CESifo, the International Platform of the Ifo Institute of Economic Research and the Center for Economic Studies of Ludwig-Maximilians University

CESifo Venice Summer Institute

19 - 24 July 2010

"Central Bank Communication, Decision-Making and Governance"

to be held on **23 - 24 July 2010**
on the island of San Servolo in the Bay of Venice, Italy

Transparency, Stabilization and Interest Rate Smoothing

Petra M. Geraats

VIU
Venice International University

Transparency, Stabilization and Interest Rate Smoothing*

Petra M. Geraats†

University of Cambridge

June 2010

Work in progress
Comments welcome

Abstract

Many central banks have become more transparent during the last decade, in particular about macroeconomic prospects. This paper shows that such economic transparency could give central banks greater flexibility to respond to macroeconomic shocks. In particular, it allows central banks to stabilize aggregate demand and supply shocks without affecting private sector inflation expectations. In contrast, opaque central banks limit their stabilization efforts to avoid disturbing inflation expectations. As a result, they no longer fully offset anticipated demand shocks but engage in interest rate smoothing. This leads to undesirable macroeconomic volatility that is socially detrimental.

*Acknowledgments: I thank seminar participants at the University of Athens for helpful comments.

†Faculty of Economics, University of Cambridge, Cambridge, CB3 9DD, United Kingdom. Email: Petra.Geraats@econ.cam.ac.uk.

1 Introduction

There has been a remarkable rise in the transparency of monetary policy during the last two decades. A majority of central banks throughout the world nowadays regularly publish their macroeconomic forecasts. This paper shows that such transparency gives the central bank greater flexibility to offset macroeconomic disturbances. In contrast, opacity forces the central bank to mute the stabilization of macroeconomic shocks to prevent upsetting private sector inflation expectations. Thus, an opaque central bank engages in interest rate smoothing and no longer fully offsets aggregate demand shocks it anticipates. As a result, greater transparency about macroeconomic forecasts leads to more effective stabilization and is welfare improving.

Intuitively, the policy rate set by the central bank reflects both its inflationary intentions and the stabilization of aggregate demand and supply shocks. Transparency about the macroeconomic shocks to which the central bank responds allows the private sector to infer the central bank's inflationary intentions from its policy actions. But when there is opacity, the private sector confuses the central bank's stabilization efforts with changes in policy intentions, thereby causing greater volatility in private sector inflation expectations. This makes the central bank more reluctant to use the policy rate to stabilize macroeconomic shocks, leading to interest rate smoothing under opacity.

This paper analyzes a two-period model of discretionary monetary policy in the tradition of Kydland and Prescott (1977) and Barro and Gordon (1983). The structure of the economy is described by an expectations-augmented Phillips equation and an aggregate demand equation, where the central bank sets the policy rate. The public is uncertain about the central bank's inflationary intentions and faces asymmetric information about the aggregate demand and supply shocks observed by the central bank. Thus, the model is similar to Geraats (2005), except that it features a central bank objective function that is quadratic in both inflation and output, does not exhibit an inflation bias and allows for intermediate degrees of transparency about macroeconomic shocks. Following Geraats (2002), the latter is referred to as 'economic transparency' and describes the extent to which the private sector faces no asymmetric information about the macroeconomic information used by the central bank for monetary policymaking.

Although Geraats (2005) shows that economic transparency is beneficial because it reduces the inflation bias, much of the rest of the literature has found it to be detrimental. For instance, Cukierman (2001) and Gersbach (2003) show that the release of aggregate supply shocks negatively affects private sector inflation expectations in a simple static model. Using a two-period model with a New Keynesian Phillips curve and uncertainty about the central bank's output gap target, Jensen (2000, 2002) finds that greater transparency hampers the stabilization of supply shocks. Walsh (2007*a*, 2007*b*, 2008), who analyzes announcements to a fraction of agents in the New Keynesian model, also finds that imperfect economic transparency is generally desirable. In contrast to these studies, the present paper shows that transparency about aggregate supply shocks could actually be beneficial and enhance the stabilization of macroeconomic shocks. Thus, it helps to explain why economic transparency has been embraced by so many central banks (Geraats 2009).

Regarding the remainder of the paper, the model is presented in section 2 and the solution in section 3. Section 4 examines the effects of greater macroeconomic transparency on the volatility the interest rate, inflation and output, and on expected social welfare. The results are further discussed in section 5 and section 6 concludes.

2 Model

The central bank has the objective function

$$W_t = -\frac{1}{2}\alpha\left(\pi_t - \tau\right)^2 - \frac{1}{2}\left(y_t - \bar{y}\right)^2 \tag{1}$$

where π_t is the rate of inflation; y_t is the level of real output; τ is the central bank's inflation target, which is stochastic but time-invariant: $\tau \sim N\left(\bar{\tau}, \sigma_\tau^2\right)$ with $\sigma_\tau^2 > 0$; $\bar{y}$ equals the natural rate of output; α is the relative weight on inflation stabilization ($\alpha > 0$); and the subscript t denotes the time period, $t \in \{1, 2\}$. The central banker is in office for two periods and maximizes the expected valued of

$$U = W_1 + \delta W_2 \tag{2}$$

where δ is the intertemporal discount factor($0 < \delta \leq 1$).

The structure of the economy is described as follows. The demand for output satisfies

$$y_t = \bar{y} - \left(i_t - \pi_t^e - \bar{r}\right) + d_t \tag{3}$$

where i_t is the nominal interest rate; π_t^e denotes inflation expectations formed by the private sector; d_t is an aggregate demand shock: $d_t \sim N\left(0, \sigma_d^2\right)$ with $\sigma_d^2 > 0$; and $\bar{r}$ is the long-run, ex ante real interest rate. The supply of output satisfies the aggregate supply (or price adjustment) relation

$$\pi_t = \pi_t^e + \left(y_t - \bar{y}\right) - s_t \tag{4}$$

where s_t is a (beneficial) aggregate supply shock: $s_t \sim N(0, \sigma_s^2)$ with $\sigma_s^2 > 0$. It is assumed that τ, d_t and s_t are independent.

For simplicity, assume that the aggregate demand and supply shocks (d_t, s_t) are known to the central bank, either through direct observation or by means of perfect forecasting. Imperfect central bank forecasts could be introduced but would not affect the conclusions.

A crucial assumption is that the private sector does not have the same information as the central bank. There are two sources of asymmetric information. First, the private sector only observes a signal of the demand and supply shocks. More precisely, the economic shocks can be decomposed into an unbiased public signal (ξ_t^d, ξ_t^s) and an independent white noise shock (η_t^d, η_t^s) only observed by the central bank:

$$d_t = \xi_t^d + \eta_t^d \quad (5)$$

$$s_t = \xi_t^s + \eta_t^s \quad (6)$$

The public's forecast errors depend on the extent of the information asymmetry: $\eta_t^d \sim N(0, (1-\kappa_d)\sigma_d^2)$ and $\eta_t^s \sim N(0, (1-\kappa_s)\sigma_s^2)$, where $0 \leq \kappa_d \leq 1$, $0 \leq \kappa_s \leq 1$, and η_t^d and η_t^s are assumed to be independent of τ. The parameters κ_d and κ_s provide a measure of the degree of economic transparency. In the special case of $\kappa_d = \kappa_s = 0$, the public is completely ignorant about the economic disturbances ($\xi_t^d = \xi_t^s = 0$); for $\kappa_d = \kappa_s = 1$, perfect transparency about the macroeconomic shocks prevails ($\xi_t^d = d_t$, $\xi_t^s = s_t$). The assumption that the central bank may have access to superior economic information is consistent with empirical evidence provided by Peek, Rosengren and Tootell (1999) and Romer and Romer (2000). The model could be modified to allow for a private sector information advantage, in which case indeterminacies may arise if the central bank attempts to infer information from private sector inflation expectations (Bernanke and Woodford 1997). But if the central bank would refrain from such attempts, the conclusions of the present model would be the same because any information asymmetry regarding economic disturbances suffices.

The second source of asymmetric information is that the private sector is uncertain about the inflation target τ that the central bank pursues. This could be the case even if there exists an explicit inflation target, as the latter is often formulated as a range and need not be perfectly credible. In addition, the central bank's preferences cannot be directly observed, so some (ex ante) uncertainty seems plausible. Although other forms of preference uncertainty may be more appealing, for instance about the relative weight on inflation stabilization, this would come at the loss of analytical tractability.

The timing of events as follows. Before the first period, the central bank's inflation target τ is drawn by nature but only observed by the central bank. In addition, private sector inflation expectations π_1^e are formed using its prior on τ. In the first period, the public signals ξ_1^d and ξ_1^s are revealed, and the central bank observes the economic disturbances d_1 and s_1, and sets the nominal interest rate i_1 accordingly. At the end of the first period, the private sector updates its prior on τ using the nominal interest rate i_1 and forms its inflation expectations π_2^e. At the beginning of the second period, the levels of inflation π_1 and output y_1 are observed. In addition, the public signals ξ_2^d and ξ_2^s are revealed, and the central bank observes the economic disturbances d_2 and s_2, and sets the nominal interest rate i_2. After this last period, inflation π_2 and output y_2 are known.

The assumption that information on inflation π_1 and output y_1 is not available when the private sector forms its inflation expectations π_2^e is due to lags in the effect of monetary policy decisions. Since the macroeconomic outcome of a previous decision is not yet known, the private sector uses the policy instrument and its information about economic disturbances to determine inflation expectations, which are relevant for the next policy decision. This captures the prevalent practice that the private sector pays close attention to the central bank's interest rate decisions to infer its intentions.

It is assumed that people have rational expectations. Formally, the information set available to the public when it forms its inflation expectations π_1^e and π_2^e equals $\Omega \equiv \{\bar{r}, \bar{y}, \alpha, \delta, \kappa_d, \kappa_s, \bar{\tau}, \sigma_\tau^2, \sigma_d^2, \sigma_s^2\}$ and $\{i_1, \Omega_1\}$, respectively, where $\Omega_1 \equiv \left\{\xi_1^d, \xi_1^s, \Omega\right\}$. The next section provides the solution to the model.

3 Solution

The model is solved by backwards induction. In period two, the central bank maximizes W_2 with respect to i_2 subject to (4) and (3), and given π_2^e, d_2 and s_2. The first order condition implies

$$i_2 = \bar{r} + \pi_2^e - \frac{\alpha}{1+\alpha}\left(\tau - \pi_2^e\right) + d_2 - \frac{\alpha}{1+\alpha} s_2 \tag{7}$$

Using (3) and (4) this yields

$$y_2 = \bar{y} + \frac{\alpha}{1+\alpha}\left(\tau - \pi_2^e\right) + \frac{\alpha}{1+\alpha} s_2 \tag{8}$$

$$\pi_2 = \pi_2^e + \frac{\alpha}{1+\alpha}\left(\tau - \pi_2^e\right) - \frac{1}{1+\alpha} s_2 \tag{9}$$

An inflation target above the expected rate of inflation has an expansionary effect and reduces the interest rate and increases output and inflation. Demand shocks d are fully offset by an increase in the interest rate, whereas the effect of a (deflationary) supply shock s is partially neutralized by a decrease in the interest rate that raises output. A more conservative central bank (higher α) has a stronger interest rate response to supply shocks, which therefore have a larger effect on output but a smaller impact on inflation.

