frac{1}{2}\left(2\theta^{-1} + q^{-1}\right) q^3 \theta^2 \alpha^2 \beta^2 \rho^2 \lambda^4 K \sigma_w^2 > 0$

[17] For instance, Westelius (2005) finds that there is a structural break in the relative weight, α , around 1980 in the U.S, indicating that the Federal Reserve became more inflation averse.

where $A = (\rho - \varphi)\left(1 - q\lambda^2\right) + \rho\varphi\alpha\lambda q$ and $B = \varphi(1 - \theta\lambda^2)$. Not surprisingly, given that (19) is in the same format as (11) and (12), the difference between interest rate volatility under perfect and imperfect transparency is negative and can be derived as:

$$\sigma_{i,IT}^2 - \sigma_{i,PT}^2 = -\left[\left(1 - q\lambda^2\right)\rho - (q - \theta)\,\varphi\lambda^2\right]^2 K\sigma_w^2 \tag{20}$$

Proposition 3 *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 decreases interest rate volatility.*

Thus, although the central bank does not directly care about interest rate stability, imperfect transparency reduces interest rate volatility nonetheless. Again, this should not come as a surprise since we already know that inflation expectations are smoothed under imperfect transparency which allows the central bank to be, on average, less aggressive with its policy instrument.

9 Asymmetric Information and Uncertainty about Potential Output

Asymmetric information between the central bank and the public can also arise due to informational differences about the current state of the economy. In fact, models built around a Lucas-type Phillips curve frequently assume that the central bank has superior information about supply shocks. This assumption is of theoretical necessity since monetary policy can only affect the real economy through surprise inflation. Aoki (2006), on the other hand, argues that firms are more likely to have better information about technology shocks than the central bank. Svensson and Woodford (2004) also argue that if there are informational differences about the state of the economy, it makes sense theoretically to assume that the central bank has less information than the public.[18] One attractive aspect of this source of asymmetric information is that the central bank's objective function is not assumed to differ from the social welfare function.

In this section I present a simple model where potential output is common knowledge to private agents but unobservable to the central bank. To simplify matters, I assume that the central bank

[18] Svensson and Woodford (2004) argue that it makes little sense for economic variables to be relevant to the central bank if they are not known to anyone in the economy. If private agents are assigned one single information set, then it is intellectually consistent to assume that this information set must be complete. Other recent papers examining the case where the central bank has inferior information relative to the public are Ehrmann and Smets (2003) and Hornstein (2003).

receives signals about potential output that are not generated by variables affected by the actions of the central bank itself. By doing so I avoid the simultaneity problem that arises when the central bank uses forward-looking variables, such as inflation, to estimate the state of the economy. That is, current policy depends on estimates of potential output which in turn depends on the public's expectations about current and future policy. As Svensson and Woodford (2003 and 2004) show, the certainty equivalence may no longer hold in this case.[19]. Although the assumption of exogenous measurement errors is not uncommon in the literature (e.g., Gerlach-Kristen, 2006, and Orphanides, Porter, Reifschneider, Tetlow, and Frederico, 2000), it is obviously not desirable from a realistic point of view. However, while the simultaneity problem is clearly an important issue, it is beyond the scope of this paper. The purpose of this section is to suggest an alternative explanation to the preference shifts discussed in the preceding sections without disturbing the underlying assumptions.

