Tilburg University

Central bank communication and output stabilization

Eijffinger, S.C.W.; Hoeberichts, M.M.; Tesfaselassie, M.F.

Published in:
Oxford Economic Papers

Publication date:
2009

[Link to publication in Tilburg University Research Portal](#)

Citation for published version (APA):
Eijffinger, S. C. W., Hoeberichts, M. M., & Tesfaselassie, M. F. (2009). Central bank communication and output stabilization. *Oxford Economic Papers*, 61(2), 395-411.
<http://oep.oxfordjournals.org/cgi/content/abstract/gpn023?ijkey=RR4C90dJRvK5WNI&keytype=ref>

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Central bank communication and output stabilization

By Marco Hoeberichts*, Mewael F. Tesfaselassie†, and
Sylvester Eijffinger‡

*De Nederlandsche Bank and University of Amsterdam, Financial Research
Department, P.o.Box 98, 1000 AB Amsterdam, The Netherlands;
e-mail: M.M.Hoeberichts@dnb.nl

†Kiel Institute for the World Economy; e-mail: mewael.tesfaselassie@ifw-kiel.de

‡CentER, Tilburg University, and RSM Erasmus University and CEPR;

e-mail: s.c.w.eijffinger@uvt.nl

Central banks around the world have a reputation for being secretive about their
operations and market assessments. It is sometimes argued that central banks need
flexibility and therefore cannot be fully transparent. We find that this explanation does
not carry through in a forward-looking New Keynesian framework, where trans-
parency about the central bank's forecasting procedures improves output stabilization.
We also show that higher transparency increases optimal conservatism, as the benefits
from higher transparency in terms of output stabilization are greater the more conser-
vative is the central bank.

JEL classifications: D83, E52, E58.

1. Introduction

Monetary policy makers broadly agree that communication is a very important part
of their business. Communication gives central bankers a tool to shape private sector
expectations, which are crucial for effective monetary policy. Blinder (1998) argues
that openness and communication with the public improve the effectiveness of
monetary policy as a macroeconomic stabilizer because 'central banks generally
control only the overnight interest rate, an interest rate that is relevant to virtually
no economically interesting transactions. Monetary policy has important macroeco-
nomic effects only to the extent that it moves financial market prices that really
matter like long-term interest rates, stock market values, and exchange rates'.

Most theoretical studies of central bank transparency assume some form
of informational asymmetry between the central bank and the private sector.
In particular, the central bank has an informational advantage about its own
goals (e.g., Cukierman and Meltzer, 1986; Jensen, 2000; Eijffinger *et al.*, 2000;

2 of 17 CB COMMUNICATION AND OUTPUT STABILIZATION

Faust and Svensson, 2001; Geraats, 2005) or the state of the economy (e.g., Jensen, 2000; Cukierman, 2001; Morris and Shin, 2002; Gersbach, 2003; Geraats, 2005).

In all these studies, it is assumed that monetary authorities can observe and respond directly to private sector expectations. While it is unquestionable that central banks can hide their true intentions, and there is some evidence that they have superior information about the economy (see for e.g. Romer and Romer, 2000), we think it is unrealistic to presume that policy makers have precise knowledge of market expectations. A more realistic setting, in the spirit of Tarkka and Mayes (1999) and Evans and Honkapohja (2003), among others, has to assume that the central bank's assessment of private sector expectations is imperfect.¹ Tarkka and Mayes (1999) have incorporated this assumption in a model that features Lucas-type transmission mechanism while Evans and Honkapohja (2003) analyse imperfect observability of private sector expectations in the context of simple monetary policy rules under adaptive learning. Evans and Honkapohja (2003) point out that although survey data on private forecasts of future inflation and output are available to central banks, there are apparent concerns about the accuracy of this data.

This paper studies a case where the information is asymmetric in two ways. First, the private sector has superior knowledge about its own expectations of future inflation and output. The central bank sets its policy based on an imperfect assessment of these private sector expectations. Likewise the private sector cannot perfectly observe these assessments made by the central bank unless the central bank publishes them. If it wishes, the central bank can provide information about the way its assessment is produced and thereby make it easier for the public to infer the judgment errors made by the central bank (see Tarkka and Mayes, 1999).

Our aim is to shed light on the implications of communication by the central bank regarding its assessments on private sector expectations and macroeconomic outcomes. We abstract from other sources of private information, such as unobservable central bank goals.² Moreover, unlike Morris and Shin (2002) and Wong (2007), in our paper the central bank is not directly tracking an exogenous fundamental variable. Instead, the central bank simply monitors private sector expectations and reacts to its noisy measure.

It should be borne in mind that the aim of central bank communication is to reduce uncertainty on the part of the private sector, since these errors are also reflected in the setting of interest rate policy. The presumption is that even if the variance of the assessment error is exogenously fixed, communication of these

¹See also Bowles *et al.* (2007).

²See for e.g., Eijffinger and Geraats (2006) for a discussion of different forms of transparency. They identify five broad categories of transparency: political (formal objectives, quantitative targets, and institutional arrangements), economic (data, models and internal forecasts used for policy decisions), procedural (strategy, minutes and voting records, capturing how policy decisions are made), policy (prompt announcement and explanation of policy actions, and policy inclination), and operational (control errors, transmission disturbances, and formal evaluation of policy outcomes).

errors to the public can change public expectations such that under certain conditions overall stabilization is improved.³

We look at the effect of communication about assessments errors on the macro-economic variables, namely, the variability in the rate of inflation and the output gap. The main result of our analysis is that communication of these errors lowers the variability of output but increases the variability of inflation, leading to a tradeoff. This tradeoff also has normative implications for policy. As will be shown later, a central bank who is sufficiently conservative (in the sense of Rogoff, 1985) improves society's welfare by communicating its assessment of market expectations of inflation and output.

