Optimal transparency under flexible inflation targeting

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Abstract

Inflation targeting central banks have been at the forefront of the movement for greater transparency. In this paper, I explore a dimension of transparency that is typically ignored in this literature – the extent to which public information provided by the central bank is disseminated. When the private sector has diverse information about aggregate shocks, and this information is less accurate than the central bank's information, widely distributed announcements by the central bank will be optimal for central banks that are flexible inflation targeters as long as the weight on output stabilization is not too large.

1 Introduction

Two of the major developments in central banking over the past fifteen years have been the spread of central bank independence and the increase in monetary policy transparency. Both developments have been fundamentally shaped by the contributions of Alex Cukierman. These two developments are not unrelated. Greater central bank independence requires greater accountability, hence the need for transparency. And newly independent central banks have often adopted inflation targeting as their framework for policy, and inflation targeting central banks have gone the furthest in adopting mechanisms to ensure greater transparency.

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At a minimum, inflation targeting involves the formal announcement of a target for the inflation rate. But in recent years, even central banks that have not formally adopted inflation targeting have become more transparent. Eijffinger and Geraats (2005) provide an index of transparency for a set of developed economies that includes some inflation targeters (Australia, Canada, New Zealand, Sweden, and the UK) as well as non-targeters (Japan, Switzerland, and the US). They find that between 1998 and 2002, transparency increased for virtually all the central banks they studied. Even the Federal Reserve, which has so far resisted calls to establish a formal inflation target, has moved to make its policy practices more transparent.

The formal monetary policy literature on central bank transparency dates to Cukierman and Meltzer (1986). They study a model in which money surprises generate output movement, the central bank's preference for output expansions varies stochastically, and the money supply is subject to a random control error. Cukierman and Meltzer then show that the central bank may prefer to adopt less efficient operating procedures than would be technically feasible (i.e., not reduce the control error variance to its minimum possible level). Private agents observe the current money growth rate, but are unable to disentangle the effects of the control error and the shifts in preferences. Thus, under a less transparent regime, disinflations are more costly as it takes private agents longer to recognize that the central bank's preferences have shifted away from greater output expansion. However, a more transparent regime reduces the ability of the central bank to create economic expansions when they are most desired. These two competing forces determine the optimal degree of transparency.

In this paper, I focus on an alternative way of modeling transparency, one that captures more closely the issues faced today by inflation targeting central banks. For such central banks, the provision of public information is less about allowing the public to learn its shifting preferences and more about revealing the central bank's assessment of the economy as a means of shaping private sector expectations. I analyze issues of transparency in a new Keynesian model. Previous work on transparency generally employed models in which policy has real effects only through its ability to create surprises. In contrast, I employ a model more in line with recent work on monetary policy in which systematic policies are the most effective in influencing the behavior of output and inflation. Rather than interpreting greater transparency as the provision of less noisy information on intentions, I model it as increases in the extent to which the central bank disseminates information about its views on the state of the economy. At one extreme, the central bank may make no announcements. At the other extreme, it may undertake to publish detailed inflation reports that are widely read and discussed by the public. In between these extremes, the central bank may partially publicize information through speeches that reach a limited audience or through less prominent or less widely read press releases.

The paper is organized as follows. Section 2 reviews some of the previous literature on monetary policy transparency. Section 3 sets out the basic model and derives the equilibrium in the absence of announcements. Section 4 analyzes a model of partial announcements along the lines of Cornand and Heinemann (2004). The extent to which information on the central bank's short-run targets is disseminated through the economy provides a measure of transparency.

Before proceeding, it should be noted that I do not address issues of accountability. Accountability is a key concern in designing institutions that lead to good policy outcomes, and the desire for clear objectives, an important means of establishing accountability, is central to discussions of inflation targeting. I focus on the role of transparency for a central bank that already behaves as an inflation targeter. When a central bank has credibly established its reputation for maintaining low and stable inflation, the release of forecasts, targets for inflation, and other information, is a means of providing the public with greater knowledge about the central bank's assessment of the state of the economy.

2 Related work

Faust and Svensson (2002) extend the work of Cukierman and Meltzer by employing quadratic preferences so that the central bank is concerned with inflation stability and with output gap stability, but the bank's desired output level varies stochastically. This desired level is unobserved by the public, and it is serially correlated. As in Cukierman and Meltzer, private agents are unable to identify the effects of a shift in the central bank's desired output target (preferences) from the effects of a control error. Ex post, the central bank reveals a noisy measure of the control error, and the signal to noise ratio of this measure is interpreted as the central bank's degree of transparency. Private agents use this measure to update their estimate of the central bank's output target. Faust and Svensson show that, when the choice of transparency is made under commitment, patient central banks with small inflation biases will prefer minimum transparency. They argue that this result might account for the (then) relatively low degree of transparency that characterized the U.S. Federal Reserve.

Jensen (2002) studies transparency in a framework similar to that of Faust and Svensson but in which inflation is forward looking in a manner consistent with recent monetary policy models. Greater transparency means policy has a larger impact on future expectations and, via this channel, on current equilibrium inflation. This leads to greater caution on the part of the central bank in its policy actions. This improves welfare if the central bank is prone to an inflation bias, but it can limit stabilization policy if the central bank's output objective is already consistent with the economy's natural rate of output.[1]

Like Cukierman and Meltzer, Faust and Svensson (2002) and Jensen (2002) interpret transparency as "the degree to which central-bank intentions can be inferred by outside observers." In contrast, my focus is on economic transparency (Geraats 2002) and the incentives the central bank has to reveal its internal information on the state of the economy.[2] I therefore ignore the

[1] The role of forward-looking expectations in disciplining the central bank is also examined in Walsh (2000).

[2] Walsh (1999, 2003) also investigates aspects of economic transparency. In Walsh (1999), the ability of the

issue of the central bank's intentions that was the focus of Cukierman and Meltzer, Faust and Svensson, and Jensen. My focus is on central banks who have already developed a reputation for maintaining low and stable inflation. The public understands the policymaker will maintain average inflation at zero as well as the manner in which the bank will respond to shocks that lead to short-run fluctuations in inflation and the output gap. Private agents still face uncertainty about monetary policy, however, because they have only imperfect knowledge of the information on which the central bank bases its policy. Simply observing a change in the central bank's instrument does not allow the public to know whether the change is designed to offset a demand shock, in which case neither expected inflation nor the expected output gap may be affected, or the change is in response to a cost shock and so will imply inflation and output gap responses. By being transparent, a central bank reveals its information about the economy to the public.

By providing more information to the public, transparency would seem to be clearly desirable. Recently, however, new questions have been raised about the value of providing more and better information to the public. When private agents have individual sources of information and must base decisions in part on what they expect others are expecting, Morris and Shin (2002) have argued that there can be a cost to providing more accurate public information. In their model, private agents must forecast an underlying shock and attempt to forecast the forecasts of others. This leads to higher order expectations (expectations of expectations of expectations...) playing a role.[3] As a result, agents may over react to public information, making the economy more sensitive to any forecast errors in the public information.

The possibility that the private sector may overreact to central bank announcements does capture a concern expressed by policy makers. For example, in discussing the release of FOMC

central bank to announce a state-contingent inflation target improves stabilization policy, while in Walsh (2003), transparency about the central bank's information improves monitoring by the public and makes it optimal for the central bank to place greater weight on achieving its inflation objectives.

[3] Woodford (2003) has investigated the role of higher order expectations in inducing persistent adjustments to monetary shocks in the Lucas-Phelps islands model. See also Hellwig (2002).

minutes, Janet Yellen expressed the view that "Financial markets could misinterpret and overreact to the minutes." (Yellen 2005). However, Svensson (2005) has argued that the Morris-Shin result is not a general one. In fact, he shows that welfare is increased by more accurate public information in the Morris-Shin model for all but unreasonable parameter values (and so he concludes their message is pro-transparency after all). A similar result is found by Hellwig (2004).