9.1 Unobservable Productivity Shocks

Assume that potential output, $\widehat{y}_t$, can be decomposed into two components:

$$\widehat{y}_t = a_{pt} + a_{Tt} \tag{21}$$

$$a_{pt} = \kappa a_{pt-1} + \upsilon_t \tag{22}$$

where a_{pt} and a_{Tt} represent persistent and temporary productivity shocks respectively. 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.,

$$s_{pt}^{cb} = a_{pt} + \chi_t^{cb} \tag{23}$$

$$s_{Tt}^{cb} = a_{Tt} + w_t^{cb} \tag{24}$$

where χ_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:

$$E_t^{cb} a_{pt} = E_{t-1}^{cb} a_{pt} + G \left(s_{pt}^{cb} - E_{t-1}^{p} s_{pt}^{cb} \right) \tag{25}$$

[19] Svensson and Woodford (2003 and 2004) show that under partial asymmetric information the certainty equivalence property still holds under discretion. That is, the optimal targing rule is the same, but actual output has to be substituted with the central bank's optimal estimate of potential output. Thus, under perfect transparency, i.e., when the public perfectly observes the central bank's measurement error, the certainty equivalence still holds. However, under imperfect transparency, the public cannot observe the measurement error and must thus create an optimal estimate. These layers of estimations further complicate matters and are beyond the scope of this paper.

where G is the constant gain coefficient. Let ε_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 (25), it is straightforward to show that the measurement error of the persistent component follows an AR(1) process, i.e.,

$$\varepsilon_t^{cb} = \rho \varepsilon_t^{cb} + \eta_t^{cb} \tag{26}$$

where $\eta_t^{cb} = G\chi_t^{cb} - (1-G)\, \upsilon_t$ 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 τ_t^{cb}, is thus equal to:

$$\tau_t^{cb} = \widehat{y}_t^{cb} - \widehat{y}_t = \left(E_t^{cb} a_{pt} - a_{pt}\right) + \left(E_t^{cb} a_{Tt} - a_{Tt}\right) = \varepsilon_t^{cb} + w_t^{cb} \tag{27}$$

A positive (negative) value of τ_t^{cb} would thus represent an overestimation (underestimation) of potential output. The fact that the central bank is making persistent measurement errors of the output gap is consistent with the findings of Orphanides (2000). In fact, Orphanides et al (2001) present point estimates of the persistency parameter, ρ , between 0.52 and 0.96.

9.2 Optimal Monetary Policy under Discretion

Optimal policy under discretion is derived by maximizing the social welfare function (15), given the private sector's inflation expectation, and subject to the new Keynesian Phillips curve (1).[20] Since the measurement errors are assumed to be exogenous the certainty equivalence holds and gives us the following targeting rule:

$$y_t - \widehat{y}_t = -\frac{\lambda}{\alpha}\pi_t \tag{28}$$

where y_t is output and $\widehat{y}_t$ is potential output. The optimal targeting rule can be found simply by substituting the central bank's optimal estimate of potential, $\widehat{y}_t^{cb}$, for $\widehat{y}_t$. Furthermore, by defining $\tau_t^{cb} = \widehat{y}_t^{cb} - \widehat{y}_t$, as the central bank's measurement error of potential output we can rewrite (28) as:

$$x_t - \tau_t^{cb} = -\frac{\lambda}{\alpha}\pi_t \tag{29}$$

Notice the similarity between (29) and (7). Comparing equations (29), (27), and (26) with equations (7), (5) and (6) it is clear that the results derived in the previous sections must also hold when the central bank's time-varying output gap target reflects exogenous measurement errors of productivity shocks.

[20] Under discretionary policy the central bank takes the private setor's expectations as given when setting policy. Thus whether these expctations are set with imperfect or perfect information does not affect the optimal target rule.

10 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 essential 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. 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 thus raises welfare. Additionally, extending the model by including an IS-curve, I show that imperfect transparency also reduces interest rate volatility.