2. The model

We use a standard forward-looking New Keynesian model. A detailed treatment of this model can be found in several recent papers that address monetary policy, including Clarida *et al.* (1999) and King (2000). The two basic structural relationships, the Phillips curve and the expectational IS curve, are a log-linear approximation to a micro-founded dynamic general equilibrium model where aggregate behavior is a result of explicit optimization by households and firms. There is monopolistic competition in the product market and firms face nominal price rigidity, thus giving monetary policy the ability to influence economic activities in the short run.

Inflation is determined by a forward-looking Phillips equation

$$\pi_t = \beta E_t^p \pi_{t+1} + \lambda x_t + u_t \quad (1)$$

where π is the inflation rate, x is the output gap, and $u \sim N(0, \sigma_u^2)$ reflects a cost-push shock to inflation, which is identically and independently distributed (in short i.i.d.). The parameter β captures the discount factor while λ is related to the average frequency of price changes and the elasticity of product demand. These parameters satisfy $0 < \beta < 1$ and $\lambda > 0$. The superscript p in $E_t^p \pi_{t+1}$ stands for private sector expectations. Thus current period inflation depends on private sector expectations of future inflation, current period output gap and the cost-push shock. The equation for inflation is derived from firms' pricing decisions, assuming that not all firms can change their prices in any given period.

The output gap is governed by a forward-looking IS equation, which is a log-linearized Euler equation associated with households' intertemporal consumption and saving decisions. It is given by

$$x_t = E_t^p x_{t+1} - \phi r_t + v_t \quad (2)$$

³Expectation formation is the result of a complicated process and involves constantly changing judgments, that is 'information, knowledge, and views outside the scope of a particular model' (Svensson, 2005). It is thus natural to assume that assessments of the forecasts of other parties is fraught with errors. See also Mankiw *et al.* (2003) for an empirical evidence on the existence of substantial disagreements regarding expectations.

4 of 17 CB COMMUNICATION AND OUTPUT STABILIZATION

where r is the real interest rate and $v \sim N(0, \sigma_v^2)$ is an i.i.d. demand shock that captures preference shocks or exogenous changes in government expenditure. The parameter ϕ is an intertemporal elasticity of substitution of consumption and satisfies $\phi > 0$. Thus, the current period output gap depends on private sector expectations of next period's output gap, the real interest rate and the demand shock.

Finally, the real interest rate is determined by the Fisher equation, which links the nominal interest rate with the real interest rate.

$$r_t = i_t - E_t^p \pi_{t+1} \quad (3)$$

where i is the nominal interest rate. Combining (2) and (3) one can rewrite the output gap as a function of private sector expectations and the central bank's policy instrument.

$$x_t = E_t^p x_{t+1} - \phi i_t + \phi E_t^p \pi_{t+1} + v_t \quad (4)$$

In each period the central bank optimizes after making an assessment of private sector expectations. It sets i_t that minimizes the expected value of its period t loss function given by

$$L_t^c = \pi_t^2 + \alpha x_t^2 \quad (5)$$

where α is the relative weight on output stabilization and superscript 'c' stands for central bank.

We point out that our use of a purely forward-looking model is not critical for our analysis and results. One may also use, for instance, a hybrid Phillips curve, which includes lagged inflation.⁴ However, it is easy to reformulate the central bank's policy problem under a hybrid Phillips curve into one with a purely forward-looking Phillips curve by allowing for a utility-based loss function. Woodford (2003) derives a hybrid Phillips curve, assuming that those firms which cannot reset their prices in any given period, index them to a fraction γ of lagged inflation

$$\pi_t - \gamma \pi_{t-1} = \beta(E_t \pi_{t+1} - \gamma \pi_t) + \lambda x_t + u_t$$

Woodford also derives a utility-based loss function associated with this hybrid form. The loss function takes the form $L_t = (\pi_t - \gamma \pi_{t-1})^2 + \alpha x_t^2$. By defining $\hat{\pi}_t = \pi_t - \gamma \pi_{t-1}$, the hybrid Phillips curve can be rewritten as

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \lambda x_t + u_t$$

with the loss function $L_t = \hat{\pi}_t^2 + \alpha x_t^2$, which is comparable to the loss function (5). Thus, the central bank's policy problem remains the same as in the purely forward-looking model.

⁴As is discussed in Paloviita (2006), recent estimates of various specifications of the Phillips curve show support for a hybrid form of the Phillips curve, where both leads and lags matter for inflation dynamics.

3. Equilibrium under full information

Before analysing optimal policy under asymmetric information, it is useful to consider a simpler, baseline scenario where the central bank has full information about the economy and observes private sector expectations without error. In this case, even if it does not directly observe current inflation and output, the central bank can infer them from private sector expectations, the prevailing interest rate, and the two shocks.

Following much of the literature, the model is solved assuming that monetary policy is conducted under discretion.⁵ The optimality condition in terms of the target variables (thus the name targeting rule) is

$$x_t = -\frac{\lambda}{\alpha}\pi_t \quad (6)$$

According to (6), in each period, the central bank contracts (expands) current output in response to a higher (lower) rate of current inflation, with the degree of response depending on the α and λ . Combining the targeting rule with (1), (2), and (3), the nominal interest rate is set according to the following instrument rule

$$i_t = \frac{1}{\phi} \left\{ \left(\phi + \frac{\beta\lambda}{\alpha + \lambda^2} \right) E_t^p \pi_{t+1} + E_t^p x_{t+1} + \frac{\lambda}{\alpha + \lambda^2} u_t + v_t \right\} \quad (7)$$

The rate of interest responds optimally to private sector expectations and the two shocks. It is straightforward to derive the rational expectations solution by solving for private sector expectations. Using (6) in (1) to substitute out x_t , the rate of inflation is give by

$$\pi_t = \frac{\alpha\beta}{\alpha + \lambda^2} E_t^p \pi_{t+1} + \frac{\alpha}{\alpha + \lambda^2} u_t \quad (8)$$

Thus the dynamics of actual inflation depends on currently held private sector expectations about next period's inflation (which in turn depends on next period's cost-push shock u_{t+1}) as well as on current period shock u_t .