The Morris-Shin analysis is conducted within a framework that fails to capture important aspects of actual monetary policy. Thus, the conclusions they reach suggesting limits to transparency, and the Svensson and Hellwig results in favor of transparency, need to be reexamined in a setting that better captures important aspects of monetary policy and its implementation. For example, the public information in Morris-Shin is a signal on an exogenous disturbance. In fact, most of the monetary policy debate on transparency has focused on the *endogenous* signals a central bank might release. By announcing its inflation forecast, the central bank provides a public signal, but one that is dependent on policy objectives as well as on the central bank's assessment of economic conditions. That is, how strongly (or weakly) the central bank reacts to its estimate of an inflation shock affects the information about the central bank's assessment of the economy that can be drawn from any policy action.

Even in the absence of explicit policy announcements about targets or forecasts, central banks that employ a short-term interest rate as their policy instrument automatically provide public information, as markets can see and react immediately to any change in the policy rate.[4] Besides its direct impact on spending, the interest rate setting signals to firms something about the central bank's beliefs about the state of the economy. And this signal is likely to then affect price setting behavior by firms. Consequently, an interest rate move by the central bank can

[4] In Faust and Svensson (2002) and Jensen (2002), there is an exogenous control error in the link between the central bank's instrument and the output gap. While the central bank is assumed to be unable to affect or react to this control error, it is assumed able to provide the public with accurate information on some fraction of the actual control error. Transparency is then interpreted as a decrease in the volatility of the unannounced component.

affect the economy through channels normally ignored. However, the signal is imperfect; a rise in the interest rate may imply the central bank is forecasting a rise in the Wicksellian real rate or it may signal the forecast of a positive cost shock. Thus, the efforts of private agents to infer what the central bank knows and what other agents think the central bank might know can play a role, even if explicit announcements are not made.

Amato and Shin (2003) have cast the Morris-Shin analysis in a more standard macro model. In their model, the central bank has perfect information about the underlying shocks. This ignores the uncertainty policy makers themselves face in assessing the state of the economy. Nor do Amato and Shin allow the private sector to use observations on the policy instrument to draw inferences about the central bank's information. In fact, market speculation about policy actions often focuses on what the policy change says about the central bank's assessment of the economy; the nominal interest rate may be the primary public signal about monetary policy that a central bank provides.

Furthermore, Amato and Shin (2003) assume one-period price setting and represent monetary policy by a price-level targeting rule. In Hellwig (2004), prices are flexible and policy is given by an exogenous stochastic supply of money; private and public information consists of signals on the nominal quantity of money. In contrast, I employ a standard Calvo-type model of imperfect price flexibility, modifying it by assuming those firms adjusting each period must do so before observing the actual aggregate price level. Thus, the need to infer what other firms are doing is present, as in Amato and Shin and in Hellwig, but the approach is consistent with standard new Keynesian models.

Hellwig provides a more micro-founded analysis that I pursue here, showing that this can be important for assessing the welfare effects of better information. In contrast, my interest is in investigating the role of announcements, not just the provision of less noisy exogenous signals. I focus on the implications for inflation and output gap volatility, as these are the most common measures used to assess macro performance. Some comments on how results might differ if a welfare-based measure were used are discussed in the concluding section.

3 The model

To study the informational role of policy instruments and announcements, I employ a simple new Keynesian model. There are a continuum of firms of measure one, each producing a differentiated product using an identical technology. Firms face a Calvo-type fixed probability of adjusting their price each period. In the standard new Keynesian model, firms have complete and common information about current shocks and about current aggregate equilibrium endogenous variables when setting prices. I assume instead that firms do not observe current shocks or the prices set by other firms until the period is over. Since any firm that is setting its price is concerned with its price relative to those of other firms, it will need to form expectations about the factors that determine its optimal relative price *and* about the behavior of other firms, since it must forecast the average price of other firms. This need to forecast the behavior of others introduces the role for public information stressed by Morris and Shin. Each period, private firms and the central bank receive noisy signals on cost and demand shocks. Each firm's signal is private information to that firm, so individual firms will have different information. The central bank may make an announcement about its output gap target.[5] It then sets its policy instrument. I assume that firms who adjust their price in period t do so after observing the central bank's instrument.

3.1 Price setting behavior

Suppose firm j is setting its price in period t. Let p^*_{jt} denote the log price it chooses. It will be convenient to treat $\pi^*_{jt} \equiv p^*_{jt} - p_{t-1}$ as the choice variable, where p_{t-1} is last period's aggregate log price level. Let $\bar{\pi}^*_t$ be the average of π^*_{jt} across the firms adjusting in period t, and let π_t

[5] In the model, this is equivalent to announcing an inflation target. Give the structure of the model, it is somewhat more straightforward to view any announcement as an announcement about the output target.

be the aggregate inflation rate.

The probability a firm does not have the opportunity to adjust its price is ω. Then

$$p_t = (1 - \omega)\bar{p}_t^* + \omega p_{t-1}, \tag{1}$$

where $\bar{p}_t^* = \int_0^1 p_{jt}^* dj$. Equation (1) implies that $\bar{p}_t^* - p_t = \omega(\bar{p}_t^* - p_{t-1})$ and

$$\pi_t = p_t - p_{t-1} = (1 - \omega)\left(\bar{p}_t^* - p_{t-1}\right) = \left(\frac{1-\omega}{\omega}\right)\left(\bar{p}_t^* - p_t\right). \tag{2}$$

Let φ denote real marginal cost, and assume a steady-state inflation rate of zero. If firm j can adjust its price, it sets its current price equal to the expected discounted value of current and future nominal marginal cost $\varphi + p$. Future marginal cost is discounted by the probability the firm has not received another opportunity to adjust ω and by the discount factor β. In addition, I assume price is affected by a mean zero aggregate cost shock s_t that alters the firm's desired price. Hence,

$$p_{jt}^* = (1 - \omega\beta)\sum_{i=0}^{\infty}(\omega\beta)^i\left(E_t^j\varphi_{t+i} + E_t^j p_{t+i} + E_t^j s_{t+i}\right), \tag{3}$$

where E_t^j denotes the expectations based on the information available to firm j. A key assumption is that prior to setting its price the firm does not observe the aggregate price level or the realization of either current marginal cost or the cost shock. Equation (3) can be re-written as

$$p_{jt}^* = (1 - \omega\beta)E_t^j p_t + (1 - \omega\beta)E_t^j\varphi_t + (1 - \omega\beta)E_t^j s_t + \omega\beta E_t^j p_{jt+1}^*.$$

Individual firms may set different prices because they base expectations on different information sets. To simplify, I assume all information is revealed at the end of each period. This will imply that $E_t^j p_{jt+1}^* = E_t^j \bar{p}_{t+1}^*$; each firm expects that, if it can adjust in $t+1$, it will set the same price as other adjusting firms.

Using (2) and the definition of π^*_{jt}, one obtains, after some manipulation,

$$\pi^*_{jt} = (1-\omega)E^j_t\bar{\pi}^*_t + (1-\omega\beta)E^j_t\varphi_t + (1-\omega\beta)E^j_t s_t + \left(\frac{\omega\beta}{1-\omega}\right)E^j_t\pi_{t+1}, \tag{4}$$

where $\bar{\pi}^*_t = \bar{p}^*_t - p_{t-1}$. Hence, firm j adjusts its price based on its expectations of what other adjusting firms are choosing ($E^j_t\bar{\pi}^*_t$), its expectations about current marginal costs and the cost shock, and on its forecast of next-period aggregate inflation.[6]

Assume real marginal cost is linearly related to an output gap measure x_t: $\varphi_t = \kappa x_t$. Then

$$\pi^*_{jt} = (1-\omega)E^j_t\bar{\pi}^*_t + (1-\omega\beta)\kappa E^j_t x_t + (1-\omega\beta)E^j_t s_t + \left(\frac{\omega\beta}{1-\omega}\right)E^j_t\pi_{t+1}. \tag{5}$$

The firm's decision will depend on its expectations about $\bar{\pi}^*_t$, about the output gap, about future inflation, and about a cost shock, s_t.