Substituting (8) and (9) into (1) and taking expectations conditional on τ and π_2^e gives

$$\mathrm{E}\left[W_2|\tau,\pi_2^e\right] = -\frac{1}{2}\frac{\alpha}{1+\alpha}\left[\left(\pi_2^e-\tau\right)^2+\sigma_s^2\right] \tag{10}$$

where moment operators with subscript t are conditional on the information set Ω_t. The expected payoff to the central bank in period two is maximized when the private sector perfectly anticipates the central bank's type: $\pi_2^e = \tau$. Thus, it is in the central bank's interest to reveal its type through its policy action i_1.

Facing imperfect information, the private sector uses the nominal interest rate i_1 and the public signals ξ_1^d and ξ_1^s to update its prior on τ and form its inflation expectations π_2^e. Suppose that the private sector uses the following updating equation:

$$\pi_2^e = u_0 + u_i i_1 + u_d \xi_1^d + u_s \xi_1^s \tag{11}$$

Below it is shown that this is consistent with a rational expectations equilibrium. The simple linear structure follows from the normality assumptions on τ, η_1^d and η_1^s.

In the first period, the central bank maximizes the expected value of (2) with respect to i_1 subject to (4) and (3), given π_1^e, d_1 and s_1, and using (1), (10) and (11). The first order condition implies

$$\begin{aligned} i_1 = \frac{1}{\left(1+\alpha\right)^2+\delta\alpha u_i^2}&\left[\left(1+\alpha\right)^2\left(\bar{r}+\pi_1^e\right)-\alpha\left(1+\alpha\right)\left(\tau-\pi_1^e\right)+\delta\alpha u_i\left(\tau-u_0\right)\right. \\ &\left.-\delta\alpha u_i\left(u_d\xi_1^d+u_s\xi_1^s\right)+\left(1+\alpha\right)^2 d_1-\alpha\left(1+\alpha\right)s_1\right] \end{aligned} \tag{12}$$

The updating coefficients u_0, u_i, u_d and u_s can be found using the condition for rational expectations: $\pi_2^e = \mathrm{E}_1\left[\pi_2|i_1\right]$. Taking expectations and rearranging (9) gives $\pi_2^e = \mathrm{E}_1\left[\tau|i_1\right]$. Before tackling the general case, it is instructive to first consider the special case of perfect economic transparency.

3.1 Perfect Economic Transparency

In the case of perfect economic transparency, which is indicated by superscript T, $\kappa_d = \kappa_s = 1$, so that $d_t = \xi_t^d$ and $s_t = \xi_t^s$. In that case, (12) can be used to infer the central bank's inflation target τ from the interest rate i_1: $\mathrm{E}_1^T\left[\tau|i_1\right] = \tau$. Hence, $\left(\pi_2^e\right)^T = \mathrm{E}_1^T\left[\tau|i_1\right] = \tau$. Solving (12) for τ, matching coefficients with (11) and rearranging yields[1]

[1]The derivation is available in appendix A.1.

$$u_0^T = (\pi_1^e)^T + \frac{1+\alpha}{\alpha}\left[\bar{r} + (\pi_1^e)^T\right] \tag{13}$$

$$u_i^T = -\frac{1+\alpha}{\alpha} \tag{14}$$

$$u_d^T = \frac{1+\alpha}{\alpha} \tag{15}$$

$$u_s^T = -1 \tag{16}$$

Intuitively, a higher interest rate i_1 reduces inflation expectations ($u_i^T < 0$) as it is (correctly) attributed to a lower inflation target τ. In addition, a higher (perceived) demand shock ξ_1^d leads to higher inflation expectations π_2^e for a given interest rate i_1 ($u_d^T > 0$) as the inflation target τ implied by i_1 rises. Similarly, a higher (perceived) supply shock ξ_1^s lowers inflation expectations π_2^e given i_1 ($u_s^T < 0$) as the implied inflation target τ declines.

Substituting these updating equations into (12), using $\xi_t^d = d_t$ and $\xi_t^s = s_t$, and simplifying produces the nominal interest rate under perfect economic transparency:

$$i_1^T = \bar{r} + (\pi_1^e)^T - \frac{\alpha}{1+\alpha}\left[\tau - (\pi_1^e)^T\right] + d_1 - \frac{\alpha}{1+\alpha}s_1 \tag{17}$$

Substituting (17) into (3) and (4), and imposing rational expectations (so that $(\pi_1^e)^T = \bar{\tau}$) gives

$$y_1^T = \bar{y} + \frac{\alpha}{1+\alpha}(\tau - \bar{\tau}) + \frac{\alpha}{1+\alpha}s_1 \tag{18}$$

$$\pi_1^T = \bar{\tau} + \frac{\alpha}{1+\alpha}(\tau - \bar{\tau}) - \frac{1}{1+\alpha}s_1 \tag{19}$$

These expressions are similar to the ones for the second period. Demand shocks are again completely offset by monetary policy.

Finally, the expected payoff to the central bank under perfect economic transparency can be found using (2) after substituting (18) and (19) into (1) and $(\pi_2^e)^T = \tau$ into (10):

$$\mathrm{E}\left[U^T|\tau\right] = -\frac{1}{2}\frac{\alpha}{1+\alpha}(\tau - \bar{\tau})^2 - \frac{1}{2}\frac{\alpha}{1+\alpha}(1+\delta)\,\sigma_s^2. \tag{20}$$

This shows that the expected payoff to the central bank is decreasing in the difference between the inflation target τ and the public's prior of it $\bar{\tau}$, and in the variance of supply shocks σ_s^2. The variance of demand shocks σ_d^2 is immaterial as they are fully offset under economic transparency.

3.2 General Case

Except for the special case of perfect economic transparency, the nominal interest rate i_1 and the public signals ξ_1^d and ξ_1^s generally do not suffice to infer the central bank's inflation target τ. To find the updating coefficients, use the fact that (12) implies that i_1 and τ have a jointly normal distribution, so that

$$\pi_2^e = \mathrm{E}_1[\tau|i_1] = \mathrm{E}_1[\tau] + \frac{\mathrm{Cov}_1\{i_1,\tau\}}{\mathrm{Var}_1[i_1]}(i_1 - \mathrm{E}_1[i_1]) \tag{21}$$

where a moment operator with subscript 1 indicates it is conditional on Ω_1. Using (12), (5) and (6), and matching coefficients between (21) and (11), and rearranging gives the following expression for u_i:[2]

$$\begin{aligned} &-\delta\alpha^2\sigma_\tau^2 u_i^2 \\ &\quad + (1+\alpha)\left[\alpha(\alpha-\delta)\sigma_\tau^2 + (1+\alpha)^2(1-\kappa_d)\sigma_d^2 + \alpha^2(1-\kappa_s)\sigma_s^2\right]u_i \\ &\quad\quad + \alpha(1+\alpha)^2\sigma_\tau^2 = 0. \end{aligned}$$

This equation has two real roots, $u_i^- < 0$ and $u_i^+ > 0$. However, the positive root u_i^+ can be excluded based on an argument by McCallum (1983). The reason is that u_i^+ is not valid for all admissible parameter values, because $\lim_{\kappa_d,\kappa_s\to 1} u_i^+ \neq u_i^T$. The remaining negative root can be written as

$$\begin{aligned} u_i = \frac{1+\alpha}{2\delta\alpha^2\sigma_\tau^2}\Bigg\{ & \alpha(\alpha-\delta)\sigma_\tau^2 + (1+\alpha)^2(1-\kappa_d)\sigma_d^2 + \alpha^2(1-\kappa_s)\sigma_s^2 \\ & - \sqrt{\begin{array}{c}\left[\alpha(\alpha+\delta)\sigma_\tau^2 + (1+\alpha)^2(1-\kappa_d)\sigma_d^2 + \alpha^2(1-\kappa_s)\sigma_s^2\right]^2 \\ -4\delta\alpha\left[(1+\alpha)^2(1-\kappa_d)\sigma_d^2 + \alpha^2(1-\kappa_s)\sigma_s^2\right]\sigma_\tau^2\end{array}}\Bigg\} \end{aligned} \tag{22}$$

From this it follows that $u_i \geq -(1+\alpha)/\alpha$, with a strict inequality if $\kappa_d \neq 1$ and/or $\kappa_s \neq 1$. Hence, $|u_i| \leq |u_i^T|$; the magnitude of the effect of the interest rate on inflation expectations is smaller under opacity because it is a noisier signal of the inflation target. Concerning intermediate degrees of transparency, $du_i/d\kappa_m \leq 0$ with a strict inequality if $\sigma_m^2 > 0$, where $m \in \{d,s\}$ denotes the macroeconomic shock. So, the magnitude of the sensitivity u_i of private sector inflation expectations π_2^e to the policy rate i_1 is increasing in the degree of economic transparency κ_m as the policy rate becomes a more accurate signal of the inflation target.

[2]The derivations for this section are in Appendix A.2.

Regarding the other updating coefficients, matching coefficients and rearranging gives

$$u_0 = \bar{\tau} + u_i \frac{\alpha}{1+\alpha} \left(\bar{\tau} - \pi_1^e\right) - u_i \left(\bar{r} + \pi_1^e\right) \tag{23}$$

$$u_d = -u_i \tag{24}$$

$$u_s = \frac{\alpha}{1+\alpha} u_i \tag{25}$$

Intuitively, a higher interest rate i_1 reduces inflation expectations ($u_i < 0$) as it is partly attributed to a lower inflation target τ. In addition, a higher perceived demand [supply] shock ξ_1^d [ξ_1^s] leads to higher [lower] inflation expectations π_2^e for a given interest rate i_1 ($u_d > 0$, $u_s < 0$) as the inflation target τ implied by i_1 rises [falls]. Compared to perfect economic transparency, these effects are qualitatively the same, but they are more muted since the private sector faces greater uncertainty about these signals.

Substituting these updating coefficients into (12), using (5) and (6), and simplifying gives the nominal interest rate:

$$\begin{aligned} i_1 = {} & \bar{r} + \pi_1^e - \frac{\alpha}{1+\alpha} \left(\tau - \pi_1^e\right) + (1-\mu) \left(\frac{\alpha}{1+\alpha} + \frac{1}{u_i}\right) (\tau - \bar{\tau}) \\ & + \left(\xi_1^d + \mu \eta_1^d\right) - \frac{\alpha}{1+\alpha} \left(\xi_1^s + \mu \eta_1^s\right) \end{aligned} \tag{26}$$

where $\mu \equiv \frac{(1+\alpha)^2}{(1+\alpha)^2 + \delta \alpha u_i^2}$ $(0 < \mu < 1)$. Note that in the special case of perfect economic transparency, $u_i = -(1+\alpha)/\alpha$, $d_1 = \xi_1^d$, $s_1 = \xi_1^s$ and $\eta_1^d = \eta_1^s = 0$, so that (26) reduces to (17). Demand and supply shocks that are publicly anticipated (ξ_1^d and ξ_1^s) have the same effect as under transparency. However, the responsiveness of the interest rate to economic disturbances that are not anticipated by the private sector (η_1^d and η_1^s) is smaller under opacity. The reason is that the central bank is concerned about affecting private sector inflation expectations. As a consequence, (publicly unanticipated) demand shocks are no longer completely offset.