To solve for $E_t^p \pi_{t+1}$ and derive the rational expectations equilibrium, note first that the only relevant state variables are u_t and the private sector's forecast of u_{t+1} . To set the stage for the case with assessment errors, we assume the private sector has full knowledge about u_{t+1} . Using the commonly followed method of undetermined coefficients,⁶ first guess a solution of the form

$$\pi_t = \theta_1 u_t + \theta_2 u_{t+1} \quad (9)$$

from which private sector rational expectations follow

$$E_t^p \pi_{t+1} = \theta_1 E_t^p u_{t+1} = \theta_1 u_{t+1} \quad (10)$$

⁵Clarida *et al.* (1999) argue that it is realistic to assume a discretionary monetary policy.

⁶McCallum (1983) emphasizes solving the model using only the fundamentals of the economy (in this case u_t and u_{t+1}), thereby avoiding bubble solutions. McCallum calls this the Minimal State Variables (MSV) method.

6 of 17 CB COMMUNICATION AND OUTPUT STABILIZATION

Using this result back in (8) and imposing rational expectations

$$\pi_t = \bar{\theta}_1 u_t + \bar{\theta}_2 u_{t+1} \quad (11)$$

where $\bar{\theta}_1 = \frac{\alpha}{\alpha + \lambda^2}$ and $\bar{\theta}_2 = \beta \bar{\theta}_1^2$.

- 5 To complete the rational expectations solution under full information, use (11) in the optimality condition to get the solution for output

$$x_t = -\frac{\lambda}{\alpha} (\bar{\theta}_1 u_t + \bar{\theta}_2 u_{t+1}) \quad (12)$$

- Thus under full information, equilibrium inflation and output are functions of the cost-push shocks. Moreover, as long as some positive weight is attached to
10 stabilization of the output gap ($\alpha > 0$), the impact of the shocks are partially absorbed by inflation and partially by output.

4. Assessment errors and disclosure

- To this point the central bank was endowed with perfect knowledge of the state of the economy and in particular regarding private sector expectations. A more realistic
15 setting, in the spirit of Tarkka and Mayes (1999) and Evans and Honkapohja (2003), among others, is that the central bank's assessment of private sector expectations about the future output gap and the future rate of inflation is imperfect. Evans and Honkapohja (2003) discuss the issue of observability of current private expectations in the context of the adaptive learning literature. They point out that
20 although survey data on private forecasts of future inflation and output are available to central banks, there are apparent concerns about the accuracy of this data. Although most experts would agree that it is very hard for the central bank to accurately measure the public's expected output gap, opinions differ about the extent to which the central bank is uncertain about inflationary expectations
25 (see, however, Mankiw *et al.*, 2003).

- One may choose a general setup, where the central bank makes an assessment error in both private sector inflationary expectations and output gap expectations (where the variances of these errors may be different). However, as shown in Appendix 2, our qualitative results are not changed by focusing only on output gap expectations. To
30 capture asymmetric information, suppose private sector output gap forecasts and the central bank's assessment of those forecasts are related by

$$E_t^c x_{t+1} = E_t^p x_{t+1} - w_t^x \quad (13)$$

where superscript c denotes central bank forecasts. Importantly, the assessment errors follow a first-order autoregressive process

$$w_t^x = \rho w_{t-1}^x + \eta_t^x \quad (14)$$

- 35 where the innovations are independently and normally distributed with $\eta_t^x \sim N(0, \sigma_\eta^2)$ and ρ is a measure for the degree of persistence of the assessment errors, satisfying $0 < \rho < 1$. Assessment errors can be persistent if the central bank only sluggishly adjusts its procedures.

Also important for our analysis is that the central bank is uncertain about the private sector's own judgment regarding the development of the cost-push shock u_{t+1} .⁷ The difference in the private sector's and the central bank's judgment regarding u_{t+1} prevents the central bank from indirectly inferring, even in equilibrium, the value of $E_t^p x_{t+1}$.

Similar to the full information setting, monetary policy is discretionary but now the central bank optimizes period by period based on its internal assessment of private sector expectations. Moreover, to make the problem realistic and our equilibrium non-revealing, we assume that the rate of inflation and the output gap are not observable, even *ex post* (see e.g., McCallum (1999) for a criticism of models that assume perfect observability of current inflation and output and Orphanides (2003) for a discussion of monetary policy under data uncertainty. Orphanides and van Norden (2002) show that *ex post* revisions of the estimated gap are as large as the estimated gap itself and that these revisions are highly persistent.) With these assumptions, the optimality condition is now written with the actual (*ex post*) values of inflation and output in (6) replaced by the respective forecasts of these variables.

$$E_t^c x_t = -\frac{\lambda}{\alpha} E_t^c \pi_t \quad (15)$$

where central bank's expectations of the Phillips equation is based on its assessment of private sector inflationary expectations.⁸ The central bank sets its policy rate, i_t , optimally such that (15) is fulfilled.

$$E_t^c \pi_t = \beta E_t^c \pi_{t+1} + \lambda E_t^c x_t + u_t \quad (16)$$

Using (16) in the optimality condition (15)

$$E_t^c x_t = -\frac{\beta\lambda}{\alpha + \lambda^2} E_t^c \pi_{t+1} - \frac{\lambda}{\alpha + \lambda^2} u_t \quad (17)$$

Likewise, taking central bank's expectation of the IS relation, (2)

$$E_t^c x_t = E_t^c x_{t+1} - \phi i_t + \phi E_t^c \pi_{t+1} + v_t \quad (18)$$

Next combine (18) and (17) to get the following expression for the nominal interest rate

$$i_t = \frac{1}{\phi} \left\{ \left(\phi + \frac{\beta\lambda}{\alpha + \lambda^2} \right) E_t^c \pi_{t+1} + E_t^c x_{t+1} + \frac{\lambda}{\alpha + \lambda^2} u_t + v_t \right\} \quad (19)$$

⁷The importance of information asymmetry can be seen, for instance, from reports of the ECB survey of professional forecasters. According to (Bowles *et al.*, 2007, p.5) 'information about such expectations can, for example, provide evidence on the extent to which shocks affecting the inflation process are perceived by agents as likely to persist or be more short-lived. . . '.