It is interesting to contrast this equation with the standard case in which all firms have identical information sets and are able to observe the current disturbances. In the standard Calvo model, $\pi^*_{jt} = \bar{\pi}^*_t$ for all j, so (4) becomes

$$\bar{\pi}^*_t = \left(\frac{1-\omega\beta}{\omega}\right)\kappa x_t + \left(\frac{1-\omega\beta}{\omega}\right)s_t + \frac{\beta}{1-\omega}E_t\pi_{t+1}.$$

Then using (2), this becomes (when shocks are serially correlated and policy operates under

[6] Equation (4) has the form

$$\pi^*_{jt} = (1-\omega)E^j_t\bar{\pi}^*_t + \omega E^j_t\theta_t,$$

where

$$E^j_t\theta_t \equiv \left(\frac{1-\omega\beta}{\omega}\right)E^j_t\varphi_t + \left(\frac{1-\omega\beta}{\omega}\right)E^j_t s_t + \left(\frac{\beta}{1-\omega}\right)E^j_t\pi_{t+1}.$$

This is the basic form of the decision rule at the heart of the Morris-Shin analysis. The adjustment by firm j depends on the firm's expectations about θ and on what firm j expects other firms to do. In Amato and Shin (2003), for example, they obtain $p_{jt} = (1-\xi)E^j_t p_t + \xi E^j_t x_t$, for the price set by firm j, where x is the output gap. In the present analysis, decisions depend on expectations of future inflation, not just on expectations concerning current variables.

discretion)

$$\pi_t = (1-\omega)\pi_t^* = \left[\frac{(1-\omega)(1-\omega\beta)}{\omega}\right](\kappa x_t + s_t) + \beta E_t \pi_{t+1},$$

which differs from the standard form only in the coefficient on the cost shock. This is due to the fact that I include the shock in the equation for the firm's optimal price (3) rather than just adding it on after the equation for inflation has been derived.

3.2 Aggregate demand and monetary policy

I represent monetary policy by the central bank's choice of an instrument x_t^I and by any announcements the central bank might make. I assume x_t^I is observed at the start of the period so that any firm that sets its price in period t can condition its choice on x_t^I. Because the most interesting policy trade offs are generated by cost shocks and not by demand shocks, I model the monetary transmission mechanism from the central bank's instrument to the output gap in the simplest possible way. Specifically, let

$$x_t = x_t^I + v_t, \tag{6}$$

where v_t is a demand shock.

Assume the central bank's objective is to minimize a standard quadratic loss function that depends on inflation variability and output gap variability.[7] Specifically, let loss be given by

$$L = \sigma_\pi^2 + \lambda\sigma_x^2, \tag{7}$$

where σ_i^2 denoted the variance of i. In the standard approach of common information, the optimal policy under discretion will insulate x_t from any predictable demand shocks while

[7] In section 5 I discuss how conclusions might be affectedby using a loss function that is directly related to the welfare costs of fluctuations in the model. Hellwig (2004) provides a welfare-based analysis of public information in the context of monetary policy.

allowing the output gap and inflation to fluctuate in response to cost shocks. In particular, the central bank will set

$$x_t^I = \alpha E_t^{cb} s_t - E_t^{cb} v_t, \tag{8}$$

where $\alpha = -\kappa\Delta^2/[(\kappa\Delta)^2 + \lambda] \leq 0$ and $\Delta = (1-\omega)(1-\omega\beta)/\omega$. With asymmetric and imperfect information, however, fully offsetting demand shocks may not be optimal if private firms are unable to distinguish between movements in x_t^I that are due to the central bank's signal on the cost shock and those due to its signal on demand shocks. I therefore consider a policy rule of the form

$$x_t^I = \alpha_1 E_t^{cb} s_t + \alpha_2 E_t^{cb} v_t, \tag{9}$$

where α_1 and α_2 are chosen to minimize (7) subject to the equilibrium process for inflation and the information structure faced by the central bank and firms.

Since $x_t = x_t^I + v_t$, the central bank's time t target for the output gap is

$$x_t^T \equiv \alpha_1 E_t^{cb} s_t + (1 + \alpha_2) E_t^{cb} v_t. \tag{10}$$

Equation (10) implies a time t inflation target of

$$\pi_t^T \equiv E_t^{cb} \pi_t = \Delta \left(1 + \alpha_1 \kappa\right) E_t^{cb} s_t + \kappa\Delta(1 + \alpha_2) E_t^{cb} v_t.$$

These targets for the output gap and the inflation rate can be interpreted as short-run targets. Under a credible inflation targeting regime, the long-run inflation target is zero.

3.3 Information

There are two primitive shocks in the model, s representing cost factors that, for a given output gap and expectations of future inflation, generate inefficient inflation fluctuations, and v, an aggregate demand disturbance. Each is assumed to be serially and mutually uncorrelated, and firms in setting prices and the central bank in setting its policy instrument must act before learning the actually realizations of the shocks. However, each firm receives an idiosyncratic, private signal about s_t. Firm j's signal is

$$s_{j,t} = s_t + \phi_{j,t}.$$

The noise term ϕ_j is identically and independently distributed across firms. These signals are private in the sense that they are unobserved by any other agent.

In a similar manner, the central bank receives private signals on the two disturbances:

$$s_{cb,t} = s_t + \phi_{cb,t}$$

$$v_{cb,t} = v_t + \xi_t.$$

The noise terms ϕ_{cb} and ξ are assumed to be independently distributed and to be independent of ϕ_j for all j and t. All stochastic variables are assumed to be normally distributed.[8]

3.4 Equilibrium

As (9) shows, observing the central bank's instrument imperfectly reveals the central bank's forecasts of demand and cost shocks. A rise in x^I could reflect the central bank's belief that a cost shock has occurred, or it could indicate that a demand shock has occurred. These have different implications for the expected output gap and so if they could be disentangled, they would affect firms' price setting decisions differently.

Price setting behavior by firm j depends on four factors: 1) the firm's expectations of what

[8] Therefore, if E_t^{cb} denotes the expectations operator based on the central bank's information set at time t, $E_t^{cb} s_t = \theta_s^{cb} s_t^{cb}$, where $\theta_s^{cb} = \sigma_s^2 / \left(\sigma_s^2 + \sigma_{cb}^2\right)$ and σ_{cb}^2 is the variance of $\phi_{cb.t}$. Similarly, $E_t^{cb} v_t = \theta_v^{cb} v_t^{cb}$, where $\theta_v^{cb} = \sigma_v^2 / \left(\sigma_v^2 + \sigma_\xi^2\right)$.

other firms are doing $(E_t^j \bar{\pi}_t^*)$, 2) what it thinks the central bank believes about current cost and demand shocks, since these beliefs affect the firm's expectation of the output gap, 3) the firm's expectation of future inflation, and 4) its expectation about the current cost shock. Not only must the firm form expectations about what other firms are expecting as in Amato and Shin (2003), it must also form expectations about the central bank's output gap target, which implicitly involves forming expectations about the central bank's expectation of shocks (and implicitly therefore, about what other firms are expecting that the central bank is expecting). Because firm j has private information on the cost shock, its expectation of s may differ from what it thinks the central bank's expectation is; that is, $E_t^j \left(E^{cb} s_t\right) \neq E_t^j s_t$. The problem is to guess what the central bank thinks, not simply to guess what the cost shock is.

When the public can observe the central bank's instrument, but no announcements are made by the central bank, the relevant information set of firm j consists of its private signal s_{jt} and the central bank's instrument setting x_t^I. Since the firm must assess the likely value of the output gap (since that is related to real marginal cost), observing x_t^I provides a noisy signal on x_t^T and therefore on x_t. It also provides information relevant for forecasting the cost shock itself. What is important to note is that the informational content of this signal depends on α_1 and α_2, the parameters that characterizes the manner in which the central bank is willing to trade off inflation and output gap fluctuations. This contrasts with Amato and Shin (2003) and Hellwig (2004) in which the public signal is exogenous; here, the setting of the policy instrument is the public signal and it depends on the policy maker's preferences.

Firm j's expectations of s_t and x_t conditional on s_{jt} and x_t^I can be written as $E_t^j s_t = \Gamma_{11} s_{jt} + \Gamma_{12} x_t^I$ and $E_t^j x_t = \Gamma_{21} s_{jt} + \Gamma_{22} x_t^I$. In Morris and Shin, Amato and Shin, and Hellwig, the weights placed on private and public information in the individual firm's forecast are independent of any aspect of the central bank's policy decisions. This is not the case here; for example, if α_1 is very small, then movements in x_t^I are due primarily to the central bank's attempt to offset demand shocks. As a consequence, private firms will place little weight on x_t^I in forming their expectations about the cost shock.