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Table 1: Welfare Effect of Imperfect Transparency under Various Parameterizations[1]

	a			l			r			s_h^2/s_w^2		
	0.01	0.0625	0.10	0.01	0.05	0.10	0.50	0.75	0.90	0.25	0.50	0.75
Perfect Transparency (PT)												
Inflation Volatility	0.156	0.630	0.816	0.160	0.581	0.630	0.151	0.274	0.63	0.449	0.63	0.769
Output Volatility	0.521	1.064	1.218	1.883	1.505	1.064	1.061	1.081	1.064	0.968	1.064	1.152
Welfare (x 10^3)	-1.35	-23.37	-40.70	-12.36	-23.98	-23.37	-4.655	-7.421	-23.37	-13.03	-23.37	-33.72
Imperfect Transparency (IT)												
Inflation Volatility	0.153	0.596	0.767	0.148	0.542	0.596	0.145	0.255	0.596	0.414	0.596	0.737
Output Volatility	0.440	1.013	1.186	1.883	1.496	1.013	1.059	1.068	1.013	0.927	1.013	1.097
Welfare (x 10^3)	-1.27	-20.96	-36.40	-12.17	-21.66	-20.96	-4.563	-6.808	-20.96	-11.24	-20.96	-30.91
Difference (IT-PT) (x 10^3)												
Inflation Volatility	-2.53	-34.00	-49.46	-11.88	-39.79	-33.98	-5.36	-19.97	-34.00	-35.77	-34.00	-32.13
Output Volatility	-81.45	-51.34	-32.56	-0.03	-9.53	-51.34	-1.92	-12.59	-51.34	-41.72	-51.34	-55.08
Welfare	0.078	2.416	4.306	0.183	2.324	2.416	0.092	0.613	2.416	1.790	2.416	2.807
Change in Welfare (%)	5.81%	10.32%	10.58%	1.48%	9.69%	10.33%	1.98%	8.26%	10.32%	13.74%	10.32%	8.32%

[1] The benchmark parameterization is $a = 0.625, l = 0.1, r = 0.9, b = 1, s_h^2 = 0.5, s_w^2 = 1$

Figure 1(a): Transparency and a Persistent Shock to the Output Target[1]