⁸We get the optimality condition (15) by minimizing the expected value of (4) subject to the central bank's expectation of the Phillips curve, which is eq. (16) below.

8 of 17 CB COMMUNICATION AND OUTPUT STABILIZATION

It is easily seen that (19) has a similar form as its full information counterpart, (7). The only difference lies in the expectational terms. Due to imperfect information about private sector output expectations, the central bank uses its own (internal) forecasts when setting the rate of interest. At the same time, unless disclosed by the central bank, the private sector can not observe the central bank's forecasts nor the current assessment error. $E_t^c x_{t+1}$ is only a noisy forecast of $E_t^p x_{t+1}$, which means that the central bank commits forecast errors and associated control errors. With (13) in mind, (19) can then be written alternatively as

$$i_t = \frac{1}{\phi} \left\{ \left(\phi + \frac{\beta\lambda}{\alpha + \lambda^2} \right) E_t^p \pi_{t+1} + (E_t^p x_{t+1} - w_t^x) + \frac{\lambda}{\alpha + \lambda^2} u_t + v_t \right\} \quad (20)$$

so that the policy rate i_t is affected by the current assessment error, w_t^x . The public understands the structure of information asymmetry in the economy and so by using (20) in (2), and the resulting equation in (1), it can infer that the actual dynamics of output and inflation is a function of private sector expectations and the assessment error.

$$x_t = -\frac{\beta\lambda}{\alpha + \lambda^2} E_t^p \pi_{t+1} + w_t^x - \frac{\lambda}{\alpha + \lambda^2} u_t \quad (21)$$

$$\pi_t = \frac{\alpha\beta}{\alpha + \lambda^2} E_t^p \pi_{t+1} + \lambda w_t^x + \frac{\alpha}{\alpha + \lambda^2} u_t \quad (22)$$

An interesting feature of (21) and (22) is that both expressions are free of the term $E_t^p x_{t+1}$. The reduced form solutions are found by first solving for $E_t^p \pi_{t+1}$ using (22). Equation (22) differs from the full information counterpart, eq. (8), by the additional term λw_t^x , which captures assessment errors reflecting our asymmetric information setting.

5. Communication and expectations

In forecasting future inflation, the public uses its knowledge of past assessment errors (in light of their persistent nature) and any information about current errors that the central bank has disclosed.⁹ We assume that the private sector gets a signal of the current period error according to

$$s_t^x = w_t^x + \varepsilon_t^x \quad (23)$$

where from (14) the assessment error is normally distributed with a given finite variance, $w_t^x \sim N(0, \sigma_{wx}^2)$, and $\sigma_{wx}^2 = \frac{1}{1-\rho^2} \sigma_{\eta x}^2$.

The degree of communication is measured by the quality of the central bank's disclosed information about its assessment of the public's state of mind. With the variance of the assessment errors, σ_{wx}^2 , exogenously fixed, a fuzzy account of the

⁹ A more general situation arises when past and present assessment errors are hidden variables so that the private sector uses a more general form of Kalman filtering to get optimal forecasts.

assessment errors by the central bank leads to large noise variance, $\sigma_{\varepsilon x}^2$, since it becomes difficult for the public to infer the unobservable assessment error from disclosed information. Here the public depends completely on available central bank models, procedures, and judgements that produce internal inflation forecasts to make inferences about the assessment errors. In a more complicated scenario one may allow the public to deduce or infer the central bank's assessment errors from observing the central bank's interest rate decisions.¹⁰

As in standard signal extraction problems, (23) represents an observation equation, where the input signal w^x is contaminated by an independent noise term ε^x , whose variance $\sigma_{\varepsilon x}^2$ is determined by the central bank's disclosure policy. Since the central bank controls the signal-to-noise ratio through its communication policy, one can think of the central bank as determining the size of $\sigma_{\varepsilon x}^2$ according to $\sigma_{\varepsilon x}^2 = \tau \sigma_{\eta x}^2$ where $0 \leq \tau < \infty$ is a measure of the degree of transparency (see for e.g. Faust and Svensson, 2001). If it opts for noiseless communication with the public, the central bank sets $\tau = 0$, while if the central bank chooses not to communicate at all, it sets $\tau \rightarrow \infty$.

The public's optimal predictor of w_t^x can be solved using the Kalman filter, where (14) is the transition equation and (23) is the observation equation. As w_{t-1}^x is in the public's information set, the steady state solution to the optimal predictor for w_t^x is (see for e.g. Sargent, 1987, and Faust and Svensson, 2001)

$$w_{t|t}^x \equiv E^P(w_t^x | s_t^x, w_{t-1}^x) = (1 - K)\rho w_{t-1}^x + K s_t^x \quad (24)$$

where $K \equiv \frac{P}{P + \sigma_{\varepsilon x}^2}$ is the Kalman gain ($0 \leq K \leq 1$). Here, P is the steady state value of the conditional variance of the optimal predictor and is given by

$$\begin{aligned} P &= \sqrt{\left(\frac{(1 - \rho^2)\sigma_{\varepsilon x}^2 - \sigma_{\eta x}^2}{2}\right)^2 + \sigma_{\eta x}^2 \sigma_{\varepsilon x}^2 - \frac{(1 - \rho^2)\sigma_{\varepsilon x}^2 - \sigma_{\eta x}^2}{2}} \\ &= \left(\sqrt{\frac{((1 - \rho^2)\tau - 1)^2}{4} + \tau} - \frac{(1 - \rho^2)\tau - 1}{2}\right) \sigma_{\eta x}^2 \end{aligned} \quad (25)$$

where we have used $\sigma_{\varepsilon x}^2 = \tau \sigma_{\eta x}^2$ and P is the limit of the conditional variance of the predictor, $P_t = E^P(w_t^x - w_{t|t}^x)^2$, which is updated recursively according to $P_t = P_{t-1} - \frac{P_{t-1}^2}{P_{t-1} + \sigma_{\varepsilon x}^2} + \sigma_{\eta x}^2$. Then, K can be rewritten as

$$K = \frac{2}{1 + \tau(1 - \rho^2) + \sqrt{4\tau + (1 - \tau(1 - \rho^2))^2}} \quad (26)$$