An equilibrium strategy for firm j is a linear function of its private signal and the policy instrument. This strategy is derived in the appendix. Aggregating over all adjusting firms and multiplying by $1-\omega$ to obtain the aggregate inflation rate, equilibrium inflation can be written as

$$\pi_t = (1-\omega)\bar{\pi}_t^* = \gamma_1 s_t + \gamma_2 x_t^I. \tag{11}$$

The appendix shows that

$$\gamma_1 = (1-\omega)\left[\frac{(1-\omega\beta)\left(\Gamma_{11}+\kappa\Gamma_{21}\right)}{1-(1-\omega)\Gamma_{11}}\right],$$

and

$$\gamma_2 = \frac{(1-\omega)(1-\omega\beta)\kappa\Gamma_{22}}{\omega} + \frac{(1-\omega)(1-\omega\beta)\Gamma_{12}}{\omega} + \frac{(1-\omega)^2\gamma_1\Gamma_{12}}{\omega}. \tag{12}$$

Equation (12) divides γ_2, the impact of the policy instrument on inflation, into three distinct terms, each of which represents a different channel through which the central bank's instrument affects inflation. The first term is the direct (and standard) effect of the instrument on the expected output gap and, therefore, on inflation. Because firms must set prices before actually knowing the current level of production, it is the expected output gap that affects inflation.[9] A unit increase in x_t^I causes firms to expect a rise in the output gap of Γ_{22}, and the output gap elasticity of inflation is $(1-\omega)(1-\omega\beta)\kappa/\omega$. The second term arises when a change in the central bank's instrument leads firms to alter their own expectations of the cost shock. A rise in the instrument will be interpreted (partially) as indicating a negative cost shock ($\Gamma_{12} \leq 0$ because $\alpha_1 \leq 0$). This tends to reduce inflation, partially offsetting the direct positive impact a rise in x_t^I has on inflation. Finally, the third term captures the Morris-Shin effect. By altering the firm's assessment of the cost shock, the public nature of the instrument means that the

[9] In the absence of demand shocks, $x_t^I = x_t$ and $\Gamma_{22} = 1$ so that $\gamma_2 = (1-\omega)(1-\omega\beta)\kappa/w$ and one obtains the standard result in the literature that the output gap elasticity of inflation is $(1-\omega)(1-\omega\beta)\kappa/\omega$.

firm will also alter its expectation about what other firms expect. Walsh (2005) finds that this Morris-Shin effect is small, consistent with Svensson's argument.

By expressing x_t^I in terms of the underlying shocks, one can express aggregate inflation as

$$\pi_t = \left(\gamma_1 + \gamma_2\alpha_1\theta_s^{cb}\right) s_t + \gamma_2\alpha_1\theta_s^{cb}\phi_{cb.t} + \gamma_2\alpha_2\theta_v^{cb}(v_t + \xi_t), \tag{13}$$

and the output gap as

$$x_t = \alpha_1\theta_s^{cb}\left(s_t + \phi_{cb,t}\right) + (1 + \alpha_2\theta_v^{cb})v_t + \alpha_2\theta_v^{cb}\xi_t. \tag{14}$$

If the central bank has complete information on the demand shock, so that $\xi_t \equiv 0$ and $\theta_v^{cb} = 1$, the output gap could be insulated from demand shocks by setting $\alpha_2 = -1$. Despite this, demand shocks will still affect inflation, as (13) will contain the term $-\gamma_2 v_t$ arising from the effects of demand shocks on the central bank's instrument. If the central bank observes a positive v_t, it lowers x_t^I; private firms partially attribute this fall in the policy instrument as the result of the central bank belief the economy has experienced a positive cost shock. Individual firms increase their estimate of the cost shock and believe other firms will do the same. Lack of transparency about the central bank's estimate of demand shocks causes inflation to fluctuate in response to demand shocks, even though the central bank has prevented these shocks from affecting the output gap.

4 Central bank announcements about its targets

While the impact of policy can depend on the informational content of the policy action, discussions of transparency generally focus on actions by the central bank that are designed explicitly to provide information. For example, the publication of the central bank's forecasts for inflation or output, or its announcement of short-run targets for inflation are among the forms of public information designed to increase policy transparency.

The market will use announcements by the central bank for two purposes. Private agents will use announcements to better understand and forecast the intentions of the central bank. But they will also try to infer from any announcements something about the central bank's assessment of the state of the economy. This means that errors in the central bank's assessment of the economy will similarly infect private sector forecasts and expectations. This may introduce undesirable volatility into private sector expectations.

Suppose the central bank announces its target for the output gap.[10] Intuitively, one would expect that announcing the target would improve economic outcomes. Since private firms are now able to distinguish between interest rate movements that are simply designed to offset demand disturbances from those reflecting the central bank's estimate of the cost shock, demand shocks will no longer cause fluctuations in the inflation rate. At the same time, releasing information on x_t^T in no way hampers the central bank's ability to achieve its output gap target. Thus, greater transparency should improve welfare.

This intuition, however, is not necessarily correct, and for reasons similar to those discussed by Morris and Shin. While greater transparency about the central bank's output gap target ensures that instrument changes designed to offset demand shocks no longer lead to fluctuations in inflation expectations, private sector expectations now become more sensitive to the announced target than they were to the instrument. Consequently, the central bank's forecast errors in estimating the cost shock now generate greater volatility in the inflation rate. If this channel dominates the reduction in volatility that occurs because demand shocks no longer affect inflation, loss can actually rise when targets are announced. Whether transparency reduces or increases loss will depend on the quantitative characteristics of the economy.

Complete opaqueness and full transparency are not the only options. As noted earlier, central banks often release information through speeches and other public venues that reach a

[10] As noted previously, this is equivalent to announcing an inflation target.

select rather than a universal audience. Financial markets closely follow and monitor central bank announcements, but this is unlikely to be the case for the wider public audience. Central banks renowned for their transparency, such as the Bank of England, the Bank of New Zealand, or the Rijksbank, produce glossy publications that explain in great detail their policy framework and forecasts, but the readership of these materials is unlikely to extend very far. Even though mass newspapers report on central bank policies and forecasts, I suspect that only the broad contours of policy reach the proverbial person in the street.

In a framework similar to the Morris-Shin model, Cornand and Heinemann (2004) have demonstrated that the partial release of information can be useful. The basic intuition for Cornand and Heinemann's result is straightforward. Wide release of information means that the public information serves to coordinate expectations and this can make the economy sensitive to the noise in the public information; this is the cost of announcements. The gain is that they provide information that leads the public to have more accurate expectations. When it is costly for the central bank to provide information, it may still pay to release information to some members of the public. If only a few agents receive the central bank's information, private sector expectations will, on average, be more accurate, but because only a few agents receive the information, it has little effect on the typical agent's expectations of what others are expecting. The impact of the noise in the public information is limited.

To consider the partial release of information, suppose the central bank announces x_t^T in a manner such that only a fraction P of all firms receive the information.[11] As $P \to 1$, and all firms learn x_t^T, demand shocks will have a reduced impact on inflation, but inflation becomes more responsive to $\phi_{cb,t}$. This may put limits to how widely the central bank wants to broadcast an announcement of x^T.

With partial announcements, firms will be in one of three classes each period; those that

[11] One might interpret this partial release of information in terms of the notion of rational inattention emphasized by Mankiw and Reis (2002). Perhaps all firms observe the announcement but only a fraction P actually incorporate the new information into their decisions.

do not receive an opportunity to adjust their price, those that do adjust but do not receive the central bank's announcement, and those that adjust and receive the announcement. Consider first those adjusting firms that receive information about x_t^T. There are a fraction P of such firms. For these firms, their expectation of the current cost shock will depend on their private information s_{jt} and on the announced target output gap:[12] For the $1-P$ fraction of adjusting firms who do not observe x_t^T, expectations can be based only on private signals and the central bank's instrument. In addition, these firms must forecast both the cost shock and the central bank's output gap target. Firms that adjust prices in period t must form expectations about what other firms are expecting, and this will now depend on the fraction of firms that receive information about the central bank's output gap target.