Substitute (26) into (3) and (4), use (5) and (6), and impose rational expectations (which yields $\pi_1^e = \bar{\tau}$) to get output and inflation:

$$\begin{aligned} y_1 = {} & \bar{y} + \left[\frac{\alpha}{1+\alpha} - (1-\mu) \left(\frac{\alpha}{1+\alpha} + \frac{1}{u_i}\right)\right] (\tau - \bar{\tau}) \\ & + (1-\mu) \eta_1^d + \frac{\alpha}{1+\alpha} \left(\xi_1^s + \mu \eta_1^s\right) \end{aligned} \tag{27}$$

$$\begin{aligned} \pi_1 = {} & \bar{\tau} + \left[\frac{\alpha}{1+\alpha} - (1-\mu) \left(\frac{\alpha}{1+\alpha} + \frac{1}{u_i}\right)\right] (\tau - \bar{\tau}) \\ & + (1-\mu) \eta_1^d - \frac{1}{1+\alpha} \left(\xi_1^s + \left[1 + (1-\mu)\alpha\right] \eta_1^s\right) \end{aligned} \tag{28}$$

Although demand shocks anticipated by the public (ξ_1^d) are perfectly offset, the central bank mutes its response to publicly unanticipated demand shocks (η_1^d), which therefore affect both output and inflation. A publicly anticipated (deflationary) supply shock (ξ_1^s) leads to more expansionary monetary policy, which raises output and partly offsets the effect of the shock on inflation. For publicly unanticipated supply shocks (η_1^s), the central bank responds less so that the effect on output is smaller and the impact on inflation is larger. Note that $u_i < 0$ and $0 < \mu < 1$ imply that the coefficient of $(\tau - \bar{\tau})$ is positive. Intuitively, if the inflation target τ is higher than the public's prior $\bar{\tau}$, the central bank implements more expansionary policy than anticipated, which increases both output and inflation. In the special case of perfect economic transparency, $u_i = -(1+\alpha)/\alpha$, $d_1 = \xi_1^d$, $s_1 = \xi_1^s$ and $\eta_1^d = \eta_1^s = 0$, so that (27) and (28) reduce to (18) and (19), respectively.

Using (26), $\pi_1^e = \bar{\tau}$ and the fact that $\text{Var}[\eta_t^m] = (1-\kappa_m)\sigma_m^2$ and $\text{Var}[\xi_t^m] = \kappa_m \sigma_m^2$, where $m \in \{d, s\}$ denotes the macroeconomic shock, the volatility of the interest rate i_1 (for a given inflation target τ) equals[3]

$$\text{Var}[i_1|\tau] = \left[1 - \left(1-\mu^2\right)(1-\kappa_d)\right]\sigma_d^2 + \frac{\alpha^2}{(1+\alpha)^2}\left[1 - \left(1-\mu^2\right)(1-\kappa_s)\right]\sigma_s^2 \quad (29)$$

In the case of perfect economic transparency ($\kappa_d = \kappa_s = 1$), this reduces to $\text{Var}\left[i_1^T|\tau\right] = \sigma_d^2 + \frac{\alpha^2}{(1+\alpha)^2}\sigma_s^2$. Clearly, $\text{Var}[i_1|\tau] \leq \text{Var}\left[i_1^T|\tau\right]$, with a strict inequality in the case of some economic opacity ($\kappa_d \neq 1$ or $\kappa_s \neq 1$). Intuitively, the lack of economic transparency induces the central bank to limit its adjustment of the policy rate in response to macroeconomic shocks to avoid affecting private sector inflation expectations. As a result, economic opacity causes the central bank to engage in interest rate 'smoothing'.

Regarding the volatility of output and inflation (given the inflation target τ), (27) and (28) imply that

$$\text{Var}[y_1|\tau] = (1-\mu)^2(1-\kappa_d)\sigma_d^2 + \frac{\alpha^2}{(1+\alpha)^2}\left[1 - \left(1-\mu^2\right)(1-\kappa_s)\right]\sigma_s^2 \quad (30)$$

$$\begin{aligned}\text{Var}[\pi_1|\tau] &= (1-\mu)^2(1-\kappa_d)\sigma_d^2 \\ &\quad + \frac{1}{(1+\alpha)^2}\left[\kappa_s + \left[1+(1-\mu)\alpha\right]^2(1-\kappa_s)\right]\sigma_s^2\end{aligned} \quad (31)$$

In the case of perfect economic transparency ($\kappa_d = \kappa_s = 1$), this reduces to $\text{Var}\left[y_1^T|\tau\right] = \frac{\alpha^2}{(1+\alpha)^2}\sigma_s^2$ and $\text{Var}\left[\pi_1^T|\tau\right] = \frac{1}{(1+\alpha)^2}\sigma_s^2$. This shows that economic transparency reduces output volatility due to demand shocks, but increases it for supply shocks, so the net

[3] Note that $1 - \left(1-\mu^2\right)(1-\kappa_m) = \kappa_m + \mu^2(1-\kappa_m)$.

effect is ambiguous. The variance of inflation is unambiguously lower under economic transparency for both demand and supply shocks, so that $\text{Var}[\pi_1|\tau] \geq \text{Var}\left[\pi_1^T|\tau\right]$.[4] The intuition is that the enhanced flexibility under economic transparency allows the central bank to respond more vigorously to demand shocks, which decreases the variance of both output and inflation, and to supply shocks, which increases output volatility but reduces inflation variability.

The degree of opacity also affects macroeconomic volatility in the second period due to the noise it creates in private sector inflation expectations π_2^e. Substituting (23), (24), (25) and (26) into (11) produces

$$\pi_2^e = \tau - \mu\left(1 + \frac{\alpha}{1+\alpha}u_i\right)(\tau - \bar{\tau}) + u_i\mu\eta_1^d - \frac{\alpha}{1+\alpha}u_i\mu\eta_1^s \tag{32}$$

Intuitively, economic shocks η^d and η^s that are unanticipated by the public affect their inflation expectations because the corresponding interest rate response is partially attributed to the central bank's inflation target. In the case of perfect economic transparency, $u_i = -(1+\alpha)/\alpha$ and $\eta_1^d = \eta_1^s = 0$, yielding $(\pi_2^e)^T = \tau$, as in section 3.1. The volatility of private sector inflation expectations (for a given inflation target τ) are equal to

$$\text{Var}[\pi_2^e|\tau] = u_i^2\mu^2(1-\kappa_d)\sigma_d^2 + \left(\frac{\alpha}{1+\alpha}\right)^2 u_i^2\mu^2(1-\kappa_s)\sigma_s^2 \tag{33}$$

Clearly, $\text{Var}[\pi_2^e|\tau] \geq \text{Var}\left[(\pi_2^e)^T|\tau\right] = 0$, with a strict inequality in the case of some economic opacity ($\kappa_d \neq 1$ or $\kappa_s \neq 1$).

Regarding the variability of the interest rate, output and inflation in the second period, (7), (8) and (9) yield

$$\begin{aligned}
\text{Var}[i_2|\tau] &= \left(1 + \frac{\alpha}{1+\alpha}\right)^2 \text{Var}[\pi_2^e|\tau] + \sigma_d^2 + \left(\frac{\alpha}{1+\alpha}\right)^2 \sigma_s^2 \\
\text{Var}[y_2|\tau] &= \left(\frac{\alpha}{1+\alpha}\right)^2 \left\{\text{Var}[\pi_2^e|\tau] + \sigma_s^2\right\} \\
\text{Var}[\pi_2|\tau] &= \left(\frac{1}{1+\alpha}\right)^2 \left\{\text{Var}[\pi_2^e|\tau] + \sigma_s^2\right\}
\end{aligned}$$

So, $\text{Var}[i_2|\tau] \geq \text{Var}\left[i_2^T|\tau\right]$, $\text{Var}[y_2|\tau] \geq \text{Var}\left[y_2^T|\tau\right]$ and $\text{Var}[\pi_2|\tau] \geq \text{Var}\left[\pi_2^T|\tau\right]$, with a strict inequality in the case of some economic opacity ($\kappa_m \neq 1$). As a result, the greater stability of private sector inflation expectations under economic transparency contributes to lower overall macroeconomic volatility in the second period.

[4] To see this, note that $\kappa_s + [1 + (1-\mu)\alpha]^2(1-\kappa_s) = 1 + [2 + (1-\mu)\alpha](1-\mu)\alpha(1-\kappa_s)$.

4 Effects of Greater Macroeconomic Transparency

The previous section has derived how perfect transparency about macroeconomic shocks affects the interest rate, inflation (expectations) and output. This section examines intermediate degrees of transparency and shows the effect of greater macroeconomic transparency on the volatility of the interest rate, inflation (expectations) and output (in section 4.1) and on expected social welfare (in section 4.2).

4.1 Macroeconomic Volatility

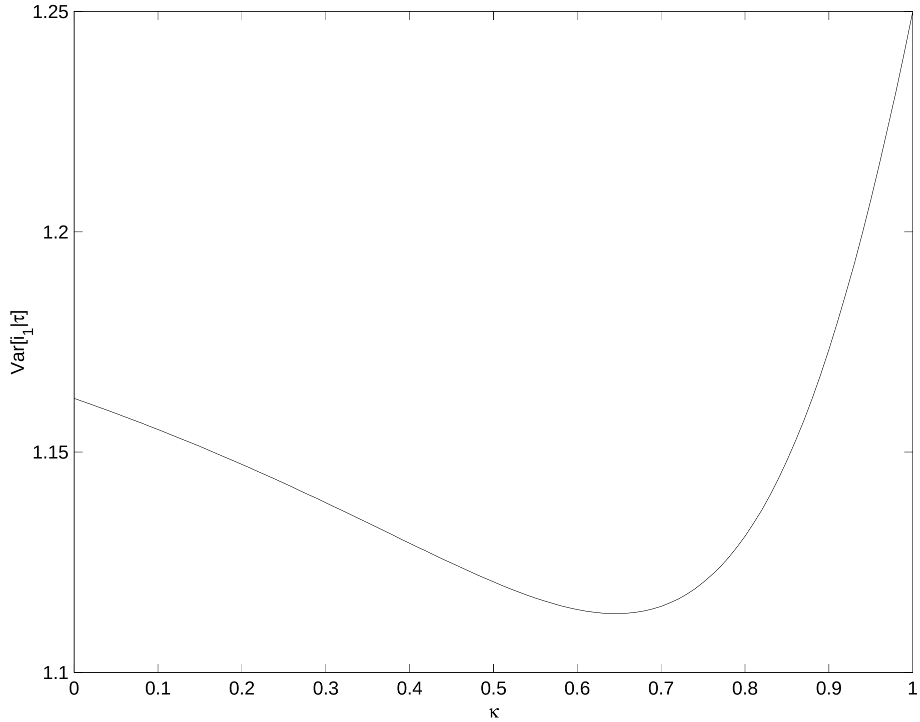
The analysis so far has shown that perfect economic transparency (i.e. $\kappa_d = \kappa_s = 1$) leads to greater interest rate variability ($\mathrm{Var}\left[i_1|\tau\right]$), but reduces the volatility of inflation and inflation expectations ($\mathrm{Var}\left[\pi_1|\tau\right]$ and $\mathrm{Var}\left[\pi_2^e|\tau\right]$), while the effect on output volatility ($\mathrm{Var}\left[y_1|\tau\right]$) is ambiguous. For intermediate degrees of transparency, (29), (30), (31) and (33) show that the effect of a change in κ_m depends on $d\mu/d\kappa_m$. Since $d\mu/du_i > 0$ and $du_i/d\kappa_m < 0$ it follows that $d\mu/d\kappa_m < 0$.[5] So, the effect of κ_m on macroeconomic volatility is in principle ambiguous.