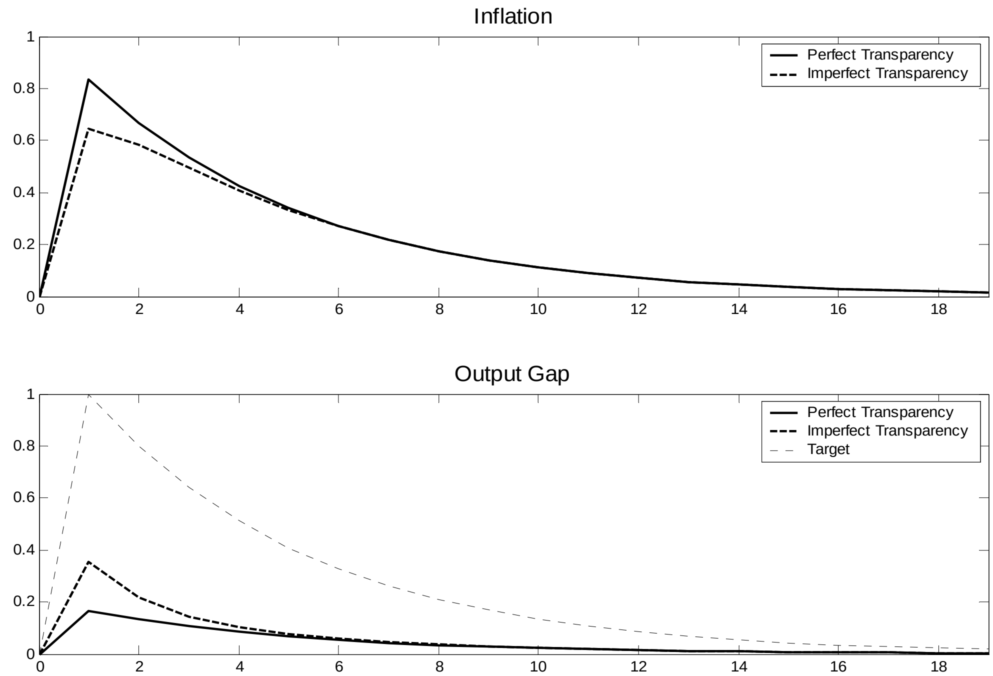
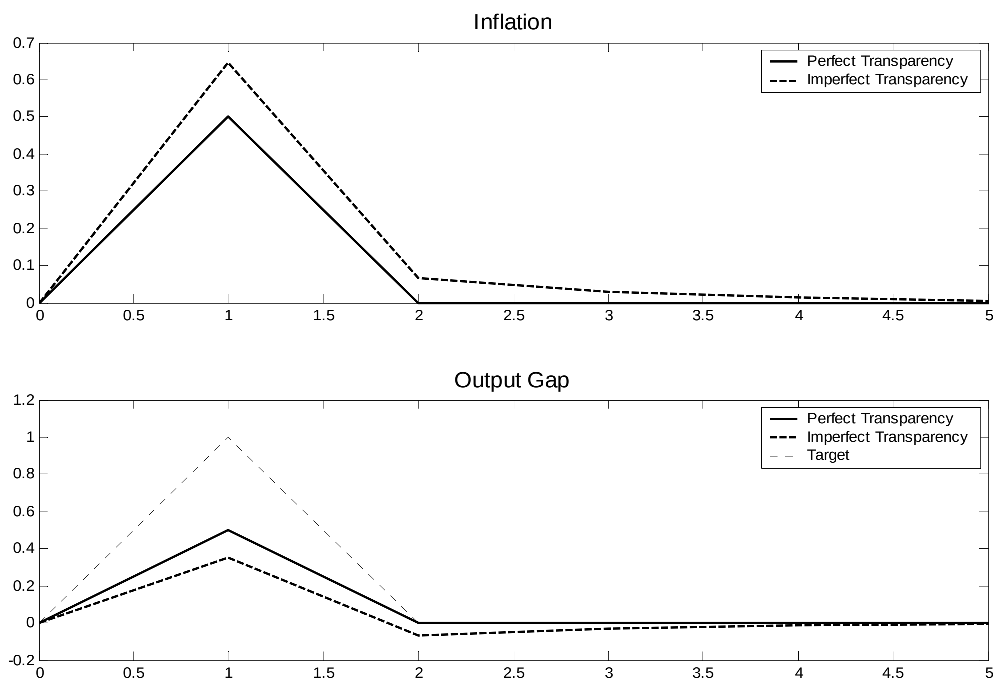


Figure 1(b): Transparency and a Temporary Shock to the Output Target



[1] The parameterization is as follows $\alpha = 0.0625$, $\lambda = 0.03$, $\sigma_\eta^2 = 0.25$, $\sigma_w^2 = 1$, $\rho = 0.8$, $\beta = 1$

Appendices

A Derivation of the Constant Gain Coefficient K

The estimation error of the persistent component, ϕ_t, cannot be correlated with the observed output gap target,τ_t , at time t. That is,

$$Cov(\tau_t, \phi_t) = Cov(\varepsilon_t + w_t, \phi_t) = Cov(\varepsilon_t, \phi_t) + Cov(w_t, \phi_t) = 0 \tag{A.1}$$

First, derive an expression for $Cov(\varepsilon_t, \phi_t)$ using equation (10),

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

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

$$Cov(\varepsilon_t, \phi_t) = \left[1 + \sum_{i=1}^{\infty} \left(\rho^2 (1 - K)\right)^i\right] (1 - K) \sigma_\eta^2 = \frac{1 - K}{1 - \rho^2 (1 - K)} \sigma_\eta^2 \tag{A.3}$$

Second, using (10), $Cov(w_t, \phi_t)$ can be derived as:

$$Cov(w_t, \phi_t) = -K\sigma_w^2 \tag{A.4}$$

Combining (A.1), (A.3) and (A.4) gives us the following relationship:

$$\frac{1 - K}{1 - \rho^2 (1 - K)} \sigma_\eta^2 = K\sigma_w^2 \tag{A.5}$$

Solving for K we have:

$$K = \frac{-\Psi - \left(1 - \rho^2\right) + \sqrt{\left(\Psi + (1 - \rho^2)\right)^2 + 4\rho^2\Psi}}{2\rho^2} \tag{A.6}$$