Consider first those adjusting firms that receive information about x_t^T (or π_t^T). There are a fraction P of such firms; let j index such a firm. For these firms, $E_t^j s_t = H_1 s_{jt} + H_2 x_t^T$ and $E_t^j x_t = x_t^T$. The pricing decision of such a firm therefore satisfies

$$\pi_{jt}^* = (1-\omega)E_t^j \bar{\pi}_t^* + (1-\omega\beta)\kappa x_t^T + (1-\omega\beta)\left(H_1 s_{jt} + H_2 x_t^T\right). \tag{15}$$

The equilibrium strategy for such a firm will take the form

$$\pi_{jt}^* = a_1 s_{jt} + a_2 x_t^I + a_3 x_t^T. \tag{16}$$

One reason the instrument x_t^I appears is because it provides information to the firms observing x_t^T that is useful is assessing the expectations of firms that do not observe x_t^T.

For the $1-P$ fraction of adjusting firms who do not observe x_t^T, expectations can be based only on private signals and the central bank's instrument. Let h index these firms. In addition,

[12] Given the assumptions about policy, the instrument x_t^I provides no relevant information once x_t^T is known. This follows because $x_t = x_t^T + v_t - E_t^{cb} v_t$, and x_t^I provides no information about $v_t - E_t^{cb} v_t$. The equilibrium strategy of a firm that observes x_t^T will depend on x_t^I, since the firm's expectations about with other firms expect will need to take into account the behavior of those firms who do not observe x_t^T.

these firms must forecast both the cost shock and the output gap. Hence, $E_t^h s_t = \Gamma_{11} s_{jt} + \Gamma_{12} x_t^I$, and $E_t^h x_t = \Gamma_{21} s_{jt} + \Gamma_{22} x_t^I$. The pricing decision of such a firm satisfies

$$\pi_{ht}^* = (1-\omega) E_t^h \bar{\pi}_t^* + (1-\omega\beta)\kappa \left(\Gamma_{21} s_{ht} + \Gamma_{22} x_t^I\right) + (1-\omega\beta)\left(\Gamma_{11} s_{ht} + \Gamma_{12} x_t^I\right). \qquad (17)$$

Assume the equilibrium strategy for such firms is

$$\pi_{ht}^* = a_1' s_{ht} + a_2' x_t^I. \qquad (18)$$

The strategies (16) and (18) will be used by all adjusting firms in forming expectations about $E_t^j \bar{\pi}_t^*$. Hence, for firms that observe x_t^T,

$$E_t^j \bar{\pi}_t^* = P\left(a_1 E_t^j s_t + a_2 x_t^I + a_3 x_t^T\right) + (1-P)\left(a_1' E_t^j s_t + a_2' x_t^I\right),$$

implying

$$\begin{aligned} E_t^j \bar{\pi}_t^* &= \left[Pa_1 + (1-P)a_1'\right] H_1 s_{jt} + \left[Pa_2 + (1-P)a_2'\right] x_t^I \\ &\quad + \left\{Pa_1 H_2 + (1-P)a_1' H_2 + Pa_3\right\} x_t^T. \end{aligned}$$

Substituting this expression into (15),

$$\begin{aligned} \pi_{jt}^* &= (1-\omega)\left\{\left[Pa_1 + (1-P)a_1'\right] H_1 s_{jt}\right\} + (1-\omega)\left[Pa_2 + (1-P)a_2'\right] x_t^I \\ &\quad + (1-\omega)\left\{Pa_1 H_2 + (1-P)a_1' H_2 + Pa_3\right\} x_t^T + (1-\omega\beta)\kappa x_t^T + \left(H_1 s_{jt} + H_2 x_t^T\right) \\ &= \left[(1-\omega)\left(Pa_1 + (1-P)a_1'\right) H_1 + (1-\omega\beta) H_1\right] s_{jt} + (1-\omega)\left[Pa_2 + (1-P)a_2'\right] x_t^I \\ &\quad + \left[(1-\omega)\left\{Pa_1 H_2 + (1-P)a_1' H_2 + Pa_3\right\} + (1-\omega\beta)(\kappa + H_2)\right] x_t^T. \end{aligned}$$

Equating coefficients with those in (16),

$$a_1 = (1-\omega)\left(Pa_1 + (1-P)a_1'\right)H_1 + (1-\omega\beta)H_1; \tag{19}$$

$$a_2 = (1-\omega)\left[Pa_2 + (1-P)a_2'\right]; \tag{20}$$

$$a_3 = (1-\omega)\left\{Pa_1H_2 + (1-P)a_1'H_2 + Pa_3\right\} + (1-\omega\beta)(\kappa + H_2). \tag{21}$$

For firms that do not observe x_t^T,

$$E_t^h\bar{\pi}_t^* = P\left(a_1E_t^hs_t + a_2x_t^I + a_3E_t^jx_t^T\right) + (1-P)\left(a_1'E_t^hs_t + a_2'x_t^I\right),$$

implying

$$\begin{aligned} E_t^h\bar{\pi}_t^* &= \left[Pa_1\Gamma_{11} + (1-P)a_1'\Gamma_{11}\right]s_{ht} \\ &\quad + \left\{Pa_1\Gamma_{12} + (1-P)a_1'\Gamma_{12} + Pa_2 + (1-P)a_2'\right\}x_t^I \\ &\quad + Pa_3E_t^hx_t^T. \end{aligned}$$

For these firms, $E_t^hx_t^T = E_t^hx_t$. Hence,

$$\begin{aligned} E_t^h\bar{\pi}_t^* &= \left[Pa_1\Gamma_{11} + (1-P)a_1'\Gamma_{11} + Pa_3\Gamma_{21}\right]s_{ht} \\ &\quad + \left[Pa_1\Gamma_{12} + (1-P)a_1'\Gamma_{12} + Pa_2 + (1-P)a_2' + Pa_3\Gamma_{22}\right]x_t^I. \end{aligned}$$

Substituting this expression into (17),

$$\begin{aligned} \pi_{ht}^* &= (1-\omega)\left[Pa_1\Gamma_{11} + (1-P)a_1'\Gamma_{11} + Pa_3\Gamma_{21}\right]s_{ht} \\ &\quad + (1-\omega)\left[Pa_1\Gamma_{12} + (1-P)a_1'\Gamma_{12} + Pa_2 + Pa_3\Gamma_{22}\right]x_t^I \\ &\quad + (1-\omega\beta)\kappa\left(\Gamma_{21}s_{ht} + \Gamma_{22}x_t^I\right) + (1-\omega\beta)\left(\Gamma_{11}s_{ht} + \Gamma_{12}x_t^I\right). \end{aligned}$$

Equating coefficients with (18),

$$a_1' = (1-\omega)\left[Pa_1\Gamma_{11} + (1-P)a_1'\Gamma_{11} + Pa_3\Gamma_{21}\right] + (1-\omega\beta)\left(\kappa\Gamma_{21} + \Gamma_{11}\right); \tag{22}$$

$$a_2' = (1-\omega)\left[Pa_1\Gamma_{12} + (1-P)a_1'\Gamma_{12} + Pa_2 + (1-P)a_2' + Pa_3\Gamma_{22}\right] + (1-\omega\beta)(\kappa\Gamma_{22} + \Gamma_{12}). \tag{23}$$

Equations (19) - (21) and (22)-(23) can be solved jointly for a_1, a_2, a_3, a_1', and a_2'. Actual inflation when a fraction P of all firms receive information on the central bank's target is

$$\begin{aligned} \pi_t^P &= (1-\omega)P\left(a_1 s_t + a_2 x_t^I + a_3 x_t^T\right) + (1-\omega)(1-P)\left(a_1' s_t + a_2' x_t^I\right) \\ &= (1-\omega)\left\{\left[Pa_1 + (1-P)a_1'\right] s_t + \left[Pa_2 + (1-P)a_2'\right] x_t^I + Pa_3 x_t^T\right\}. \end{aligned} \tag{24}$$

4.1 Optimal policy with partial announcements

The optimal policy responses to the central bank's signals on cost and demand shocks will depend on the degree of transparency. To assess the way α_1 and α_2 vary with P, I numerically solve the model. I set $\omega = 0.5$, $\kappa = 2$, and $\beta = 0.99$. A value of 0.5 for ω is consistent with evidence on the frequency of price adjustment in the U.S. (Bils and Klenow 2004). In micro-founded models, κ is the sum of the coefficient of relative risk aversion and the inverse of the wage elasticity of labor supply. Values of one for each of these parameters are not uncommon, yielding $\kappa = 2$. The value chosen for the discount factor β is standard when dealing with quarterly data. For the variances of the various stochastic shocks, I set the variances of the cost and demand shocks equal to each other and normalize so that $\sigma_s^2 = \sigma_v^2 = 1$. Following Amato and Shin, I assume for the benchmark case that the private sector noise variance is equal to 0.2. While Amato and Shin assume the central bank has perfect information on the shocks, I assume the noise variances in the central bank's signals also equal 0.2, so for the baseline case, $\sigma_{\phi,j}^2 = \sigma_{\phi,cb}^2 = \sigma_\xi^2 = 0.2$.