To facilitate the analysis, assume that $\kappa_d = \kappa_s = \kappa$, i.e. the degree of economic transparency is the same for demand and supply shocks. Then it is straightforward to show that $\lim_{\kappa\to 1} d\,\mathrm{Var}\left[i_1|\tau\right]/d\kappa > 0$, $\lim_{\kappa\to 1} d\,\mathrm{Var}\left[\pi_1|\tau\right]/d\kappa < 0$ and $\lim_{\kappa\to 1} d\,\mathrm{Var}\left[\pi_2^e|\tau\right]/d\kappa < 0$. So, greater macroeconomic transparency increases interest rate variability but decreases the volatility of inflation and inflation expectations for sufficiently high κ. For lower κ the effects tend to be reversed. This is illustrated in Figures 1, 2 and 4 for the parameter configuration $\alpha = \delta = 1$ and $\sigma_\tau^2 = \sigma_d^2 = \sigma_s^2 = 1$.

Figure 1 shows that starting from complete opacity ($\kappa = 0$), higher macroeconomic transparency κ initially reduces and subsequently increases interest rate variability. Intuitively, for low levels of economic transparency, the interest rate i_1 is dominated by the central bank's response to publicly unanticipated shocks η_1^m. As the degree of economic transparency rises, the public rationally increases its reliance on the interest rate i_1 to update its inflation expectations π_2^e, so the central bank reduces its response to unanticipated shocks to prevent upsetting private sector expectations. Hence, the variability of the interest rate i_1 initially declines. But for a sufficiently high level of economic transparency, publicly anticipated shocks ξ_1^m start prevailing. Since the central bank need not mute its response to these shocks, the variance of the interest rate increases as anticipated shocks become more important at higher levels of economic transparency. As a result, there is a

[5] Recall that $\mu \equiv (1+\alpha)^2 / \left[(1+\alpha)^2 + \delta\alpha u_i^2\right]$ and $u_i < 0$.

Figure 1: The effect of economic transparency on interest rate variability



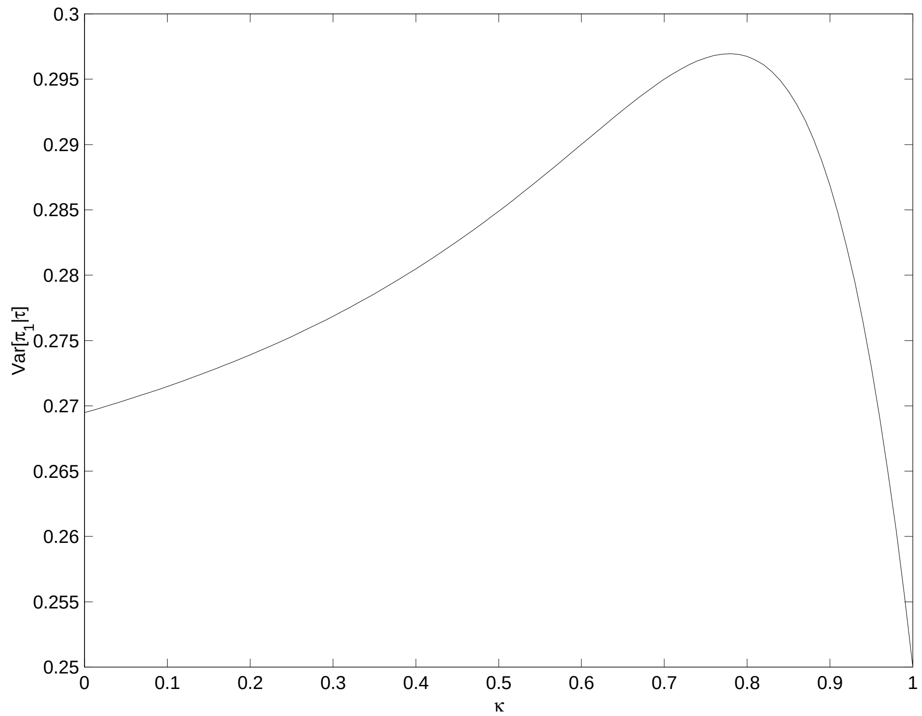
The effect of economic transparency κ for parameter values $\alpha = \delta = 1$ and $\sigma_\tau^2 = \sigma_d^2 = \sigma_s^2 = 1$.

U-shaped effect on interest rate volatility.

Figure 2 shows that more macroeconomic transparency κ initially raises and subsequently reduces inflation volatility in period one. As explained above, a rise in economic transparency causes the central bank to reduce its interest rate response to publicly unanticipated shocks, which therefore cause greater inflation volatility. But for higher levels of economic transparency, publicly anticipated shocks start becoming more important. These are adequately offset by the central bank, resulting in a reduction of the variability of inflation.

The effect of higher macroeconomic transparency κ on output volatility in period one exhibits a more peculiar pattern. For the baseline case of $\alpha = \delta = 1$ and $\sigma_\tau^2 = \sigma_d^2 = \sigma_s^2 = 1$ shown in Figure 3, the variance of y_1 is initially decreasing, then increasing and finally decreasing again. However, this result is very sensitive to the parameter values. In particular, for higher values of α or σ_s^2, or lower values of σ_d^2 the response becomes U-shaped, whereas for higher values of σ_τ^2, the response becomes hump-shaped. Clearly, the effect of macroeconomic transparency on first period output volatility critically depends on the precise parameter configuration.

Figure 2: The effect of economic transparency on inflation volatility

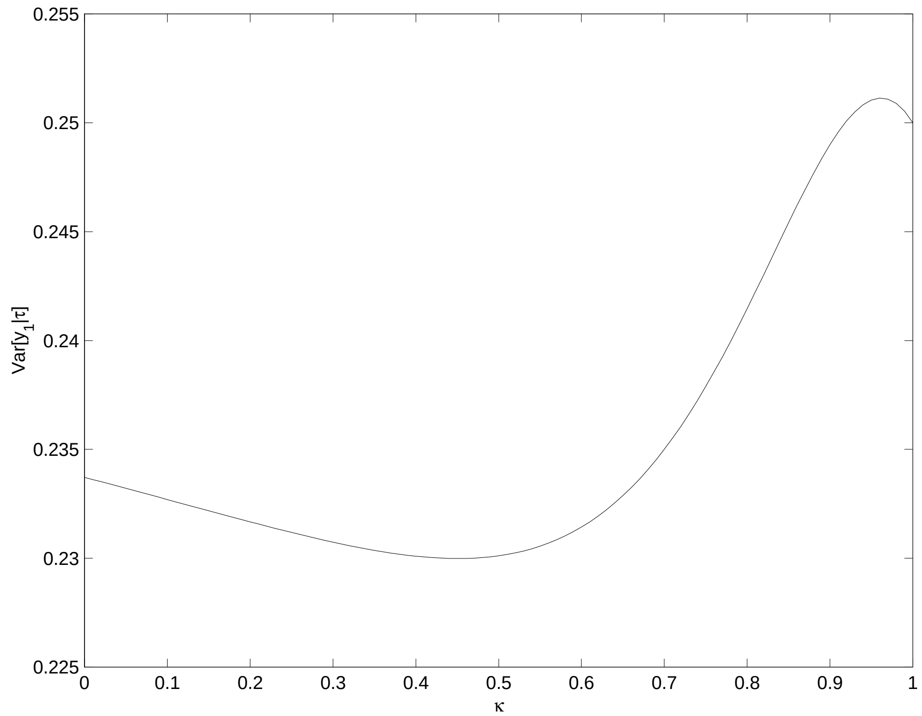


The effect of economic transparency κ for parameter values $\alpha = \delta = 1$ and $\sigma_\tau^2 = \sigma_d^2 = \sigma_s^2 = 1$.

In the second period, greater macroeconomic transparency κ initially raises and subsequently reduces the volatility of private sector inflation expectations, as shown in Figure 4. The same holds for the volatility of the interest rate, output and inflation in period two. Intuitively, only macroeconomic shocks η_1^m that are not anticipated by the public affect its expectations. When the degree of economic transparency goes up, the public rationally relies more on the interest rate i_1 to update its inflation expectations π_2^e since it becomes a better signal of the central bank's intentions τ. This also raises the response of expectations to the noise caused by unanticipated shocks, which initially increases the volatility of inflation expectations. However, as the degree of economic transparency further rises, the unanticipated shocks start diminishing in importance and the variance of private sector inflation expectations declines.

The U-shaped effect of macroeconomic transparency κ on $\mathrm{Var}\,[i_1|\tau]$ in Figure 1 and the hump-shaped effect for $\mathrm{Var}\,[\pi_1|\tau]$ and $\mathrm{Var}\,[\pi_2^e|\tau]$ in Figures 2 and 4 are fairly typical for reasonable parameter values, but they are by no means universal. Intuitively, the U-shaped and hump-shaped patterns arise from the differential effects of publicly unanticipated macroeconomic disturbances η_1^m, which dominate when economic transparency

Figure 3: The effect of economic transparency on output volatility



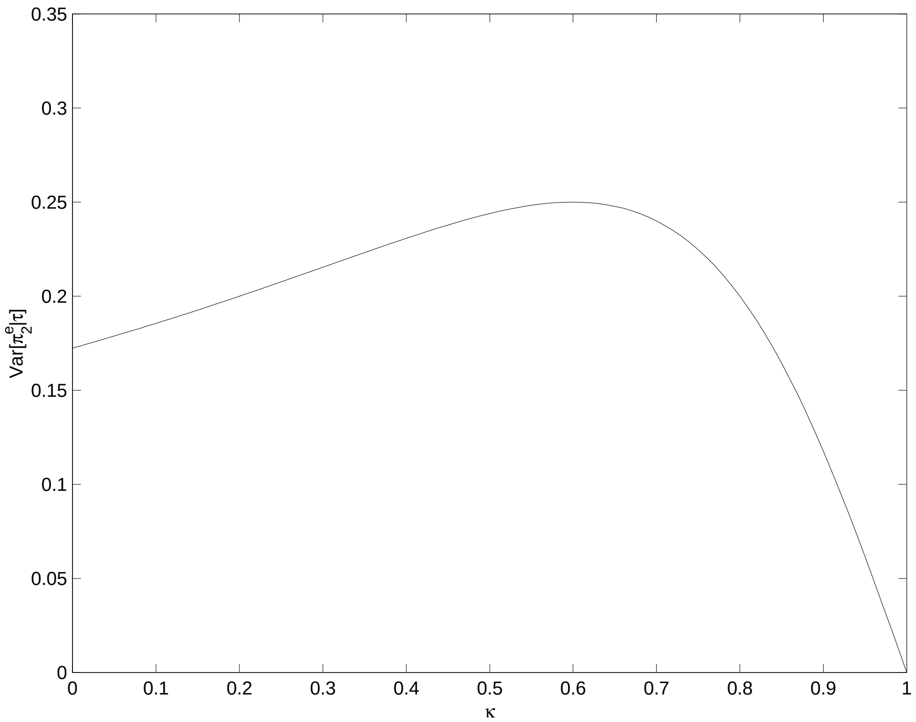
The effect of economic transparency κ for parameter values $\alpha = \delta = 1$ and $\sigma_\tau^2 = \sigma_d^2 = \sigma_s^2 = 1$.

is low, and publicly anticipated shocks ξ_1^m, which prevail when economic transparency is high. But the latter may already dominate straightaway, depending on the parameter values.