Note that there is a monotonic relationship between K and τ . Thus, the optimal choice of the degree of communication τ can be analysed equivalently in terms

¹⁰When the public is uncertain about central bank goals, (in addition to uncertainty about the assessment errors), communication can play a different role. In this case Faust and Svensson (2001) define transparency as 'how easily the public can deduce central bank unobserved goals and intentions from observables.'

10 of 17 CB COMMUNICATION AND OUTPUT STABILIZATION

of the Kalman gain K . When there is no persistence in w_t^x (i.e., $\rho = 0$), $K = \frac{1}{1+\tau}$ and (24) collapses to $E^p(w_t^x | s_t^x) = \frac{1}{1+\tau} s_t^x$, so that forecasts depend only on the current period signal. In that case, $E^p(w_t^x | s_t^x) = w_t^x$ if $\tau = 0$, while $E^p(w_t^x | s_t^x) = 0$ if $\tau \rightarrow \infty$.

Equation (24) says that in forming expectations about the current assessment error of the central bank, the private sector takes a weighted average of its signal s_t^x and a forecast ρw_{t-1}^x based on the AR(1) process. The weighting factor K in turn depends on the degree of precision of central bank communication. Obviously when the public receives no signal, ($K = 0$), the best available forecast of w_t^x is given by ρw_{t-1}^x .

6. Equilibrium with assessment errors

As before, we solve the model by applying the method of undetermined coefficients. First, we conjecture that π_t depends on the cost-push shocks, u_t and u_{t+1} , last period assessment error, w_{t-1}^x , and its innovation, η_t^x , and the noise that is introduced by the central bank's communication policy, ε_t^x

$$\pi_t = B_{\pi 2} w_{t-1}^x + B_{\pi 4} \varepsilon_t^x + B_{\pi 6} \eta_t^x + B_{\pi 7} u_t + B_{\pi 8} u_{t+1} \quad (27)$$

Then from this follows private sector inflation expectations assuming knowledge of the signal s_t^x , the AR(1)-structure of w_t^x and its previous realization w_{t-1}^x .

$$E_t^p \pi_{t+1} = B_{\pi 2} w_{t|t}^x + B_{\pi 7} u_{t+1} = B_{\pi 2} ((1 - K) \rho w_{t-1}^x + K s_t) + B_{\pi 7} u_{t+1} \quad (28)$$

Essential here is that the public, using the signal of current period error and the error's autoregressive process, is able get an optimal forecast of the unobserved assessment error. Next, substituting (28) in (22) and simplifying

$$\begin{aligned} \pi_t = & \left(\frac{\alpha \beta B_{\pi 2}}{\alpha + \lambda^2} + \lambda \right) \rho w_{t-1}^x + \frac{\alpha \beta K B_{\pi 2}}{\alpha + \lambda^2} \varepsilon_t^x \\ & + \left(\frac{\alpha \beta K B_{\pi 2}}{\alpha + \lambda^2} + \lambda \right) \eta_t^x + \frac{\alpha}{\alpha + \lambda^2} u_t + \frac{\alpha \beta}{\alpha + \lambda^2} B_{\pi 7} u_{t+1} \end{aligned} \quad (29)$$

Consistency of rational expectations requires equalizing the coefficients of (29) with those of (27).

$$\begin{aligned} \bar{B}_{\pi 2} &= \frac{\rho \lambda (\alpha + \lambda^2)}{(1 - \beta \rho) \alpha + \lambda^2} \\ \bar{B}_{\pi 4} &= \frac{\alpha \beta \rho \lambda K}{(1 - \beta \rho) \alpha + \lambda^2} \geq 0 \\ \bar{B}_{\pi 6} &= \lambda + \frac{\alpha \beta \rho \lambda K}{(1 - \beta \rho) \alpha + \lambda^2} \geq 0 \\ \bar{B}_{\pi 7} &= \frac{\alpha}{\alpha + \lambda^2} \\ \bar{B}_{\pi 8} &= \beta \bar{B}_{\pi 7}^2 \end{aligned}$$

Note that with respect to communication the relevant coefficients $\bar{B}_{\pi 4}$ and $\bar{B}_{\pi 6}$ are both nonnegative and directly proportional to K . Thus, inflation has more variability with a higher degree of transparency.

By using (28) in (21) (with $\bar{B}_\pi$'s in mind) the equilibrium output process will be

$$x_t = \bar{B}_{x2}w_{t-1}^x + \bar{B}_{x4}\varepsilon_t^x + \bar{B}_{x6}\eta_t^x + \bar{B}_{x7}u_t + \bar{B}_{x8}u_{t+1} \quad (30)$$

where

$$\begin{aligned} \bar{B}_{x2} &= \frac{\rho(\alpha + \lambda^2)}{\alpha + \lambda^2(1 - \beta\rho)^{-1}} \\ \bar{B}_{x4} &= -\frac{\beta\rho\lambda^2K}{(1 - \beta\rho)\alpha + \lambda^2} \leq 0 \\ \bar{B}_{x6} &= 1 - \frac{\beta\rho\lambda^2K}{(1 - \beta\rho)\alpha + \lambda^2} \geq 0 \\ \bar{B}_{x7} &= -\frac{\lambda}{\alpha + \lambda^2} \\ \bar{B}_{x8} &= -\frac{\alpha\beta}{\lambda}\bar{B}_{x7}^2 \end{aligned}$$

- 5 Equation (30) makes it clear that output, like inflation, responds positively to current innovations to the assessment error η_t^x but, unlike inflation, it responds negatively to the current observation noise ε_t^x . Note also that $\bar{B}_{\pi7}$, $\bar{B}_{\pi8}$, $\bar{B}_{x7}$ and $\bar{B}_{x8}$ are not functions of K . In our model, as the communication policy is about assessment errors, it does not influence the effect of the cost-push shocks on
10 inflation and output.