Figure 1 shows how the policy coefficients vary with P. The horizontal solid line in each panel shows the value of the coefficient for the standard, common information, optimal discretionary policy. Turning first to the reaction to the central bank's estimate of the cost shock, we see that the central bank reacts more strongly (α_1 is larger in absolute value) to the cost shock the less transparent it is (the smaller is P). To understand why the optimal responses is larger with imperfect transparency, consider the situation in which the central bank receives a positive signal on the cost shock ($s_{cb,t} > 0$). In response, it lowers its instrument to reduce output and partially stabilize inflation. With a lack of transparency, the response is stronger for two reasons. First, because the private sector attributes part of the instrument cut to a response to a negative demand shock, the effect of the instrument on inflation is muted. Second, to the extent that firms interpret the fall in the instrument as a sign the central bank is expecting a positive cost shock, price adjusting firms revise their expectations about the cost shock and this, by acting to raise inflation, also mutes the impact of the instrument on inflation. To stabilize inflation requires a stronger instrument response. As transparency increases, this first effect is reduced, allowing the central bank to response less strongly to its cost shock signal.

The lower panel shows that, in the standard case, $\alpha_2 = -1$; demand shocks should be fully offset. In contrast, the central bank's optimal response to its estimate of the demand shock is muted in absolute value when $P < 1$. This reflects the incentive effect that arises when the central bank is not fully transparent (Geraats 2002) and is easiest to understand when $P = 0$. Private agents observe only the policy instrument in this case, and they attempt to infer the central bank's cost shock estimate from the instrument. Reacting more strongly to demand shocks adds more noise to the signal provided to the private sector. Errors in the central bank's demand forecast influence inflation, and this too leads to a more muted response to $E_t^{cb} v_t$. As $P \to 1$, the central bank can adjust its policy instrument to fully offset demand shocks, since private agents are able to distinguish between movements in the instrument due to cost shocks and those due to demand shocks.

4.2 The optimal degree of transparency

To understand the factors that determine the optimal degree of transparency, it is useful to first contrast outcomes with no announcements ($P = 0$) to the case of complete transparency ($P = 1$). When $P = 0$, private firms will incorrectly attribute interest rate movements designed to simply offset demand shocks as a signal the central bank expects a cost shock. By making announcements, the central bank can eliminate this confusion. This should make inflation more stable as well as allowing the central bank to more completely neutralize expected demand shocks. Thus, transparency can make both inflation and the output gap more stable.

However, by announcing its output target to all firms, inflation can become very sensitive to the central bank's output target. Any noise in the central bank's cost shock signal will now have a greater impact on inflation. If expectations and inflation react strongly to the central bank's announced output gap target, and therefore to any noise in the central bank's estimate of the cost shock, inflation could become more volatile. In addition, because the central bank reacts more strongly to its signal on demand shocks, any noise in that signal will have a bigger impact on the output gap.

The effects of making announcements can be illustrated using equation (24). When $P = 0$, this becomes

$$\pi_t^{P=0} = 0.050 s_t + 0.008 x_t^I = 0.048 s_t - 0.004 \phi_{cb,t} - 0.007 v_{cb,t}.$$

Inflation rises in the face of a positive cost shock; there is little direct impact of the instrument on inflation. When the optimal policy rule for the instrument is used to eliminate x_t^I, inflation is seen to be affected negatively by the noise in the central bank's signal on the cost shock and by its signal on the demand shock. In contrast, when $P = 1$, (24) becomes

$$\pi_t^{P=1} = 0.149 s_t + 0.253 x_t^T = 0.049 s_t - 0.100 \phi_{cb,t}.$$

Inflation reacts much more strongly to the cost shock, conditional on the target, and the response to the announced target is much greater than it had been to the observed instrument. However, substituting for the optimal output gap target shows that the net impact of the cost shock on inflation is similar, whether $P = 0$ or $P = 1$. The central bank's signal on demand no longer affects inflation. However, inflation is now much more sensitive to any noise in the central bank's signal on the cost shock. If the variance of ϕ_{cb} is large, inflation may become more volatile under complete transparency, even though transparency eliminates the effect of v^{cb} on inflation.

Tables 1 and 2 report the equilibrium coefficients in (24) as P varies for inflation (panels A) and the output gap (panels B) for two different values of λ ($\lambda = 1$ in Table 1, $\lambda = 2$ in Table 2).[13] When $\lambda = 1$, the impact of the cost shock on inflation is roughly constant as the degree of transparency varies (see Table 1A). However, the effect of ϕ_{cb} increases (in absolute value) as transparency increases; the effect of ξ, while not monotonic, generally decreases in absolute value with greater transparency. In contrast, the effect of greater transparency on the output gap is to reduce the effects of both the cost and the demand shock (see Table 1B). With greater transparency, it is optimal to more completely offset demand shock signals and to react less strongly to cost shock signals. Both effects tend to stabilize the output gap.

When policy adjusts to be optimal for each P, the relationship between the extent of announcements and loss for $\lambda = 1$ is shown by the solid line in Figure 2. Lowest loss is achieved with $P = 0.6$; the announcement of the output gap target should be made to reach most but not all firms. The reason full transparency is not optimal is due to the increase in inflation volatility that occurs as $P \to 1$.

Table 2 gives the equilibrium expressions for inflation and the output gap when a greater weight is placed on output gap stability in the loss function. Comparing panel B of Table 2 to Table 1A shows that for all P, inflation is allowed to fluctuate more in response to the cost

[13] The values of λ are based on inflation expressed at annual rates.

shock when λ is larger. As expected, the effects of the demand shock on the output gap are smaller for all P when λ is larger. By offsetting more of the demand shock, the instrument provides a noisier measure of the central bank's output gap intentions when $P = 0$ than is the case when λ is smaller. Thus, instrument movements tend to have a smaller impact on firms' expectations about the output gap. As transparency increases, firms have better information about the central bank's output gap target. This increases the central bank's impact on firms' expectations and increases the effectiveness of monetary policy. As a consequence, increased transparency allows the central bank to reduce the impact of cost shocks on inflation; the coefficient on s_t falls by just over 11% as P goes from 0 to 1. The dashed line in Figure 2 shows that loss falls monotonically with transparency. When $\lambda = 2$, it is optimal to be completely transparent.

Figure 3 shows the optimal P as a function of λ for the benchmark parameters. With $P = 1$, the central bank can set $\alpha_2 = -1$; that is, it will completely insulate the output gap from any forecasted demand shock. The gain from setting $\alpha_2 = -1$ is larger for central banks that place a correspondingly large weight on stabilizing the output gap. However, if λ is small, so that the central bank cares primarily about inflation stability, then the optimal P is less than one. By setting $P < 1$, the central bank ensures that private firms do not overreact to its instrument or to the announcement. It will be optimal, in this case, not to fully offset demand shocks, but the resulting increase in output gap volatility leads to only a small impact on the loss function when λ is small.

For the benchmark value of $\sigma^2_{\phi,j}$, the noise variance in firms' private signals, the critical value of λ at which it becomes optimal to fully announce targets decreases as the quality of the central bank's information about the cost shock rises. With more accurate information on the cost shock, the central bank is less concerned that its forecast errors will create excessive inflation volatility. However, if private information is very poor, announcements can increase inflation volatility and the optimal P will fall.