To assess the robustness of the results, a grid search was conducted for $\alpha \in \{0.1, 0.25 : 0.25 : 10\}$, $\delta \in [0.5 : 0.1 : 1]$, $\sigma_\tau^2 \in \{0.1, 0.25 : 0.25 : 10\}$, $\sigma_d^2 \in \{0.1, 0.25 : 0.25 : 10\}$ and $\sigma_s^2 \in \{0.1, 0.25 : 0.25 : 10\}$, covering 16,954,566 parameter configurations.[6] For this parameter space, the result of a U-shaped effect on the variability of the interest rate i_1 and/or the hump-shaped effect on the volatility of inflation π_1 and inflation expectations π_2^e does not hold for 14.99% of parameter values. Although the exceptions occur throughout the parameter space, there is a systematic deviation from the usual pattern when σ_τ^2 is large relative to σ_d^2 and/or σ_s^2. In particular, when macroeconomic volatility σ_m^2 is sufficiently small compared to preference uncertainty σ_τ^2, $\text{Var}[i_1|\tau]$ is monotonically increasing in κ, and $\text{Var}[\pi_1|\tau]$ and $\text{Var}[\pi_2^e|\tau]$ are monotonically decreasing. More formally, for $\sigma_m^2 \to 0$,

[6] Values of α, σ_τ^2, σ_d^2 or σ_s^2 closer to zero are not used as they regularly give rise to numerical problems when computing (22).

Figure 4: The effect of economic transparency on the volatility of inflation expectations



The effect of economic transparency κ for parameter values $\alpha = \delta = 1$ and $\sigma_\tau^2 = \sigma_d^2 = \sigma_s^2 = 1$.

$du_i/d\kappa \to 0$ so $d\mu/d\kappa \to 0$.[7] Hence, (29), (31) and (33) yield $\lim_{\sigma_m^2 \to 0} d\,\mathrm{Var}\left[i_1|\tau\right]/d\kappa > 0$, $\lim_{\sigma_m^2 \to 0} d\,\mathrm{Var}\left[\pi_1|\tau\right]/d\kappa < 0$ and $\lim_{\sigma_m^2 \to 0} d\,\mathrm{Var}\left[\pi_2^e|\tau\right]/d\kappa < 0$. In other words, relatively low macroeconomic volatility yields the same result as high macroeconomic transparency ($\kappa \to 1$), which is an intuitive finding.

4.2 Welfare Analysis

The analysis so far has shown that the effect of economic transparency on the volatility of inflation and output tends to be nonmonotonic. Even the effect of perfect economic transparency ($\kappa = 1$) appears ambiguous as the variance is lower for π_1, π_2 and y_2, but may be higher for y_1. Thus, it is essential to conduct a welfare analysis. Assume that the social welfare function is the same as the central bank's objective function: (1) and (2). This is a useful benchmark because it means that monetary policy is not affected by a principal-agent problem, but only by transparency issues.

[7]This follows from (43).

Substituting (32) into (10) yields:

$$\mathrm{E}[W_2] = -\frac{1}{2}\frac{\alpha}{1+\alpha}\left\{\mu^2\left(1+\frac{\alpha}{1+\alpha}u_i\right)^2\sigma_\tau^2 + u_i^2\mu^2(1-\kappa_d)\sigma_d^2 + \left[\frac{\alpha^2}{(1+\alpha)^2}u_i^2\mu^2(1-\kappa_s)+1\right]\sigma_s^2\right\} \tag{34}$$

Under perfect economic transparency, $u_i = -(1+\alpha)/\alpha$ and $\kappa_d = \kappa_s = 1$, so $\mathrm{E}\left[W_2^T\right] = -\frac{1}{2}\frac{\alpha}{1+\alpha}\sigma_s^2 > \mathrm{E}[W_2]$. Not surprisingly, opacity is socially detrimental in period two as it makes private sector inflation expectations π_2^e more noisy and thereby increases the volatility of macroeconomic outcomes in the second period.

Substituting (27) and (28) into (1) produces after some rearranging:[8]

$$\begin{aligned}\mathrm{E}[W_1] \;=\; & -\frac{1}{2}\frac{\alpha}{1+\alpha}\left\{1+\alpha(1-\mu)^2\left(\frac{1+\alpha}{\alpha u_i}+1\right)^2\right\}\sigma_\tau^2 \\ & -\frac{1}{2}(1+\alpha)(1-\mu)^2(1-\kappa_d)\sigma_d^2 - \frac{1}{2}\frac{\alpha}{1+\alpha}\left\{1+\alpha(1-\mu)^2(1-\kappa_s)\right\}\sigma_s^2\end{aligned} \tag{35}$$

Under perfect economic transparency, $u_i = -(1+\alpha)/\alpha$ and $\kappa_d = \kappa_s = 1$, so $\mathrm{E}\left[W_1^T\right] = -\frac{1}{2}\frac{\alpha}{1+\alpha}\sigma_\tau^2 - \frac{1}{2}\frac{\alpha}{1+\alpha}\sigma_s^2 > \mathrm{E}[W_1]$. Intuitively, economic transparency reduces the variance of inflation and output due to demand shocks. Although there is greater output volatility due to supply shocks, this actually allows the central bank to achieve a more desirable trade-off between inflation and output volatility. Hence, perfect economic transparency is socially beneficial in period one.

Substituting (35) and (34) into (2) yields

$$\mathrm{E}[U] = -\frac{1}{2}A_\tau\sigma_\tau^2 - \frac{1}{2}A_d\sigma_d^2 - \frac{1}{2}A_s\sigma_s^2 \tag{36}$$

where

$$A_\tau = \frac{\alpha}{1+\alpha}\left\{1+\delta\mu\left(1+\frac{\alpha}{1+\alpha}u_i\right)^2\right\} \tag{37}$$

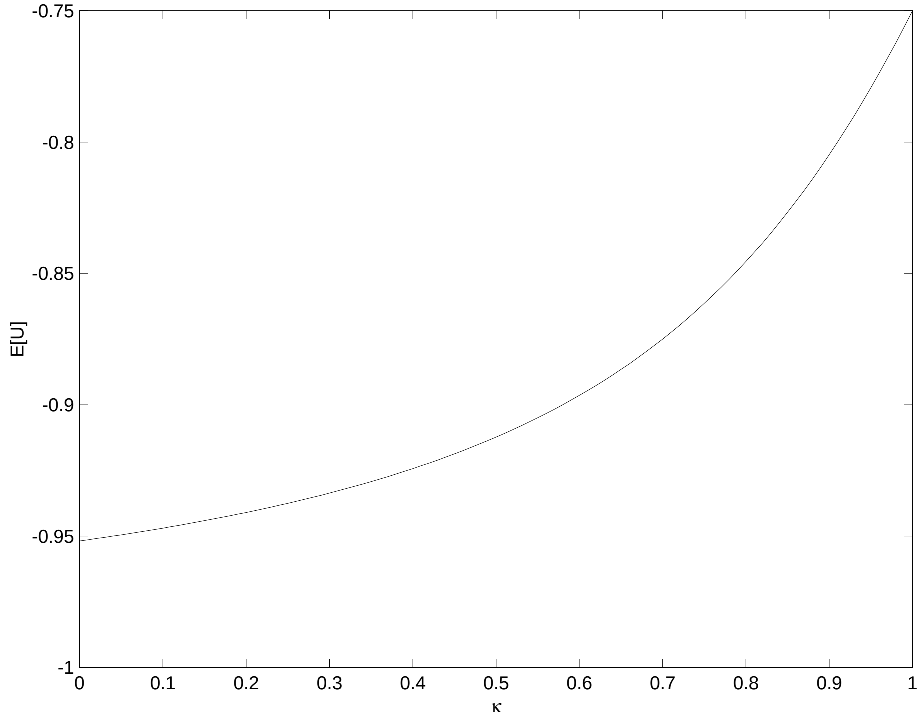
$$A_d = (1+\alpha)(1-\mu)(1-\kappa_d) \tag{38}$$

$$A_s = \frac{\alpha}{1+\alpha}\left\{1+\delta+\alpha(1-\mu)(1-\kappa_s)\right\} \tag{39}$$

Note that $A_\tau > 0$, $A_d > 0$ and $A_s > 0$, so greater uncertainty about the inflation target τ and a higher volatility of demand and supply disturbances all increase social welfare losses. In the special case of perfect economic transparency, $u_i = -(1+\alpha)/\alpha$ and

[8] The derivations for this section are in Appendix A.3.

Figure 5: The effect of economic transparency on expected social welfare



The effect of economic transparency κ for parameter values $\alpha = \delta = 1$ and $\sigma_\tau^2 = \sigma_d^2 = \sigma_s^2 = 1$.

$\kappa_d = \kappa_s = 1$, so $A_\tau^T = \frac{\alpha}{1+\alpha}$, $A_d^T = 0$ and $A_s^T = \frac{\alpha}{1+\alpha}(1+\delta)$. Clearly, $A_\tau^T \leq A_\tau$, $A_d^T \leq A_d$ and $A_s^T \leq A_s$, with a strict inequality if $\kappa_m \neq 1$. So, perfect economic transparency is socially optimal, as could already have been inferred immediately from the welfare effects for period one and two.

Concerning intermediate degrees of economic transparency, it is straightforward to show that $dA_\tau/d\kappa_m \leq 0$ using the fact that $d\mu/d\kappa_m < 0$ and $du_i/d\kappa_m < 0$. However, A_d and A_s are generally nonmonotonic in κ_d and κ_s, respectively. Assuming again that $\kappa_d = \kappa_s = \kappa$, Figure 5 shows that the net effect of κ on $\mathrm{E}[U]$ is unambiguously positive for the baseline parameter configuration with $\alpha = \delta = 1$ and $\sigma_\tau^2 = \sigma_d^2 = \sigma_s^2 = 1$. Moving from complete economic opacity ($\kappa = 0$) to full transparency ($\kappa = 1$) reduces expected social welfare losses stemming from macroeconomic volatility by over 20%.

The result that greater economic transparency is welfare improving holds more generally. In particular, it can be shown that $\mathrm{E}[U]$ is monotonically increasing in κ:

$$\frac{d\,\mathrm{E}[U]}{d\kappa} = \frac{1}{2}\frac{1-\mu}{1+\alpha}\left[(1+\alpha)^2\sigma_d^2 + \alpha^2\sigma_s^2\right] > 0 \tag{40}$$

As a result, the net effect of greater economic transparency on expected social welfare is always positive. Intuitively, it gives the central bank more flexibility to offset demand shocks without worrying about perturbing private sector inflation expectations. For the same reason, the central bank is able to achieve a more desirable trade-off between inflation and output volatility due to supply shocks.