Next, using the reduced forms of (29) and (30), we can show the effect of changing K (the degree of transparency) on the variability of inflation and output.

$$\sigma_\pi^2 = \left(\frac{\bar{B}_{\pi2}^2}{1 - \rho^2} + \frac{(1 - K)\bar{B}_{\pi4}^2}{K(1 - (1 - K)\rho^2)} + \bar{B}_{\pi6}^2 \right) \sigma_{\eta x}^2 + (\bar{B}_{\pi7}^2 + \bar{B}_{\pi8}^2) \sigma_u^2 \quad (31)$$

$$\sigma_x^2 = \left(\frac{\bar{B}_{x2}^2}{1 - \rho^2} + \frac{(1 - K)\bar{B}_{x4}^2}{K(1 - (1 - K)\rho^2)} + \bar{B}_{x6}^2 \right) \sigma_{\eta x}^2 + (\bar{B}_{x7}^2 + \bar{B}_{x8}^2) \sigma_u^2 \quad (32)$$

- 15 where we have made use of the relations

$$\begin{aligned} \sigma_{wx}^2 &= \frac{\sigma_{\eta x}^2}{1 - \rho^2} \\ \sigma_{\varepsilon x}^2 &= \tau \sigma_{\eta x}^2 \\ &= \frac{1 - K}{K(1 - (1 - K)\rho^2)} \sigma_{\eta x}^2 \end{aligned}$$

from (23) and (26), respectively.

- 20 It is not difficult to show that increasing the value of K unambiguously raises the variability of inflation while it reduces the variability of the output gap.¹¹

.....
¹¹From (31) and (32) the partial derivatives of the coefficients of $\sigma_{\eta x}^2$ with respect to K are positive and negative, respectively.

Thus increasing K (higher degree of transparency) improves the performance of output at the expense of inflation, and vice versa.

Equation (28) shows that, in equilibrium $E_t^p \pi_{t+1}$ responds positively to changes in w_t^x , and this response is stronger the larger is K , at least within the admissible values of K and ρ . It follows from (21) that $E_t^p \pi_{t+1}$ offsets the effect of the assessment error w_t^x on x_t . Thus, $E_t^p \pi_{t+1}$ can play a stabilizing role with respect to w_t^x .

Moreover, using eq. (28), the variance of inflation expectations is

$$\begin{aligned} \sigma_{E_t^p \pi_{t+1}}^2 &= \bar{B}_{\pi 2}^2 (\rho^2 \sigma_{w_x}^2 + K^2 (\sigma_{\eta_x}^2 + \sigma_{\epsilon_x}^2)) + \bar{B}_{\pi 7}^2 \sigma_u^2 \\ &= B_{\pi 2}^2 \left(\rho^2 \sigma_{w_x}^2 + \left(K^2 + \frac{K^2(1-K)}{K(1-(1-K)\rho^2)} \right) \sigma_{\eta_x}^2 \right) \\ &\quad + \left(\frac{\alpha}{\alpha + \lambda^2} \right)^2 \sigma_u^2 \end{aligned} \quad (33)$$

which increases with K and decreases with α . Therefore, a sufficiently conservative central bank lowers $\sigma_{E_t^p \pi_{t+1}}^2$, offsetting the positive effect of communication on $\sigma_{E_t^p \pi_{t+1}}^2$.

7. When does society benefit from central bank communication?

In order to analyse the effect of communication by the central bank about the assessment errors, we allow for the possibility that the society differs from the central banker in the way it weighs the relative benefits from inflation and output stabilization. To formalize this

$$L_t^s = \pi_t^2 + \alpha_s x_t^2 \quad (34)$$

where α_s represents society's concern about output stabilization relative to inflation. Taking unconditional expectation of the loss function

$$E(L_t^s) = \sigma_\pi^2 + \alpha_s \sigma_x^2 \quad (35)$$

In what follows we analyse the optimal choice of central bank conservatism given α_s and how this choice is related to communication policy.¹² As we show below, it turns out that given society's preference for output stabilization α_s , it is optimal for society to appoint a conservative central banker ($\alpha < \alpha_s$). Moreover, if this central banker is sufficiently conservative, communication makes the society better off. We first analyse optimal conservatism and then analyse optimal communication.

Proposition 1 Given society's preferences and the structure of the economy, it is always optimal for society to select a central banker who is conservative in the sense that she puts less weight on output stabilization than society ($\alpha < \alpha_s$).

¹²See Hughes Hallett and Libich (2007) for a discussion of transparency vs. goal-independence in monetary policy.

