# Optimal Degrees of Transparency in Monetary Policymaking

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Discussion paper 04/01
Economic Research Centre
of the Deutsche Bundesbank

January 2001

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ISBN 3–933747–68–6

## Abstract

According to most academics and policymakers, transparency in monetary policymaking is desirable. I examine this proposition in a small theoretical model emphasizing forward-looking private sector behavior. Transparency makes it easier for price setters to infer the central bank's future policy intentions, thereby making current inflation more responsive to policy actions. This induces the central bank to pay more attention to inflation rather than output gap stabilization. Then, transparency may be disadvantageous. It may actually be a policy-distorting straitjacket if the central bank enjoys low-inflation credibility, and there is need for active monetary stabilization policy.



**Keywords:** Transparency; monetary policy; central bank institutions

JEL Classification numbers: **E42, E52, F58**

## Zusammenfassung

Den meisten Akademikern und politischen Entscheidungsträgern zufolge ist Transparenz in der Geldpolitik wünschenswert. Ich untersuche diese Behauptung anhand eines kleinen theoretischen Models, das das vorausschauende Verhalten des privaten Sektors hervorhebt. Transparenz erleichtert es denjenigen, die Preise festsetzen, auf die künftigen geldpolitischen Absichten der Zentralbank zu schließen, wodurch die laufende Inflation stärker auf stabilitätspolitische Maßnahmen reagiert. Dies führt dazu, dass die Zentralbank sich eher auf die Inflation als auf die Stabilisierung der Produktionslücke konzentriert. In diesem Fall kann Transparenz negative Folgen haben. Sie kann sich sogar als eine die Geldpolitik verzerrende Zwangsjacke herausstellen, wenn die Zentralbank sich stabilitätspolitischer Glaubwürdigkeit erfreut und eine aktive monetäre Stabilisierungspolitik benötigt wird.



Schlüsselwörter: Transparenz; Geldpolitik; Zentralbankinstitutionen.

JEL-Ordnungszahlen: **E42, E52, F58.**

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## 1. Introduction

If the definition contained in a standard dictionary is representative for the common perception about a subject, there is no doubt that being transparent is something considered desirable. For example, Webster's Encyclopedic Unabridged Dictionary of the English Language (1989) states:

> **transparent**, *adj.* **1.** having the property of transmitting rays of light through its substance so that bodies situated beyond or behind can be distinctly seen (...) **4.** open; frank; candid: *the man's transparent earnestness.* (...) —**Ant. 1.** opaque. **4.** secretive.

In terms of monetary policymaking, transparency must therefore be something to strive for. E.g., is "opaque" and "secretive" policymaking under any circumstances desirable? Or policy conducted with lack of "earnestness?" The answers to such rhetorical questions in policy debates are, obviously, almost universally "no." This has recently been evident in discussions on the transparency of the newly established European Central Bank (ECB), most clearly exemplified by the following quotes:

[0]I thank Thomas Alslev Christensen, Alex Cukierman, John Driffill, Petra Geraats, Andrew Hughes Hallett, Christian Schultz, Lars E. O. Svensson, Bernhard Winkler, and seminar participants at Tel Aviv University, the Bank of Finland/CEPR Workshop on "The Transparency of Monetary Policy: Theory and Empirical Evidence," the European Economic Association meetings in Bolzano-Merano-Bolzano, the Bundesbank/CfS conference on "Transparency in Monetary Policy (Theory and Empirical Experience)," and the EPRU conference on "Perspectives on Danish and European Economic Policy" for helpful comments and discussions. Any errors and non-transparencies are obviously my own responsibility. Parts of this paper were written while visiting The Eitan Berglas School of Economics, Tel Aviv University. Its warm hospitality is gratefully acknowledged. I thank EPRU for financial support (the activities of EPRU are financed by a grant from The Danish National Research Foundation). Correspondence to: Henrik Jensen, Institute of Economics, University of Copenhagen, Studiestraede 6, DK-1455 Copenhagen K, Denmark. E-mail: Henrik.Jensen@econ.ku.dk. Web: http://www.econ.ku.dk/personal/henrikj/.

*"the enforcer for the ECB Opaqueness Squad"*

Willem H. Buiter on Otmar Issing in "Alice in Euroland," Buiter (1999, p. 193).

*"transparency — appropriately defined — can be regarded as absolutely crucial for the effectiveness of monetary policy and the credibility of a young institution like the ECB"*

Otmar Issing in "The Eurosystem: Transparent and Accountable or 'Willem in Euroland'," Issing (1999, p. 517).