5 Discussion

The model shows how macroeconomic transparency gives the central bank greater flexibility to stabilize aggregate demand and supply shocks. In fact, central banks that are opaque about macroeconomic shocks optimally decide to engage in interest rate smoothing to prevent undesired effects on private sector inflation expectations. As a result, opaque central banks effectively become less conservative in their reaction to supply shocks and no longer fully offset aggregate demand shocks they anticipate.

Nevertheless, more macroeconomic transparency could lead to greater volatility of inflation (expectations) and output, in particular when the degree of macroeconomic transparency is low and preference transparency is high. This finding is similar to Morris and Shin (2002), who show that greater transparency about economic fundamentals increases economic volatility when public signals are noisy compared to private signals (i.e. economic transparency is low). But their result relies on a coordination motive of private agents that induces them to put greater weight on the public signal, whereas this paper considers a signal extraction problem that is not distorted by other motives.

Although greater macroeconomic transparency could increase volatility, it is always welfare improving in the model. Of course, this result may be sensitive to the assumptions of the model. For instance, since high levels of economic transparency make the interest rate more volatile, they may no longer be desirable if the central bank directly cares about interest rate volatility, for instance because of financial stability considerations. In addition, if the central bank's objective does not coincide with social welfare due to the presence of a principal-agent problem, opacity may be beneficial because it leads to a level of inflation that is closer to the public's prior and slows down the updating of inflation expectations. So, economic opacity could be advantageous, similar to the finding by Geraats (2007), who considers a model in which political pressures make monetary mystique desirable.

6 Conclusion

Central banks have increasingly become transparent about macroeconomic prospects, often far beyond any formal disclosure requirements. This paper shows that such macroeconomic transparency may be beneficial to the central bank. The reason is that it allows the central bank to stabilize macroeconomic shocks without disturbing private sector inflation expectations. This makes it easier for the central bank to reach its macroeconomic objectives of inflation and output gap stabilization. But when there is opacity about the shocks to which the central bank responds, the policy rate becomes a noisier signal of the central bank's inflationary intentions, which induces greater volatility of private sector inflation expectations. To mitigate this problem, the central bank mutes the stabilization of macroeconomic shocks, leading to interest rate smoothing under opacity. In particular, an opaque central bank no longer fully offsets aggregate demand shocks it anticipates to avoid upsetting inflation expectations. As a result, opacity leads to undesirable macroeconomic volatility. The paper shows that expected social welfare is monotonically increasing in the degree of macroeconomic transparency. This helps to explain why so many central banks have become more transparent about macroeconomic shocks.

A Appendix

This appendix derives (13), (14), (15) and (16) in section A.1, and (23), (22), (24) and (25) in section A.2.

A.1 Perfect Economic Transparency

In the special case of perfect economic transparency $\kappa_d = \kappa_s = 1$, so that $d_t = \xi_t^d$ and $s_t = \xi_t^s$. Use this to solve (12) for τ:

$$\tau = \frac{1}{\alpha(1+\alpha) - \delta\alpha u_i} \left\{ -\left[\left((1+\alpha)^2 + \delta\alpha u_i^2\right)\right] i_1 + (1+\alpha)^2 \bar{r} + \left[(1+\alpha)^2 + \alpha(1+\alpha)\right] \pi_1^e \right. \\ \left. -\delta\alpha u_i u_0 + \left[-\delta\alpha u_i u_d + (1+\alpha)^2\right] \xi_1^d - \left[\delta\alpha u_i u_s + \alpha(1+\alpha)\right] \xi_1^s \right\}$$

Then, use $(\pi_2^e)^T = \mathrm{E}_1^T [\tau | i_1] = \tau$ and match coefficients with (11):

$$\begin{aligned}
u_0 &= \frac{1}{\alpha(1+\alpha) - \delta\alpha u_i} \left\{ (1+\alpha)^2 \bar{r} + \left[(1+\alpha)^2 + \alpha(1+\alpha)\right] \pi_1^e - \delta\alpha u_i u_0 \right\} \\
u_i &= -\frac{(1+\alpha)^2 + \delta\alpha u_i^2}{\alpha(1+\alpha) - \delta\alpha u_i} \\
u_d &= \frac{1}{\alpha(1+\alpha) - \delta\alpha u_i} \left[-\delta\alpha u_i u_d + (1+\alpha)^2\right] \\
u_s &= -\frac{1}{\alpha(1+\alpha) - \delta\alpha u_i} \left[\delta\alpha u_i u_s + \alpha(1+\alpha)\right]
\end{aligned}$$

Solving these equations yields (13), (14), (15) and (16):

$$\begin{aligned}
u_0^T &= \frac{1}{\alpha(1+\alpha)} \left\{ (1+\alpha)^2 \bar{r} + \left[(1+\alpha)^2 + \alpha(1+\alpha)\right] (\pi_1^e)^T \right\} = (\pi_1^e)^T + \frac{1+\alpha}{\alpha} \left(\bar{r} + (\pi_1^e)^T\right) \\
u_i^T &= -\frac{1+\alpha}{\alpha} \\
u_d^T &= \frac{1+\alpha}{\alpha} \\
u_s &= -1
\end{aligned}$$

A.2 General Case

To derive the updating coefficients for the general case, first substitute (5) and (6) into (12):

$$i_1 = \frac{1}{(1+\alpha)^2 + \delta\alpha u_i^2} \left\{ (1+\alpha)^2 (\bar{r} + \pi_1^e) - \alpha(1+\alpha)(\tau - \pi_1^e) + \delta\alpha u_i (\tau - u_0) \right. \\ + \left[-\delta\alpha u_i u_d + (1+\alpha)^2\right] \xi_1^d - \left[\delta\alpha u_i u_s + \alpha(1+\alpha)\right] \xi_1^s \\ \left. + (1+\alpha)^2 \eta_t^d - \alpha(1+\alpha) \eta_t^s \right\} \tag{41}$$

As a result,

$$\begin{aligned}
\mathrm{Cov}_1\{i_1,\tau\} &= -\frac{1}{(1+\alpha)^2+\delta\alpha u_i^2}\left[\alpha(1+\alpha)-\delta\alpha u_i\right]\sigma_\tau^2 \\
\mathrm{Var}_1[i_1] &= \frac{1}{\left[(1+\alpha)^2+\delta\alpha u_i^2\right]^2}\Big\{\left[\alpha(1+\alpha)-\delta\alpha u_i\right]^2\sigma_\tau^2 \\
&\quad +(1+\alpha)^4(1-\kappa_d)\sigma_d^2+\alpha^2(1+\alpha)^2(1-\kappa_s)\sigma_s^2\Big\}
\end{aligned}$$

recalling that $\mathrm{Var}\left[\eta_t^d\right]=(1-\kappa_d)\sigma_d^2$ and $\mathrm{Var}\left[\eta_t^s\right]=(1-\kappa_s)\sigma_s^2$. So, matching coefficients between (21) and (11) yields

$$u_i=-\frac{\left[(1+\alpha)^2+\delta\alpha u_i^2\right]\left[\alpha(1+\alpha)-\delta\alpha u_i\right]\sigma_\tau^2}{\left[\alpha(1+\alpha)-\delta\alpha u_i\right]^2\sigma_\tau^2+(1+\alpha)^4(1-\kappa_d)\sigma_d^2+\alpha^2(1+\alpha)^2(1-\kappa_s)\sigma_s^2}$$

Rearranging gives

$$\begin{aligned}
&\left[\alpha(1+\alpha)-\delta\alpha u_i\right]^2 u_i\sigma_\tau^2+\left\{(1+\alpha)^4(1-\kappa_d)\sigma_d^2+\alpha^2(1+\alpha)^2(1-\kappa_s)\sigma_s^2\right\}u_i= \\
&\qquad -\left[(1+\alpha)^2+\delta\alpha u_i^2\right]\alpha(1+\alpha)\sigma_\tau^2+\left[(1+\alpha)^2+\delta\alpha u_i^2\right]\delta\alpha u_i\sigma_\tau^2
\end{aligned}$$

Note that $\delta^2\alpha^2u_i^3\sigma_\tau^2$ drops out from both sides, leaving the quadratic equation

$$\begin{aligned}
&-\delta\alpha^2\sigma_\tau^2u_i^2 \\
&+(1+\alpha)\left[\alpha(\alpha-\delta)\sigma_\tau^2+(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2\right]u_i \\
&\qquad +\alpha(1+\alpha)^2\sigma_\tau^2 \qquad = 0
\end{aligned} \tag{42}$$

This equation has two real roots, $u_i^+>0$ and $u_i^-<0$:

$$\begin{aligned}
u_i &= \frac{1+\alpha}{2\delta\alpha^2\sigma_\tau^2}\Bigg\{\alpha(\alpha-\delta)\sigma_\tau^2+(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2 \\
&\quad \pm\sqrt{\begin{array}{c}\left[\alpha(\alpha-\delta)\sigma_\tau^2+(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2\right]^2 \\ +4\delta\alpha^2\sigma_\tau^2\alpha\sigma_\tau^2\end{array}}\Bigg\}
\end{aligned}$$

The argument of the square root can be rearranged as follows:

$$\begin{aligned}
&\left[\alpha(\alpha-\delta)\sigma_\tau^2+(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2\right]^2+4\delta\alpha^2\sigma_\tau^2\alpha\sigma_\tau^2= \\
&\qquad \left[\alpha(\alpha+\delta)\sigma_\tau^2+(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2\right]^2 \\
&\qquad\qquad -4\delta\alpha\left[(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2\right]\sigma_\tau^2
\end{aligned}$$

Substitute this into u_i^- to obtain (22):

$$\begin{aligned}
u_i &= \frac{1+\alpha}{2\delta\alpha^2\sigma_\tau^2}\Bigg\{\alpha(\alpha-\delta)\sigma_\tau^2+(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2 \\
&\quad -\sqrt{\begin{array}{c}\left[\alpha(\alpha+\delta)\sigma_\tau^2+(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2\right]^2 \\ -4\delta\alpha\left[(1+\alpha)^2(1-\kappa_d)\sigma_d^2+\alpha^2(1-\kappa_s)\sigma_s^2\right]\sigma_\tau^2\end{array}}\Bigg\}
\end{aligned}$$

Note that

$$\begin{aligned}
u_i &\geq \frac{1+\alpha}{2\delta\alpha^2\sigma_\tau^2}\left\{\alpha\left(\alpha-\delta\right)\sigma_\tau^2+\left(1+\alpha\right)^2\left(1-\kappa_d\right)\sigma_d^2+\alpha^2\left(1-\kappa_s\right)\sigma_s^2\right. \\
&\quad \left. -\left[\alpha\left(\alpha+\delta\right)\sigma_\tau^2+\left(1+\alpha\right)^2\left(1-\kappa_d\right)\sigma_d^2+\alpha^2\left(1-\kappa_s\right)\sigma_s^2\right]\right\} \\
&= -\frac{1+\alpha}{\alpha}
\end{aligned}$$

where the lower bound is reached if $\sigma_d^2 \to 0$ and $\sigma_s^2 \to 0$ or if $\kappa_d = \kappa_s = 1$. Hence, $-\frac{1+\alpha}{\alpha} = u_i^T \leq u_i < 0$.