As discussed earlier, the benchmark calibration, in which the firm's private information and central bank information about the aggregate cost shock are equally noisy, may overstate the accuracy of the private information that an individual firm is likely to have about aggregate conditions. When the central bank has relatively more accurate information about any aggregate cost shock, private sector expectations will become more sensitive to the information provided by the central bank. In this case, completely transparency may cause firms' expectations about the cost shock to largely offset the impact of the output gap target on inflation. To stabilize inflation would then require larger movements in the output gap target. When a large weight is placed on output gap stabilization in the loss function, complete transparency may be undesirable. Figure 4 shows the relationship between optimal transparency and λ when $\sigma^2_{\phi,j}$ is doubled to 0.4 (and $\sigma^2_{\phi,cb}$ is kept constant at 0.2). When the central bank has relatively more accurate information about any aggregate cost shock, it is optimal to widely announcement the output gap target as long as some weight but not a large weight is placed on output gap volatility in the loss function. Figures 4 offers an interesting perspective on the rise of central bank transparency. If inflation targeting central banks are viewed as focusing primarily on inflation objectives, while still caring about output fluctuations – so that λ is positive but not too large – they are likely to find a policy of complete transparency to be optimal.

5 Summary

In this paper, I have investigated the role of transparency when private information is diverse and the central bank provides public information either implicitly, by setting its policy instrument, or explicitly, by making announcements about its short-run targets. Transparency was modeled as the extent to which announcements are disseminated among the public. Under full transparency, the central bank's announced target reaches all firms. This way of modeling transparency differs from earlier approaches building on the work of Cukierman and Meltzer

(1986) and Faust and Svensson (2002) in which transparency concerned the accuracy of the public's information about the central bank's control error.

By announcing its short-run output gap target (equivalently, its short-run inflation target), the central bank reveals information on its forecast of demand and cost shocks. This provides more accurate public information to price setting firms, but it also makes private section decisions more sensitive to the central bank's forecast errors. As a result, inflation may become more volatile when the central bank announcements its short-run target. For most combinations of the relative accuracy of private and central bank information, however, the net result of making announcements was to reduce inflation variability.

Being transparent is not an all or nothing proposition. Partial announcements provide one means of investigating how widely central banks should disseminate information about their targets. If, as I would argue it is most plausible to assume central banks have more accurate information about aggregate disturbances than private firms (i.e., $\sigma^2_{\phi,j} > \sigma^2_{\phi,cb}$), inflation targeters should be very transparent, i.e., $P = 1$. Only inflation nutters or central banks that place a large weight on output gap stability would find it optimal to make no announcements.

To determine the optimal extent to which information should be made public, I employed a standard quadratic loss function. As Hellwig (2004) demonstrates, this can be misleading and will tend to undervalue the gains from transparency. The reason is based on the underlying distortion that makes inflation costly in new Keynesian models. The welfare costs of inflation are due to the increase in price dispersion across firms that inflation generates. When firms have private information, this introduces a new source of price dispersion and exacerbates the welfare costs of inflation. By providing information that is common to all firms, the central bank can reduce the extent of price dispersion. This represents a welfare gain and increases the advantages of adopting a transparent policy regime. In terms of the model of partial announcements, employing an explicit welfare criterion is likely to increase the optimal degree of transparency.

6 Appendix

6.1 No announcements

In the absence of announcements, the information available to firm j is derived from its private signal s_{jt} and from observing the policy instrument x_t^I. These are related to the cost shock innovation and the output gap according to

$$\begin{bmatrix} s_t \\ x_t \end{bmatrix} = \begin{bmatrix} s_{jt} \\ x_t^I \end{bmatrix} + \begin{bmatrix} \phi_{s,t} \\ v_t \end{bmatrix}.$$

Let $\Gamma = V_{ou}V_{oo}^{-1}$, where V_{ou} is the covariance matrix between the observed signals $\left[s_{jt}\ x_t^I\right]$ and the unobserved variables $[s_t\ x_t]$ and V_{oo} is the covariance matrix of the observed signals. Then, firm j's expectation of $[s_t,\ x_t]$ conditional on s_{jt} and x_t^I is

$$E_t^j \begin{bmatrix} s_t \\ x_t \end{bmatrix} = \Gamma \begin{bmatrix} s_{jt} \\ x_t^I \end{bmatrix}.$$

Let Γ_{ij} denote the ij^{th} element of Γ. Then $E_t^j s_t = \Gamma_{11}s_{jt} + \Gamma_{12}x_t^I$, and $E_t^j x_t^T = \Gamma_{21}s_{jt} + \Gamma_{22}x_t^I$. In Morris and Shin, Amato and Shin, and Hellwig, the weights placed on private and public information in the individual firm's forecast are independent of any aspect of the central bank's policy decisions. This is not the case when, as in the present case, the public signal is the central bank's instrument. Γ_{ij} will generally depend on the policy parameters α_1 and α_2 (see equation 9).

Firm j's price setting is now given by

$$\begin{aligned} \pi_{jt}^* &= (1-\omega)E_t^j \bar{\pi}_t^* + (1-\omega\beta)\kappa\left(\Gamma_{21}s_{jt} + \Gamma_{22}x_t^I\right) \\ &\quad +(1-\omega\beta)\left(\Gamma_{11}s_{jt} + \Gamma_{12}x_t^I\right), \end{aligned} \tag{25}$$

where the assumption of serially uncorrelated shocks has been used to set $E_t^j \pi_{t+1} = 0$. An equilibrium strategy for firm j will take the form

$$\pi_{jt}^* = \tilde{\gamma}_1 s_{jt} + \tilde{\gamma}_2 x_t^I. \tag{26}$$

In forming expectations about the pricing behavior of other firms adjusting in the current period, firm j's expectation of $\bar{\pi}_t^*$ is given by

$$E_t^j \bar{\pi}_t^* = \tilde{\gamma}_1 E_t^j s_t + \tilde{\gamma}_2 x_t^I = \tilde{\gamma}_1 \Gamma_{11} s_{jt} + (\tilde{\gamma}_1 \Gamma_{12} + \tilde{\gamma}_2)\, x_t^I.$$

Substituting this into (25) yields

$$\begin{aligned} \pi_{jt}^* &= [(1-\omega)\tilde{\gamma}_1 \Gamma_{11} + (1-\omega\beta)\,(\Gamma_{11} + \kappa\Gamma_{21})]\, s_{jt} \\ &\quad + [(1-\omega)\,(\tilde{\gamma}_1 \Gamma_{12} + \tilde{\gamma}_2) + (1-\omega\beta)\,(\Gamma_{12} + \kappa\Gamma_{22})]\, x_t^I, \end{aligned}$$

and equating coefficients in this expression to those in (26), it follows that

$$\tilde{\gamma}_1 = \frac{(1-\omega\beta)\,(\Gamma_{11} + \kappa\Gamma_{21})}{1 - (1-\omega)\Gamma_{11}},$$

and

$$\tilde{\gamma}_2 = \frac{(1-\omega)\tilde{\gamma}_1 \Gamma_{12} + (1-\omega\beta)\,(\Gamma_{12} + \kappa\Gamma_{22})}{\omega}. \tag{27}$$

By aggregating over all adjusting firms,

$$\bar{\pi}_t^* = \tilde{\gamma}_1 s_t + \tilde{\gamma}_2 x_t^I.$$

Let $\gamma_1 = (1-\omega)\tilde{\gamma}_1$ and $\gamma_2 = (1-\omega)\tilde{\gamma}_2$. The equilibrium aggregate inflation rate is given by

$$\begin{aligned}\pi_t &= (1-\omega)\bar{\pi}_t^* = \gamma_1 s_t + \gamma_2 x_t^I \\ &= \left(\gamma_1 + \gamma_2 \alpha_1 \theta_s^{cb}\right) s_t + \gamma_2 \alpha_1 \theta_s^{cb} \phi_{cb,t} + \gamma_2 (1+\alpha_2) \theta_v^{cb} \left(v_t + \xi_{cb,t}\right),\end{aligned}$$

and the output gap is equal to

$$\begin{aligned}x_t &= \alpha_1 \theta_s^{cb} \left(s_t + \phi_{cb,t}\right) + \alpha_2 \theta_v^{cb} \left(v_t + \xi_{cb,t}\right) + v_t \\ &= \alpha \theta_s^{cb} \left(s_t + \phi_{cb,t}\right) + (1-\alpha_2 \theta_v^{cb}) v_t + \alpha_2 \theta_v^{cb} \xi_{cb,t}.\end{aligned}$$

Using (27), the impact of the instrument on inflation, γ_2, can be divided into three components:

1. $\frac{(1-\omega)(1-\omega\beta)\kappa\Gamma_{22}}{\omega}$ is the direct effect of the instrument on the output gap and inflation. Since firms that adjust prices must do so before observing the actual output gap, Γ_{22} appears because the instrument affects inflation only by affecting these firms' expectations of the output gap.