The fact that a critic of the ECB's transparency recommends more transparency is hardly surprising, and given that non-transparency is usually considered synonymous with opaqueness, secrecy and maybe even dishonesty, cf. above, the statement of Issing is not surprising either. Most debates on transparency of monetary policy therefore often reduce to ones where proponents of more transparency are met by claims that the central bank is indeed aiming at exceptionally high degrees of transparency. Irrespective of who is right or wrong, a firm consensus about the virtues of transparency remains: transparency is a self-evident necessity in order to obtain sound monetary policy. In addition, it helps holding independent central banks accountable for their actions, and for political reasons transparency may compensate for the "democratic loss" society incurs by central bank independence. On this latter point, see, e.g., Stiglitz (1998) who indeed states that "*transparency — openness — is now recognized as a central aspect of democratic processes*" (p. 216). Likewise, in an earlier study of the pros and cons of secrecy about policy decisions *per se,* Goodfriend (1986) advocates against secrecy on the grounds that it is "*inconsistent with the healthy functioning of a democracy*" (p. 90).

Viewed in the above, deliberately naïve, semantic setting, it is perhaps not surprising that relatively limited formal research on the economic consequences of transparency exists.[1] Triggered mainly by the formation of the ECB, however, analyses moving beyond simple rhetoric of the topic are emerging (see below). The purpose of this paper is to contribute to this line of research by examining the optimal degrees of transparency in a simple model of monetary policymaking. In real-life policymaking, transparency is obviously a multi-facetted concept, which can illustrate openness and information disclosure in several dimensions. For example with regards to the decisionmaking body's operational procedures, goals of policy, economic forecasts upon which policy decisions are based, minutes from board meetings, policy decision as such, and so forth. In this paper, I take a

[1] Early literature on central bank preference uncertainty — a feature related to transparency — did, however, touch the transparency issue; cf. Backus and Driffill (1985), Cukierman and Meltzer (1986) and Lewis (1991) (see also the references in Goodfriend, 1986).

rather pragmatic stand. Transparency is meant as a metaphor for any institutional feature facilitating the private sector's expectation formation about future monetary policy, and thus future economic developments.[2]

The main result of the paper is in contrast with the popular perceptions alluded to above, and also most recent literature, as I find that transparency need not be advantageous. Furthermore, transparency is rarely an "either or" issue. As is the case in virtually all areas of institutional design, trade-offs are involved, implying here that the optimal degree of transparency may involve intermediate information disclosure.

The general intuition for this result is as follows. As mentioned above, transparency facilitates private sector expectations formation and thus inference about future economic developments. Monetary policy actions thus become more informative. In consequence, expectations react much stronger to policy changes compared to a case with little transparency. In the latter situation, policy actions provide little information to market participants who therefore rationally take only small notice of these.

When assessing how optimal monetary policy is affected by transparency, *how and when* expectation formation affects relevant economic variables are of great importance. If relevant variables are *forward-looking*, their current realization depends on their *expected future values*. As a result, more transparency causes current monetary policy actions to affect current forward-looking aggregates much stronger due to the stronger reactions by expectations.[3] The implication can therefore be that the policymaker is induced to act excessively cautious, because it to a greater extent becomes a "*hostage of market sentiments*" (Remsperger and Worms, 1999). This may be advantageous, however, if the policymaker lacks credibility and needs the "discipline of the market" in order not to pursue unduly expansive policies. On the other hand, it is undesirable if the policymaker actually has credibility, and therefore does not need to be "disciplined," but instead needs to perform macroeconomic stabilization without the restraints imposed by transparency. Since several aggregates of relevance for monetary policy are forward-looking (e.g., exchange rates, asset prices, durable good prices, inflation rates, bond rates, to name a few), this insight may have general importance. In this paper it is formalized in a small model exhibiting the

[2]See, e.g., Geraats (2000) or Winkler (2000), for examples of conceptual frameworks formally distinguishing various forms of transparency.

[3]This is somewhat equivalent of the behavior of variables determined in conventional present-value models, e.g., those of asset price determination. In such models, less noise in the process of fundamentals causes expectations to respond stronger to new information, thereby implying more variability in the variable itself; see, e.g., Schiller (1979) and LeRoy and Porter (1981). If less noise in fundamentals represents more transparency, and new information represents monetary policy actions, the analogy is quite close.

trade-off between inflation and output gap volatility featured in most analyses of monetary policy.