Using (42) it follows from the implicit function theorem that

$$\begin{aligned}
\frac{du_i}{d\kappa_d} &= \frac{\left(1+\alpha\right)^3\sigma_d^2 u_i}{-2\delta\alpha^2\sigma_\tau^2 u_i+\left(1+\alpha\right)\left[\alpha\left(\alpha-\delta\right)\sigma_\tau^2+\left(1+\alpha\right)^2\left(1-\kappa_d\right)\sigma_d^2+\alpha^2\left(1-\kappa_s\right)\sigma_s^2\right]} \\
\frac{du_i}{d\kappa_s} &= \frac{\left(1+\alpha\right)\alpha^2\sigma_s^2 u_i}{-2\delta\alpha^2\sigma_\tau^2 u_i+\left(1+\alpha\right)\left[\alpha\left(\alpha-\delta\right)\sigma_\tau^2+\left(1+\alpha\right)^2\left(1-\kappa_d\right)\sigma_d^2+\alpha^2\left(1-\kappa_s\right)\sigma_s^2\right]}
\end{aligned}$$

Substituting for the term in square brackets using (42) and simplifying yields

$$\begin{aligned}
\frac{du_i}{d\kappa_d} &= \frac{\left(1+\alpha\right)^3\sigma_d^2 u_i^2}{-2\delta\alpha^2\sigma_\tau^2 u_i^2+\delta\alpha^2\sigma_\tau^2 u_i^2-\alpha\left(1+\alpha\right)^2\sigma_\tau^2} = -\frac{\left(1+\alpha\right)^3\sigma_d^2 u_i^2}{\delta\alpha^2\sigma_\tau^2 u_i^2+\alpha\left(1+\alpha\right)^2\sigma_\tau^2} \\
\frac{du_i}{d\kappa_s} &= \frac{\left(1+\alpha\right)\alpha^2\sigma_s^2 u_i^2}{-2\delta\alpha^2\sigma_\tau^2 u_i^2+\delta\alpha^2\sigma_\tau^2 u_i^2-\alpha\left(1+\alpha\right)^2\sigma_\tau^2} = -\frac{\left(1+\alpha\right)\alpha^2\sigma_s^2 u_i^2}{\delta\alpha^2\sigma_\tau^2 u_i^2+\alpha\left(1+\alpha\right)^2\sigma_\tau^2}
\end{aligned}$$

Hence, $\frac{du_i}{d\kappa_d} < 0$ and $\frac{du_i}{d\kappa_s} < 0$. When the degree of economic transparency is the same for demand and supply shocks, i.e. $\kappa_d = \kappa_s = \kappa$, then

$$\frac{du_i}{d\kappa} = -\frac{\left(1+\alpha\right)^2\sigma_d^2+\alpha^2\sigma_s^2}{\left[\delta\alpha u_i^2+\left(1+\alpha\right)^2\right]\alpha\sigma_\tau^2}\left(1+\alpha\right)u_i^2 = -\frac{\left(1+\alpha\right)^2\sigma_d^2+\alpha^2\sigma_s^2}{\left(1+\alpha\right)\alpha\sigma_\tau^2}\mu u_i^2 < 0 \qquad (43)$$

using the fact that $\mu \equiv \frac{(1+\alpha)^2}{(1+\alpha)^2+\delta\alpha u_i^2} > 0$ implies $\frac{\delta\alpha u_i^2}{(1+\alpha)^2} = \frac{1-\mu}{\mu}$.

To derive the other updating coefficients, write (21) as $\pi_2^e = \bar{\tau} + u_i i_1 - u_i \mathrm{E}_1\left[i_1\right]$ and use (41) to substitute for $\mathrm{E}_1\left[i_1\right]$. Then, matching coefficients between (21) and (11) yields:

$$\begin{aligned}
u_0 &= \bar{\tau} - \frac{u_i}{\left(1+\alpha\right)^2+\delta\alpha u_i^2}\left\{\left(1+\alpha\right)^2\left(\bar{r}+\pi_1^e\right)-\alpha\left(1+\alpha\right)\left(\bar{\tau}-\pi_1^e\right)+\delta\alpha u_i\left(\bar{\tau}-u_0\right)\right\} \\
u_d &= -\frac{u_i}{\left(1+\alpha\right)^2+\delta\alpha u_i^2}\left[-\delta\alpha u_i u_d+\left(1+\alpha\right)^2\right] \\
u_s &= \frac{u_i}{\left(1+\alpha\right)^2+\delta\alpha u_i^2}\left[\delta\alpha u_i u_s+\alpha\left(1+\alpha\right)\right]
\end{aligned}$$

Rearranging each equation gives (23), (24) and (25):

$$\begin{aligned} u_0 &= \bar{\tau} + u_i \frac{\alpha}{1+\alpha}\left(\bar{\tau} - \pi_1^e\right) - u_i\left(\bar{r} + \pi_1^e\right) = -\frac{\alpha}{1+\alpha} u_i \pi_1^e + \left(1 + \frac{\alpha}{1+\alpha} u_i\right)\bar{\tau} - u_i\left(\bar{r} + \pi_1^e\right) \\ u_d &= -u_i \\ u_s &= \frac{\alpha}{1+\alpha} u_i \end{aligned}$$

Substituting these updating coefficients into (12) and using (5) and (6) yields (26):

$$\begin{aligned} i_1 = & \frac{1}{(1+\alpha)^2 + \delta\alpha u_i^2}\Big\{(1+\alpha)^2\left(\bar{r} + \pi_1^e\right) - \alpha(1+\alpha)\left(\tau - \pi_1^e\right) \\ & + \delta\alpha u_i\left(\tau - \bar{\tau} - u_i\frac{\alpha}{1+\alpha}\left(\bar{\tau} - \pi_1^e\right) + u_i\left(\bar{r} + \pi_1^e\right)\right) \\ & + \delta\alpha u_i^2 \xi_1^d - \delta\alpha u_i^2 \frac{\alpha}{1+\alpha}\xi_1^s + (1+\alpha)^2 d_1 - \alpha(1+\alpha) s_1\Big\} \\ = & \frac{(1+\alpha)^2}{(1+\alpha)^2 + \delta\alpha u_i^2}\left\{\left[1 + \frac{\delta\alpha u_i^2}{(1+\alpha)^2}\right]\left(\bar{r} + \pi_1^e\right) - \frac{\alpha}{1+\alpha}\left(\tau - \pi_1^e\right)\right. \\ & \left. + \frac{\delta\alpha u_i}{(1+\alpha)^2}\left[\left(1 + u_i\frac{\alpha}{1+\alpha}\right)\left(\tau - \bar{\tau}\right) - u_i\frac{\alpha}{1+\alpha}\left(\tau - \pi_1^e\right)\right]\right\} \\ & + (1-\mu)\left(\xi_1^d - \frac{\alpha}{1+\alpha}\xi_1^s\right) + \mu d_1 - \mu\frac{\alpha}{1+\alpha} s_1 \\ = & \bar{r} + \pi_1^e - \frac{\alpha}{1+\alpha}\left(\tau - \pi_1^e\right) + (1-\mu)\left(\frac{1}{u_i} + \frac{\alpha}{1+\alpha}\right)\left(\tau - \bar{\tau}\right) \\ & + \left(\xi_1^d + \mu\eta_1^d\right) - \frac{\alpha}{1+\alpha}\left(\xi_1^s + \mu\eta_1^s\right) \end{aligned}$$

where $\mu \equiv \frac{(1+\alpha)^2}{(1+\alpha)^2 + \delta\alpha u_i^2}$ $(0 < \mu < 1)$.

Substituting (26) into (3) and (4), and using (24) and (25) produces

$$\begin{aligned} y_1 &= \bar{y} + \frac{\alpha}{1+\alpha}\left(\tau - \pi_1^e\right) - (1-\mu)\left(\frac{1}{u_i} + \frac{\alpha}{1+\alpha}\right)\left(\tau - \bar{\tau}\right) \\ &\quad + (1-\mu)\eta_1^d + \frac{\alpha}{1+\alpha}\xi_1^s + \mu\frac{\alpha}{1+\alpha}\eta_1^s \\ \pi_1 &= \pi_1^e + \frac{\alpha}{1+\alpha}\left(\tau - \pi_1^e\right) - (1-\mu)\left(\frac{1}{u_i} + \frac{\alpha}{1+\alpha}\right)\left(\tau - \bar{\tau}\right) \\ &\quad + (1-\mu)\eta_1^d - \frac{1}{1+\alpha}\xi_1^s - \left(1 - \mu\frac{\alpha}{1+\alpha}\right)\eta_1^s \end{aligned}$$

Use the latter equation and impose rational expectations (i.e. $\pi_1^e = \mathrm{E}\left[\pi_1\right]$) to get $\pi_1^e = \bar{\tau}$.

As a result, (27) and 28) follow:

$$\begin{aligned} y_1 &= \bar{y} + \left[\frac{\alpha}{1+\alpha} - (1-\mu)\left(\frac{1}{u_i} + \frac{\alpha}{1+\alpha}\right)\right](\tau - \bar{\tau}) \\ &+ (1-\mu)\,\eta_1^d + \frac{\alpha}{1+\alpha}\left(\xi_1^s + \mu\eta_1^s\right) \\ \pi_1 &= \bar{\tau} + \left[\frac{\alpha}{1+\alpha} - (1-\mu)\left(\frac{1}{u_i} + \frac{\alpha}{1+\alpha}\right)\right](\tau - \bar{\tau}) \\ &+ (1-\mu)\,\eta_1^d - \frac{1}{1+\alpha}\left(\xi_1^s + (1 + (1-\mu)\,\alpha)\,\eta_1^s\right) \end{aligned}$$

To find second period inflation expectations, substitute (23), (24) and (25) into (11) to get

$$\pi_2^e = \bar{\tau} + u_i\frac{\alpha}{1+\alpha}\left(\bar{\tau} - \pi_1^e\right) + u_i\left[i_1 - \left(\bar{r} + \pi_1^e\right)\right] - u_i\xi_1^d + \frac{\alpha}{1+\alpha}u_i\xi_1^s$$

Substituting (26) then yields (32):

$$\pi_2^e = \tau - \mu\left(1 + \frac{\alpha}{1+\alpha}u_i\right)(\tau - \bar{\tau}) + u_i\mu\eta_1^d - \frac{\alpha}{1+\alpha}u_i\mu\eta_1^s$$

This reduces to $(\pi_2^e)^T = \tau$ in the case of perfect economic transparency as $u_i = -(1+\alpha)/\alpha$ and $\eta_1^d = \eta_1^s = 0$.