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

B 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:

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

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

$$(x_t - \tau_t) = c_x \varepsilon_t + d_x w_t + f_x \phi_t \tag{B.2}$$

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 $E_t^p \varepsilon_{t+1} = \rho E_t^p \varepsilon_t$. Forwarding equation (B.2) and taking the expectations with respect to the publics information set we have:

$$E_t^p (x_{t+1} - \tau_{t+1}) = c_x \rho E_t^p \varepsilon_t = c_x \rho \varepsilon_t - c_x \rho \phi_t \tag{B.3}$$

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

$$\left(1 + \frac{\lambda^2}{\alpha}\right)(x_t - \tau_t) = \left(\beta c_x \rho - \frac{\lambda^2}{\alpha}\right)\varepsilon_t - \frac{\lambda^2}{\alpha} w_t - \beta c_x \rho \phi_t \tag{B.4}$$

Comparing (B.4) and (B.2), we can solve for the coefficients c_x, d_x and f_x . That is

$$c_x = -\frac{\lambda^2}{\lambda^2 + \alpha(1 - \beta\rho)} \tag{B.5}$$

$$d_x = \frac{\lambda^2}{(\lambda^2 + \alpha)} \tag{B.6}$$

$$f_x = -\frac{\beta\rho\alpha}{\lambda^2 + \alpha(1 - \beta\rho)(\lambda^2 + \alpha)}\lambda^2 = \left(\frac{1}{\lambda^2 + \alpha(1 - \beta\rho)} - \frac{1}{(\lambda^2 + \alpha)}\right)\lambda^2 \tag{B.7}$$

The equilibrium output gap can then be written as:

$$x_t = \tau_t - \frac{1}{\lambda^2 + \alpha(1 - \beta\rho)}\lambda^2 \varepsilon_t + \frac{1}{(\lambda^2 + \alpha)}\lambda^2 w_t - \left(\frac{1}{\lambda^2 + \alpha(1 - \beta\rho)} - \frac{1}{(\lambda^2 + \alpha)}\right)\lambda^2 \phi_t \tag{B.8}$$

Setting $q = \left(\lambda^2 + \alpha\left(1 - \beta\rho\right)\right)^{-1}$and $\theta = \left(\lambda^2 + \alpha\right)^{-1}$ we have equation (12). The equilibrium expression for inflation (11) can be derived by inserting (B.8) into the targeting rule (7):

$$\pi_t = \frac{1}{\lambda^2 + \alpha(1 - \beta\rho)}\alpha\lambda\varepsilon_t + \frac{1}{(\lambda^2 + \alpha)}\alpha\lambda w_t - \left(\frac{1}{\lambda^2 + \alpha(1 - \beta\rho)} - \frac{1}{(\lambda^2 + \alpha)}\right)\alpha\lambda\phi_t \tag{B.9}$$

C Inflation and Output Gap Volatility under Discretion

Rewrite equation (11)as:

$$\pi_t = A\varepsilon_t + Bw_t - (A - B)\,\phi_t \tag{C.1}$$

were $A = q\alpha\lambda$ and $B = \theta\alpha\lambda$. Taking the unconditional variance of (C.1) we have:

$$\begin{aligned} \sigma^2_{\pi,IT} \quad = \quad & A^2 \frac{1}{1 - \rho^2}\sigma^2_\eta + B^2\sigma^2_w + (A - B)^2\,\sigma^2_\phi \\ & -2\,(A - B)\,ACov\,(\varepsilon_t, \phi_t) - 2(A - B)BCov\,(w_t, \phi_t) \end{aligned} \tag{C.2}$$