More specifically, the model compactly describe an economy by a New-Keynesian "Phillips curve," where inflation depends positively on expected *future* inflation and the current output gap (cf. Roberts, 1995). Hence, inflation is forward-looking. This is a variant of supply-side models, which have become standard in recent monetary policy analyses (see, e.g., the contributions in Taylor, 1999, and the references in these). Also, it is a specification of inflation dynamics receiving increasingly empirical support, see, e.g., Galí and Gertler (1999) or Rudebusch (2000) for recent US evidence on forward-looking price setting, and Galí *et al.* (2000) and Smets (2000) for similar evidence for Euroland.

A formal modeling of transparency obviously requires asymmetric information between the central bank and the public. In this model, the asymmetry emerges through a shock to the central bank's preferred value of the output gap, which the private sector cannot observe (cf. Faust and Svensson, 2000). Nor can the private sector observe a "control error" in policymaking. Hence, when forming expectations about future inflation, and thus determining current inflation, the private sector can only imperfectly infer the central bank's true policy intentions. For example, a booming economy could either be a result of an expansive control error or a high preferred output value. Clearly, expectations about future inflation increase by more, the more the latter is believed to be the case, since this implies that the central bank will also act relatively expansionary in the future.

Following Faust and Svensson (2000), I then model transparency as the central bank's release of information about the control error. This serves as a proxy for revelation of various informations about economic conditions prior to expectations formation. The more information is revealed, the easier it is for the private sector to infer the true policy intentions of the central bank, and thus to form more precise expectations about future inflation. I.e., policy intentions and conduct become more transparent — they can to a larger extent *be distinctly seen.*

As explained above, more transparency implies that expectations become more sensitive to the central bank's actions (as is also the case in Faust and Svensson, 2000). This is because the private sector is then better capable of distinguishing between, say, an "accidental" boom and a deliberate one. As the private sector's concern is to forecast the deliberate part, more knowledge about what is accidental, implies that a deliberate increase in demand is more likely to be attributed to a higher output target of the central bank. Inflation expectations, and thus inflation, therefore increase by more. For the central bank, this means that the marginal cost of demand at the planning stage (in terms of inflation) increases. In consequence, more transparency induces the central bank to pay more attention to its inflation target relative to its output gap target. This is beneficial if the bank has poor inflation credibility, and thus needs the "disciplinary force" of transparency. If, on the other hand, the central bank enjoys low-inflation credibility, there is no such need. In contrast, transparency will be a policy distorting straitjacket, because when attempting to strike an optimal balance between output gap and inflation variability in the face of macroeconomic shocks, the central bank is induced to be excessively inflation averse (i.e., "conservative" in the sense of Rogoff, 1985). Therefore, the optimal degree of transparency generally involves trading off credibility gains against flexibility losses.

As evident, my analysis draws on a number of aspects of Faust and Svensson (2000).[4] The results differ substantially, however. Their main message is that a high degree of transparency is always beneficial for society. The difference arises from different specifications of the economies. They adopt a Lucas-style supply function, where inflation expectations are formed at the *beginning* of any period. Hence, as more transparency makes inflation expectations more sensitive to policy actions, current policy decisions affect inflation expectations in the future. This, however, has no implications on current aggregates as none are forward-looking. Transparency thus introduces a constant marginal cost of loose monetary policy, but leaves unchanged the marginal cost of current inflation. This is beneficial given that the central bank is aiming at an output level above the natural, resulting in a Barro and Gordon (1983) inflation bias. Moreover, it implies that no costs are incurred in terms of stabilization policy.[5] By contrast, in my model where the economy has forward-looking properties, changes in inflation expectations affect the marginal cost of inflation *within* the planning period. Transparency then distorts the intra-temporal output and inflation variability trade-off.

A formal modeling of the economic benefits of transparency is also the aim of Geraats (2000) who finds that transparency puts downward pressure on inflation expectations, and thus mitigates excessive equilibrium inflation. The main intuition for this result is related to that of Faust and Svensson (2000). Her results, however, are cast in a different model and in contrast with Faust and Svensson (2000) (and my model), transparency is concerned with release of information about shocks hitting the economy before policy implementa-

[4] Their paper extends Cukierman and Meltzer (1986) mainly by positing a clear distinction between transparency and control errors. In Cukierman and Meltzer (1986), these concepts were essentially interchangeable.

[5] Transparency in their model therefore works analogous to a linear inflation contract, cf. Walsh (1995). As is well known, this particular incentive mechanism indeed eliminates average credibility problems without distorting shock stabilization.

tion.[6] Furthermore, she shows how the implementation of full transparency corresponds to the publication of conditional forecasts of inflation (and output). In contrast with Faust and Svensson (2000), she finds that stabilization policy is affected by transparency, and in an unambiguously beneficial manner. As her model does not feature forward-looking variables, this illustrates once more that conclusions about the desirability of transparency depends critically on the model specification of the economy.