A.3 Welfare Analysis

Substituting (32) into (10) yields (34):

$$\mathrm{E}\left[W_2\right] = -\frac{1}{2}\frac{\alpha}{1+\alpha}\left\{\mu^2\left(1 + \frac{\alpha}{1+\alpha}u_i\right)^2\sigma_\tau^2 + u_i^2\mu^2\left(1-\kappa_d\right)\sigma_d^2 + \left[\frac{\alpha^2}{(1+\alpha)^2}u_i^2\mu^2\left(1-\kappa_s\right) + 1\right]\sigma_s^2\right\}$$

Substituting (27) and (28) into (1) produces (35) after some rearranging:

$$\begin{aligned}
\mathrm{E}\left[W_1\right] &= -\frac{1}{2}\alpha\left\{\left[\frac{1}{1+\alpha}+(1-\mu)\left(\frac{1}{u_i}+\frac{\alpha}{1+\alpha}\right)\right]^2\sigma_\tau^2\right. \\
&\qquad \left. +(1-\mu)^2(1-\kappa_d)\,\sigma_d^2+\frac{1}{(1+\alpha)^2}\left[\kappa_s+(1+(1-\mu)\,\alpha)^2(1-\kappa_s)\right]\sigma_s^2\right\} \\
&\quad -\frac{1}{2}\left\{\left[\frac{\alpha}{1+\alpha}-(1-\mu)\left(\frac{1}{u_i}+\frac{\alpha}{1+\alpha}\right)\right]^2\sigma_\tau^2\right. \\
&\qquad \left. +(1-\mu)^2(1-\kappa_d)\,\sigma_d^2+\frac{\alpha^2}{(1+\alpha)^2}\left[\kappa_s+\mu^2(1-\kappa_s)\right]\sigma_s^2\right\} \\
&= -\frac{1}{2}\left\{\frac{\alpha}{1+\alpha}+(\alpha+1)(1-\mu)^2\left(\frac{1}{u_i}+\frac{\alpha}{1+\alpha}\right)^2\right\}\sigma_\tau^2 \\
&\quad -\frac{1}{2}(1+\alpha)(1-\mu)^2(1-\kappa_d)\,\sigma_d^2 \\
&\quad -\frac{1}{2}\frac{\alpha}{(1+\alpha)^2}\left\{(1+\alpha)\,\kappa_s+\left[(1+\alpha-\alpha\mu)^2+\alpha\mu^2\right](1-\kappa_s)\right\}\sigma_s^2 \\
&= -\frac{1}{2}\frac{\alpha}{1+\alpha}\left\{1+\alpha(1-\mu)^2\left(\frac{1+\alpha}{\alpha u_i}+1\right)^2\right\}\sigma_\tau^2 \\
&\quad -\frac{1}{2}(1+\alpha)(1-\mu)^2(1-\kappa_d)\,\sigma_d^2-\frac{1}{2}\frac{\alpha}{1+\alpha}\left\{1+\alpha(1-\mu)^2(1-\kappa_s)\right\}\sigma_s^2
\end{aligned}$$

Substituting (35) and (34) into (2) yields

$$\mathrm{E}\left[U\right]=-\frac{1}{2}A_\tau\sigma_\tau^2-\frac{1}{2}A_d\sigma_d^2-\frac{1}{2}A_s\sigma_s^2$$

where

$$\begin{aligned}
A_\tau &= \frac{\alpha}{1+\alpha}\left\{1+\left[(1-\mu)^2\frac{(1+\alpha)^2}{\alpha u_i^2}+\delta\mu^2\right]\left(1+\frac{\alpha}{1+\alpha}u_i\right)^2\right\} \\
A_d &= (1+\alpha)(1-\mu)^2(1-\kappa_d)+\frac{\alpha}{1+\alpha}\delta u_i^2\mu^2(1-\kappa_d) \\
A_s &= \frac{\alpha}{1+\alpha}\left\{1+\alpha(1-\mu)^2(1-\kappa_s)+\delta\left[\frac{\alpha^2}{(1+\alpha)^2}u_i^2\mu^2(1-\kappa_s)+1\right]\right\}
\end{aligned}$$

Using the fact that $\mu\equiv\frac{(1+\alpha)^2}{(1+\alpha)^2+\delta\alpha u_i^2}$ implies $\frac{\delta\alpha u_i^2}{(1+\alpha)^2}=(1-\mu)/\mu$, rearranging gives (37), (38) and (39):

$$\begin{aligned}
A_\tau &= \frac{\alpha}{1+\alpha}\left[1+\delta\mu\left(1+\frac{\alpha}{1+\alpha}u_i\right)^2\right] \\
A_d &= (1+\alpha)(1-\mu)(1-\kappa_d) \\
A_s &= \frac{\alpha}{1+\alpha}\left[1+\delta+\alpha(1-\mu)(1-\kappa_s)\right]
\end{aligned}$$

It is straightforward to show that

$$\frac{dA_\tau}{du_i} = \frac{\alpha}{1+\alpha}\left[\delta\left(1+\frac{\alpha}{1+\alpha}u_i\right)^2\frac{d\mu}{du_i} + 2\frac{\alpha}{1+\alpha}\delta\mu\left(1+\frac{\alpha}{1+\alpha}u_i\right)\right] \geq 0$$

using $\frac{d\mu}{du_i} = -\mu^2\frac{2\delta\alpha u_i}{(1+\alpha)^2} > 0$ and $u_i \geq -\frac{1+\alpha}{\alpha}$, with a strict inequality if $\kappa \neq 1$. Since $du_i/d\kappa_m < 0$ it follows that $dA_\tau/d\kappa_m \leq 0$, with a strict inequality if $\kappa_m \neq 1$. However, A_d and A_s are generally nonmonotonic in κ_d and κ_s, respectively. So, it is important to investigate the net effect of κ on $\mathrm{E}[U]$. Using (36), (37), (38) and (39) and substituting (43) gives

$$\begin{aligned}
\frac{d\,\mathrm{E}[U]}{d\kappa} &= -\frac{1}{2}\left\{\frac{\alpha}{1+\alpha}\left[\delta\left(1+\frac{\alpha}{1+\alpha}u_i\right)^2\frac{d\mu}{du_i} + 2\frac{\alpha}{1+\alpha}\delta\mu\left(1+\frac{\alpha}{1+\alpha}u_i\right)\right]\frac{du_i}{d\kappa}\sigma_\tau^2\right.\\
&\qquad\left.-\frac{1}{1+\alpha}\left[(1-\kappa)\frac{d\mu}{d\kappa}+(1-\mu)\right]\left[(1+\alpha)^2\sigma_d^2+\alpha^2\sigma_s^2\right]\right\}\\
&= \frac{1}{2}\frac{1}{1+\alpha}\left\{\left[-\delta\left(1+\frac{\alpha}{1+\alpha}u_i\right)^2\mu^2\frac{2\delta\alpha u_i}{(1+\alpha)^2} + 2\frac{\alpha}{1+\alpha}\delta\mu\left(1+\frac{\alpha}{1+\alpha}u_i\right)\right]\frac{\mu u_i^2}{1+\alpha}\right.\\
&\qquad\left.+\left[(1-\kappa)\mu^2\frac{2\delta\alpha u_i}{(1+\alpha)^2}\frac{(1+\alpha)^2\sigma_d^2+\alpha^2\sigma_s^2}{(1+\alpha)\alpha\sigma_\tau^2}\mu u_i^2 + (1-\mu)\right]\right\}\left[(1+\alpha)^2\sigma_d^2+\alpha^2\sigma_s^2\right]\\
&= \frac{1}{2}\frac{1-\mu}{1+\alpha}\left\{-\delta\left(1+\frac{\alpha}{1+\alpha}u_i\right)^2\mu^2\frac{2u_i}{1+\alpha} + 2\mu\left(1+\frac{\alpha}{1+\alpha}u_i\right)\right.\\
&\qquad\left.+\left[2\mu^2\frac{\delta\alpha u_i^2-(1+\alpha)^2-(1+\alpha)(\alpha-\delta)u_i}{(1+\alpha)^2}+1\right]\right\}\left[(1+\alpha)^2\sigma_d^2+\alpha^2\sigma_s^2\right]
\end{aligned}$$

where the last equality uses the fact that $\frac{\delta\alpha u_i^2}{(1+\alpha)^2} = \frac{1-\mu}{\mu}$ and substitutes for $(1-\kappa)\left[(1+\alpha)^2\sigma_d^2+\alpha^2\sigma_s^2\right]u_i$ using (42). The term in curly brackets can be further simplified to

$$\begin{aligned}
&\left[-\delta\left(1+\frac{\alpha}{1+\alpha}u_i\right)\mu^2\frac{2u_i}{1+\alpha}+2\mu-2\mu^2\right]\left(1+\frac{\alpha}{1+\alpha}u_i\right)+2\mu(1-\mu)+2\mu^2\frac{\delta u_i}{1+\alpha}+1\\
&\qquad= -\delta\mu^2\frac{2u_i}{1+\alpha}\left(1+\frac{\alpha}{1+\alpha}u_i\right)+2\mu(1-\mu)+2\mu^2\frac{\delta u_i}{1+\alpha}+1 = 1
\end{aligned}$$

Therefore, the effect of greater economic transparency on expected social welfare is unambiguously positive:

$$\frac{d\,\mathrm{E}[U]}{d\kappa} = \frac{1}{2}\frac{1-\mu}{1+\alpha}\left[(1+\alpha)^2\sigma_d^2+\alpha^2\sigma_s^2\right] > 0$$

References

Barro, R. J. and Gordon, D. B. (1983), 'A positive theory of monetary policy in a natural rate model', *Journal of Political Economy* **91**(1), 589–610.

Bernanke, B. S. and Woodford, M. (1997), 'Inflation forecasts and monetary policy', *Journal of Money, Credit, and Banking* **29**(4), 653–686.

Cukierman, A. (2001), Accountability, credibility, transparency and stabilization policy in the eurosystem, *in* C. Wyplosz, ed., 'The Impact of EMU on Europe and the Developing Countries', Oxford University Press, chapter 3, pp. 40–75.

Geraats, P. M. (2002), 'Central bank transparency', *Economic Journal* **112**(483), F532–F565.

Geraats, P. M. (2005), 'Transparency and reputation: The publication of central bank forecasts', *Topics in Macroeconomics* **5**(1.1), 1–26.

Geraats, P. M. (2007), 'Political pressures and monetary mystique', CESifo Working Paper 1999.

Geraats, P. M. (2009), 'Trends in monetary policy transparency', *International Finance* **12**(2), 235–268.

Gersbach, H. (2003), 'On the negative social value of central banks' knowledge transparency', *Economics of Governance* **4**(2), 91–102.

Jensen, H. (2000), 'Optimal degrees of transparency in monetary policymaking: The case of imperfect information about the cost-push shock', mimeo, University of Copenhagen.

Jensen, H. (2002), 'Optimal degrees of transparency in monetary policymaking', *Scandinavian Journal of Economics* **104**(3), 399–422.

Kydland, F. E. and Prescott, E. C. (1977), 'Rules rather than discretion: The inconsistency of optimal plans', *Journal of Political Economy* **85**(3), 473–491.

McCallum, B. T. (1983), 'On non-uniqueness in rational expectations models: An attempt at perspective', *Journal of Monetary Econonomics* **11**(2), 139–168.

Morris, S. and Shin, H. S. (2002), 'Social value of public information', *American Economic Review* **92**(5), 1521–1534.

Peek, J., Rosengren, E. S. and Tootell, G. M. B. (1999), 'Is bank supervision central to central banking?', *Quarterly Journal of Economics* **114**(2), 629–653.

Romer, C. D. and Romer, D. H. (2000), 'Federal Reserve information and the behavior of interest rates', *American Economic Review* **90**(3), 429–457.

Walsh, C. E. (2007*a*), 'Optimal economic transparency', *International Journal of Central Banking* **3**(1), 5–36.

Walsh, C. E. (2007*b*), Transparency, flexibility, and inflation targeting, *in* F. S. Mishkin and K. Schmidt-Hebbel, eds, 'Monetary Policy Under Inflation Targeting', Banco Central de Chile, pp. 227–263.

Walsh, C. E. (2008), Transparency, the opacity bias, and optimal flexible inflation targeting. Paper presented at the ASSA meetings, January 2008.