Proof Evaluate the first-order condition of society's loss function with respect to the weight attached to output stabilization α at the point where $\alpha = \alpha_s$. This expression is positive if $K=0$ and increasing in K for $0 \leq K \leq 1$. Therefore, for every admissible value of K , society's welfare is improved by selecting a conservative central banker. $\square$

This proposition tells us that, optimally, we will be in a situation where the central bank decides on interest rate policy based on its own weight on output stabilization while the society assigns a higher weight on output stabilization. The central bank is then weight-conservative, as in Rogoff (1985). More specifically, the first order condition for optimal central bank preferences can be thought of as being of the following shape

$$\alpha_s = \alpha^* h(\alpha^*) + g(\alpha_s, \alpha^*, K) \frac{\sigma_{\eta x}^2}{\sigma_u^2} \quad (36)$$

where $h(\alpha^*) = [(\alpha^{*2}(1 + 2\beta^2) + 2\alpha^*\lambda^2 + \lambda^4)/(\alpha^{*2}(1 + \beta^2) + \alpha^*(2 - \beta^2)\lambda^2 + \lambda^4)] > 1$, $\sigma_u^2 > 0$ and $g(\alpha_s, \alpha^*, K) > 0$.

So, in absence of shocks to the assessment error ($\sigma_{\eta x}^2 = 0$), it is optimal to choose α^* such that $\alpha^* = \frac{\alpha_s}{h(\alpha^*)} < \alpha_s$. This result is due to the information structure about future shocks u_{t+1} , which affect private sector inflation expectations and in turn current inflation and the output gap. It turns out that the effect on inflation is more pronounced than the effect on the output gap. A more conservative central bank (but not too conservative) helps stabilize inflation, at a smaller cost in terms of higher output volatility. When innovations to the assessment errors have a positive variance, a lower value of α^* will have to be chosen, for a given α_s .

Proposition 2 A higher variance of assessment errors makes the optimal central bank more conservative, while a higher variance of the cost-push shock makes the optimal central bank less conservative.

Proof $\partial E(L_t^s)/\partial \alpha$ is increasing in $\sigma_{\eta x}^2$ and decreasing in σ_u^2 . To see this $\partial E(L_t^s)/\partial \alpha = F_\alpha^1 \sigma_{\eta x}^2 + F_\alpha^2 \sigma_u^2 + \alpha_s (F_\alpha^3 \sigma_{\eta x}^2 + F_\alpha^4 \sigma_u^2)$. From eq. (31) and (32) $F_\alpha^1, F_\alpha^2, F_\alpha^3 > 0$, and $F_\alpha^4 < 0$ are the derivatives of the coefficients of $\sigma_{\eta x}^2$ and σ_u^2 with respect to α . Therefore, given α_s , α^* should decrease with $\sigma_{\eta x}^2$ and increase with σ_u^2 . $\square$

We now turn to the analysis of the optimal level of communication, K . The coefficient of $\sigma_{\eta x}^2$ in (31) monotonically increases with K while that in (32) monotonically decreases with K . This implies that more communication increases the variability of inflation and reduces the variability of output. Which of these two opposing effects dominates, can be checked by analysing society's loss function. Analysis of the first and second order conditions of society's loss with respect to communication parameter K reveals that there can never be a situation where we only have to consider interior solutions. Either $K=0$ or $K=1$ (possibly both)

14 of 17 CB COMMUNICATION AND OUTPUT STABILIZATION

is always at least a local optimum. In Appendix 1 we also derive conditions under which it is possible, in principle, to have an interior optimum. We thus consider the extreme (but probably optimal) cases of no communication $K=0$ and full communication $K=1$.

5 For this case, take the difference

$$E(L_t^s)|_{K=1} - E(L_t^s)|_{K=0} = \frac{\beta\rho\lambda^2}{((1-\beta\rho)\alpha + \lambda^2)^2} Q\sigma_{\eta x}^2 \quad (37)$$

where $Q = 2(\alpha - \alpha_s)(\alpha + \lambda^2) - \beta\rho(\alpha^2 - \alpha_s(2\alpha + \lambda^2))$. Note that K does not affect the coefficients of σ_u^2 in the variances of inflation (31) and output gap (32). Therefore, the term containing σ_u^2 vanishes from (37). Given the structural parameters of the economy, the sign of the right hand side of (37) depends on the sign of Q , that in turn depends on the value of α relative α_s . For example if the central banker shares the same preferences as society ($\alpha_s = \alpha$) we have $Q = \alpha\beta\rho(\alpha + \lambda^2) > 0$, so that communication is welfare decreasing. It is then clear that when society has a central banker who shares the society's loss function (i.e. the central banker is neither conservative nor liberal compared to society), publication of central bank assessments actually makes the society worse-off. This result also shows that if left to her own decision (in other words, if she is independent regarding disclosure policy) the central banker would prefer not to reveal her assessments.

Thus in our setup there arises a situation where communication may not be desired by a central banker but may benefit the society. Proposition 3 below summarizes the result.

Proposition 3 Communication about the central bank's assessment error of output expectations improves society's welfare if the central bank is sufficiently conservative, i.e., if

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

Proof From (37) $Q < 0$ if and only if $\alpha_s/\alpha > (2\lambda^2 + \alpha(2 - \beta\rho))/(\lambda^2(2 - \beta\rho) + \alpha(2 - 2\beta\rho))$. $\square$

Since the term on the right hand side of the inequality sign is greater than one, the proposition says that for the society to benefit from transparency, it must have appointed a central banker who is sufficiently conservative. The positive effect of communication on stabilization of the output gap is stronger when the central banker is more conservative (the smaller is α). On the other hand stabilization of the output gap contributes more to social welfare if society puts more weight on output gap stabilization (the larger is α_s). Thus, what matters is the ratio of α_s to α ; society benefits more from communication the higher the degree of conservatism of the central banker.

Take for instance a positive assessment error in period t . That means the central bank underestimates the expected level of next period's output gap. The policy it

has planned is therefore too loose and the interest rate it plans to set too low (see equation (20)). If the public is aware of the fact that the procedure used by the central bank leads to an underestimation of the expected output gap (i.e. this error is communicated) the public will expect this error to persist in the future (this follows from eq. (28)), increasing inflation expectations. Equation (21) makes it clear that under communication inflation expectations play a stabilizing role vis-a-vis the assessment error (see also eq. (33)). The instrument rule (20) is only indirectly affected by communication, as the interest rate simply responds to changes in private sector expectations.