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

$$\sigma^2_{\pi,PT} = A^2 \frac{1}{1 - \rho^2}\sigma^2_\eta + B^2\sigma^2_w \tag{C.3}$$

Subtracting (30) from (C.3) and noting that $Cov(\varepsilon_t, \phi_t) + Cov(w_t, \phi_t) = Cov(\tau_t, \phi_t) = 0$ we can express $\sigma^2_{\pi,IT} - \sigma^2_{\pi,PT}$ as:

$$\sigma^2_{\pi,IT} - \sigma^2_{\pi,PT} = (A - B)^2 \left[\sigma^2_\phi + 2Cov(w_t, \phi_t)\right] \tag{C.4}$$

Taking the unconditional variance of ϕ as defined by equation (10) and using the relationship (A.5) we have that $\sigma^2_\phi = -Cov(w_t, \phi_t) = K\sigma^2_w$. Thus it must be the case that $\sigma^2_\phi + 2Cov(w_t, \phi_t) = -K\sigma^2_w$. Inserting this expression into (C.4) gives us expression (13). It is straightforward to apply the same methodology in order to get the output gap volatility under perfect and imperfect transparency and derive (14).

D Imperfect Transparency and Welfare

The average expected welfare level is simply the weighted sum of the variance of inflation and output gap i.e.,

$$W_t = -\frac{1}{2}\left[var(\pi) + \alpha var(x)\right] \tag{D.1}$$

The welfare difference between imperfect and perfect transparency can thus be written as

$$W_{IT} - W_{PT} = -\frac{1}{2}\left(\sigma^2_{\pi,IT} - \sigma^2_{\pi,PT}\right) - \frac{1}{2}\alpha\left(\sigma^2_{x,IT} - \sigma^2_{x,PT}\right) \tag{D.2}$$

Inserting (13) and (14) into (D.2) we have

$$W_{IT} - W_{PT} = \frac{1}{2}(\alpha + \lambda^2)(q - \theta)^2 \alpha\lambda^2 K\sigma^2_w = \frac{1}{2}\frac{(q-\theta)^2}{\theta}\lambda^2\alpha K\sigma^2_w \tag{D.3}$$

E Interest Rate Dynamics

From the equilibrium expressions for inflation and the output gap we have that $E^p_t\pi_{t+1} = q\alpha\rho(\varepsilon_t + \phi_t)$ and $E^p_t x_{t+1} = \left(1 - q\lambda^2\right)\rho(\varepsilon_t + \phi_t)$. Given the interest rate rule (18) we can derive the equilibrium interest rate simply by substituting the expressions for $E^p_t\pi_{t+1}$ and $E^p_t\Delta x_{t+1}$. After some algebraic manipulation we get:

$$\begin{aligned} i_t \;\; = \;\; & \left[(\rho - \varphi)\left(1 - q\lambda^2\right) + \rho\varphi\alpha\lambda q\right]\varepsilon_t - \varphi(1 - \theta\lambda^2)w_t - ((\rho - \varphi)\left(1 - q\lambda^2\right) \\ & + \rho\varphi\alpha\lambda q - \varphi(1 - \theta\lambda^2))\phi_t \end{aligned} \tag{E.1}$$

Denoting $A = (\rho - \varphi)\left(1 - q\lambda^2\right) + \rho\varphi\alpha\lambda q$ and $B = \varphi(1 - \theta\lambda^2)$ we have expression (19). We can now apply the same methodology as in Appendix C. Thus, the difference between interest rate volatility under imperfect and perfect transparency can be written as:

$$\sigma_{i,IT}^2 - \sigma_{i,IT}^2 = (A - B)^2 \left[\sigma_\phi^2 + 2Cov\left(w_t, \phi_t\right)\right] \tag{E.5}$$

Given that $\sigma_\phi^2 + 2Cov\left(w_t, \phi_t\right) = -K\sigma_w^2$, expression (E.5) must be negative, indicating that interest rate volatility decreases under imperfect transparency.