Another recent paper of relevance is Cukierman (2000), who, like me, points to potential social inefficiencies of transparency. He presents two different models to support this view. One is a simple stochastic Lucas-supply function model, where transparency is synonymous with full revelation of information about supply shocks to the private sector before inflation expectations are formed. In consequence, monetary policy loses the ability to stabilize these disturbances; basically, the central bank *needs* an informational advantage in order to perform efficient stabilization policy. A very related result is found by Gersbach (1998). The second model is one where the central bank affects demand through nominal interest rates. Again, transparency is synonymous with full revelation of information about shocks. Monetary policy does not become impotent for this reason though. Inflation expectations, however, become more sensitive policy actions. Hence, to attain a desired change in demand, larger changes in the nominal interest rate are needed. If society dislikes changes in the nominal interest rate *per se*, transparency is therefore disadvantageous.

It should be stressed that a maintained assumption throughout this paper is that the central bank operates faithfully according to the institutional environment it faces (of which the main characteristic of interest here is the degree of transparency). Hence, I ignore the issue of accountability, i.e., the design of mechanisms enforcing such faithful behavior.

The remainder of the paper is organized as follows. The simple model of monetary policy conduct is presented in Section 2, and the solution in the case of no informational asymmetries is provided in Section 2.1. Subsequently, Section 2.2 derives the equilibrium in the case of asymmetric information and describes the essential implications of transparency. Section 3 then presents a number of numerical analyses illustrating how the structural features of the model economy affect the optimal degrees of transparency. Through these exercises, one is capable of identifying the trade-offs involved in the determination of the appropriate degree of central bank openness. Section 4 concludes. Some proofs and derivations are found in the Appendix.

[6] In a note, Jensen (2000), I also consider a case where transparency concerns shocks hitting the economy before policy implementation. I find within my model that transparency distorts stabilization policy in this case as well.

## 2. A simple model of monetary policy

The model describes a closed economy in two periods, 1 and 2. Loosely, one may think of period 1 as the present, and period 2 as the future. In accordance with this view, it is decisions taken in period 1 that will be of main interest for the subject at hand, whereas period 2 merely serves to represent the "long run." Monetary policymaking is a matter of inflation and output gap stabilization, and monetary policy has real effects due to price stickiness. In contrast with existing literature on transparency in monetary policymaking, the supply side of the economy is modelled by a simple variant of the so-called New-Keynesian Phillips curve emphasizing forward-looking behavior in price setting (Roberts, 1995). Prices are set by monopolistically competitive firms, and assuming staggered price-setting along the lines of Calvo (1983), or quadratic price adjustment costs as in Rotemberg (1982), one can show that optimal price setting approximately results in the following inflation dynamics (see, e.g., Rotemberg and Woodford, 1998):

$$\pi_1 = \mathrm{E}\left[\pi_2 | I_1^P\right] + \kappa x_1 + \varepsilon, \quad \kappa > 0, \tag{1}$$

$$\pi_2 = \mathrm{E}\left[\pi_3 | I_2^P\right] + \kappa x_2, \tag{2}$$

where $\pi_i$ is the inflation rate in period $i$ and $x_i$ is the output gap, i.e., output deviations from the natural rate of output. Both variables are measured as percentage deviations from some steady state. Inflation in period 1 is subject to a disturbance $\varepsilon$ assumed to have zero mean and variance $\sigma_\varepsilon^2$ (a "cost-push" shock; cf. Clarida *et al.*, 1999).[7] $\mathrm{E}\left[.|I_i^P\right]$ is the expectations operator and $I_i^P$ is the information set of the price setters. Forward-looking behavior in (1)-(2) arises because firms that are "allowed" to change prices today, know that it may not get a chance to change prices in the next period. To maximize current and future expected real profits, expectations about future aggregate prices thus become important.[8]

The demand side could be modelled by introducing an IS curve. For simplicity though, I assume that demand, and since technology shocks are ignored, the output gap, is simply given by

$$x_1 = x_1^I + \eta, \tag{3}$$

[7] Letting only period 1 inflation be subject to a shock is assumed for convenience. As will be clear below, it has no qualitative implications for the results.