2. $\frac{(1-\omega)(1-\omega\beta)\Gamma_{12}}{\omega}$ is the effect of the instrument on adjusting firms' expectations about the cost shock. This measures what is called the firm signalling effect in the text.

3. $\frac{(1-\omega)(1-\omega)\gamma_1\Gamma_{12}}{\omega}$ is the impact of the instrument in altering the individual firm's assessment of what other firms' expectations of the cost shock is. This measures the aggregate signalling effect, and corresponds to the Morris-Shin effect.

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Table 1: Effect of transparency

$\sigma^2_{\phi,J} = \sigma^2_{\phi,CB} = 0.2$

A: Inflation $(\lambda = 1)$

P	s_t	ϕ_{cb}	v_{cb}
0	0.048	-0.004	-0.007
.2	0.044	-0.022	-0.003
.4	0.043	-0.041	0.001
.6	0.044	-0.062	0.003
.8	0.046	-0.082	0.002
1	0.049	-0.100	-0.000

B: Output gap $(\lambda = 1)$

P	s_t	ϕ_{cb}	v	ξ
0	-0.435	-0.435	0.190	-0.811
.2	-0.431	-0.431	0.189	-0.811
.4	-0.424	-0.424	0.187	-0.813
.6	-0.424	-0.424	0.183	-0.817
.8	-0.424	-0.424	0.175	-0.825
1	-0.393	-0.393	0.166	-0.833

Table 2: Effect of Transparency

$\sigma^2_{\phi,J} = \sigma^2_{\phi,CB} = 0.2$

A: Inflation $(\lambda = 2)$

P	s_t	ϕ_{cb}	v_{cb}
0	0.080	-0.004	-0.010
.2	0.077	-0.016	-0.004
.4	0.074	-0.029	-0.000
.6	0.072	-0.045	0.002
.8	0.071	-0.062	0.002
1	0.071	-0.078	-0.000

B: Output gap $(\lambda = 2)$

P	s_t	ϕ_{cb}	v	ξ
0	-0.387	-0.387	0.174	-0.826
.2	-0.387	-0.387	0.177	-0.823
.4	-0.386	-0.386	0.179	-0.822
.6	-0.383	-0.383	0.178	-0.823
.8	-0.378	-0.378	0.173	-0.827
1	-0.371	-0.371	0.167	-0.833

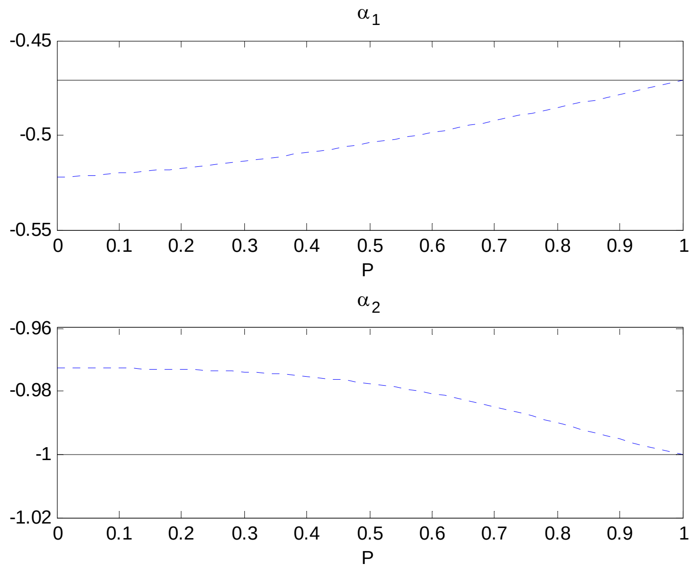

Figure 1: Optimal policy coefficients as a function of P.

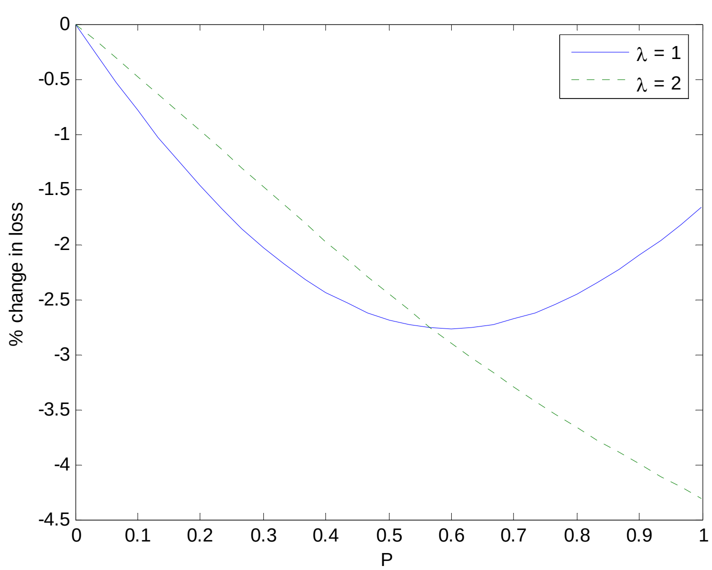

Figure 2: Perent change in loss as a function of the degree of transparency (P)

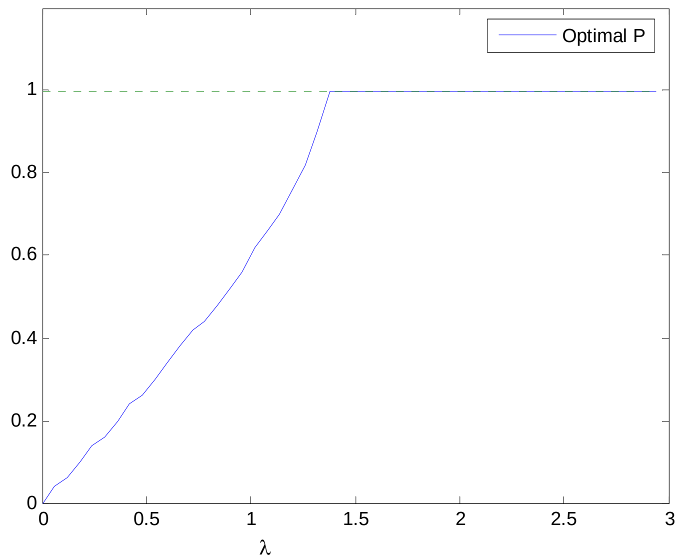

Figure 3: The optimal extent of announcements as a function of λ: $\sigma^2_{\phi,j} = \sigma^2_{\phi,cb} = 0.2$.

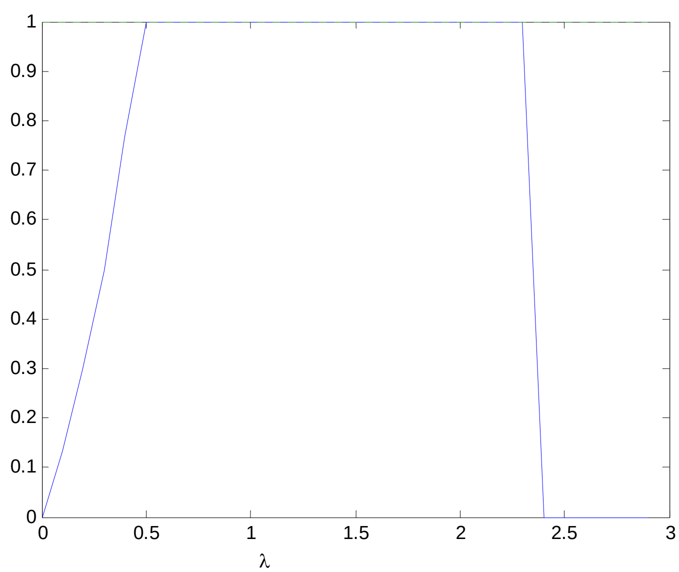

Figure 4: The optimal extent of announcements as a function of λ: $\sigma^2_{\phi,j} = 0.4$, $\sigma^2_{\phi,cb} = 0.2$.