8. Concluding remarks

It is sometimes argued that central banks need to be secretive in order to maintain flexibility, which enables them to stabilize the economy. We find that this explanation does not carry through in a forward-looking New Keynesian framework, where transparency about the central bank's forecasting procedures improves output stabilization. By communicating and being transparent about its procedures that may lead to assessment errors of private sector expectations, the central bank is better able to stabilize the output gap than when its assessment errors come as a surprise to the public. The reason is that under communication inflation expectations move in the direction that helps to stabilize the impact of the errors on the output gap. The inflation rate, however, becomes more volatile, as inflation expectations amplify the impact of the assessment errors on inflation.

A crucial element in our analysis is that, with communication by the central bank, the public is able to forecast the error that the central bank will make in assessing private sector expectations. In our welfare analysis we showed that a sufficiently conservative central bank improves society's welfare by communicating its assessment of private sector expectations.

Furthermore, we analyse the relationship between communication and central bank conservatism. We find that a transparent central bank can afford to be more conservative, as the benefits from higher transparency in terms of output stabilization are greater the more conservative is the central bank.

Supplementary material

Supplementary material (Appendix 1 and Appendix 2) is available online at the OEP website.

Acknowledgements

Views expressed are those of the individual authors and do not necessarily reflect official positions of De Nederlandsche Bank or the Kiel Institute for the World Economy. We thank David Andolfatto, Niamh Sheridan, Frank Smets, seminar participants at the University of Cambridge, Tilburg University and participants at the 6th DNB Annual Research Conference on 'Information and Communication in Central Banking' and in

16 of 17 CB COMMUNICATION AND OUTPUT STABILIZATION

particular two anonymous referees for their excellent comments. All remaining errors are ours.

References

- Blinder, A. (1998) *Central Banking in Theory and Practice*, MIT Press, Cambridge, MA.
- 5 Bowles, C., Friz, R., Genre, V., Kenny, G., Meyler, A., and Rautanen, T. (2007) The ECB survey of professional forecasters (SPF): a review after eight years' experience, *Occasional Paper*, 59, European Central Bank, Frankfurt.
- Clarida, R., Gali, J., and Gertler, M. (1999) The science of monetary policy: a New-Keynesian perspective, *Journal of Economic Literature*, 37, 1661–707.
- 10 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, Oxford.
- Cukierman, A. and Meltzer, A. (1986) A theory of ambiguity, credibility and inflation under discretion and asymmetric information, *Econometrica*, 54, 1099–128.
- 15 Eijffinger, S. and Geraats, P. (2006) How transparent are central banks? *European Journal of Political Economy*, 22, 1–21.
- Eijffinger, S., Hoeberichts, M., and Schaling, E. (2000) Why money talks and wealth whispers: monetary uncertainty and mystique, *Journal of Money, Credit and Banking*, 32, 218–35.
- Evans, G. and Honkapohja, S. (2003) Adaptive learning and monetary policy design, *Journal of Money, Credit and Banking*, 35, 1045–72.
- 20 Faust, J. and Svensson, L. (2001) Transparency and credibility: monetary policy with unobservable goals, *International Economic Review*, 42, 369–97.
- Geraats, P. (2005) Transparency and reputation: the publication of central bank forecasts, *Topics in Macroeconomics*, 5, Article 1.
- 25 Gersbach, H. (2003) On the negative social value of central bank's knowledge transparency, *Economics of Governance*, 4, 91–102.
- Hughes Hallett, A. and Libich, J. (2007) Explicit inflation targets, communication, and central bank independence: friends or foes? mimeo, George Mason University, Fairfax, VA.
- Jensen, H. (2000) The optimal degree of transparency in monetary policymaking: the case of imperfect information about the cost-push shock, mimeo, University of Copenhagen.
- 30 King, R. (2000) The new IS-LM model: language, logic, and limits, *Federal Reserve Bank of Richmond Economic Quarterly*, 86, 45–103.
- Mankiw, N., Reis, R., and Wolfers, J. (2003) Disagreement about inflation expectations, *NBER Macroeconomics Annual*, The MIT Press, Cambridge, MA.
- 35 McCallum, B. (1983) On non-uniqueness in rational expectations models, *Journal of Monetary Economics*, 11, 139–68.
- McCallum, B. (1999) Issues in the design of monetary policy rules, in J. Taylor and M. Woodford (eds) *Handbook of Macroeconomics*, North-Holland, Amsterdam.
- Morris, S. and Shin, H. (2002) The social value of public information, *American Economic Review*, 92, 1521–34.
- 40 Orphanides, A. (2003) Monetary policy evaluation with noisy information, *Journal of Monetary Economics*, 50, 605–31.

- Orphanides, A. and van Norden, S. (2002) The unreliability of output-gap estimates in real time, *The Review of Economics and Statistics*, **84**, 569–83.
- Paloviita, M. (2006) Inflation dynamics in the Euro area and the role of expectations, *Empirical Economics*, **31**, 847–60.
- 5 Rogoff, K. (1985) The optimal degree of commitment to an intermediate monetary target, *The Quarterly Journal of Economics*, **100**, 1169–89.
- Romer, C. and Romer, D. (2000) Federal reserve information and the behavior of interest rates, *American Economic Review*, **90**, 429–57.
- Sargent, T. (1987) *Macroeconomic Theory*, 2nd ed., Academic Press, New York.
- 10 Svensson, L. (2005) Monetary policy with judgment: forecast targeting, *International Journal of Central Banking*, **1**, 1–54.
- Tarkka, J. and Mayes, D. (1999) The value of publishing official central bank forecasts, Bank of Finland Discussion Paper, 22, Bank of Finland, Helsinki.
- 15 Wong, J. (2007) Information acquisition, dissemination and transparency of monetary policy, *Canadian Journal of Economics*, **41**, 46–79.
- Woodford, M. (2003) *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press, Princeton, NJ.