[8] In most empirical analyses, including those referred to in the Introduction, inflation typically exhibits persistence; i.e., lagged inflation is a significant determinant of current inflation. I, however, adopt a simple, purely forward-looking specification here for analytical tractability. As long as expected future inflation has importance, the qualitative statements relating to transparency remain valid in the presence of inflation persistence also.

where, along the lines of Faust and Svensson (2000), $x_1^I$ is the central bank's *intention* for the output gap in period 1, and where $\eta \sim \mathrm{N}(0, \sigma_\eta^2)$. Although $x_1^I$ below is treated as the central bank's choice variable, it is *not* the policy instrument. The policy instrument (for example the short interest rate) is subsumed in this model, due to the lack of modelling of the demand side.[9] The shock $\eta$ could represent a control error, or disturbances to demand and technology which the central bank for various reasons is unable to counteract (say, due to informational problems). For convenience, however, I refer to $\eta$ as a control error. As focus is on period 1, cf. above, I assume that the central bank controls $x_2$ perfectly.

In order to evaluate the desirability of various forms of monetary policymaking, it is assumed that society has the following conventional quadratic loss function:

$$L^S = \mathrm{E}\left[\sum_{i=1}^{2}\left[\lambda\left(x_i - x^*\right)^2 + \pi_i^2\right]\right], \quad \lambda > 0, \quad x^* > 0. \tag{4}$$

This is merely the unconditional expectation of the sum of the two periods' deviations in the output gap and inflation from $x^*$ and zero, respectively. (For simplicity, I ignore discounting.) In accordance with the underlying assumption of imperfect competition in product markets, the natural rate of output is inefficient, thus explaining a positive target value for the output gap. The choice of zero as the preferred rate of inflation is just a convenient normalization.

The conduct of monetary policy is, before period 1 begins, delegated to an independent central bank which shares the main aspects of society's preferences, except for the fact that its target value for the output gap is stochastic. This follows Faust and Svensson (2000), and can be interpreted as reflecting a change in the composition of the bank's board members (with heterogeneous preferences) such that the outcome of, say, a vote on policy effectively changes the central bank's preferred output gap. Alternatively, it can be interpreted as capturing political pressures against the central bank, either by the government or strong lobby groups, forcing it to target the output gap at some value (e.g., a higher value if, say, the central bank is under pressure from a "left-wing" government). In the remainder I will mainly adopt this interpretation. The loss function of the central bank is therefore given as

$$L^{CB} = \mathrm{E}\left[\sum_{i=1}^{2}\left[\lambda\left(x_i - x_i^*\right)^2 + \pi_i^2\right]\right], \tag{5}$$

[9] If the policy instrument was explicitly included in the model, it could be perfectly observable by the private sector, i.e., there would be full transparency about policy *decisions*. Equation (3) thus merely expresses — realistically — that *intended* outcomes are only imprecisely linked to actual outcomes.

where

$$x_1^* = x_0^* + \theta, \quad x_2^* = x_1^*, \quad x_0^* \text{ given,} \tag{6}$$

is the central bank's output targets, and where $\theta \sim \mathrm{N}(0, \sigma_\theta^2)$ is the shock to the target in period 1. Again, as the focus is on the decisions under uncertainty in period 1, I assume away any shocks to the output target in period 2.

To model transparency formally, I follow Faust and Svensson (2000) and assume that after monetary policy has been conducted in period 1, the price setters will get some information about the shock, $\eta$. More specifically, the shock is split into two parts:

$$\eta = \xi + \upsilon, \tag{7}$$

where $\xi \sim \mathrm{N}(0, \sigma_\xi^2)$ becomes known to the price setters, whereas $\upsilon \sim \mathrm{N}(0, \sigma_\upsilon^2)$ does not. One may interpret this information as stemming from public statements or reports by the central bank by which it elaborates on the economic situation, the shocks that are hitting the economy, the uncertainties involved, and so forth. It is imagined that the more detailed are such statements the more becomes known about $\eta$. By assumption, the revelation of $\xi$ is truthful; i.e., the analysis does not consider implications of possibly strategic misrepresentation of information.

Clearly, the more of the control error that is known to price setters, the more precise is inference about the central bank's policy intentions from observing actual demand and, thus, output gap. Policymaking of the central bank becomes more *transparent* as its intentions to a larger extent *can be distinctly seen.* Formally, this is modelled as

$$\sigma_\xi^2 = \tau \sigma_\eta^2, \qquad \sigma_\upsilon^2 = (1 - \tau)\, \sigma_\eta^2, \tag{8}$$

where $0 \leq \tau < 1$ is an index of transparency. E.g., as $\tau \rightarrow 1$ all variability of the control error becomes publicly known, and hence the central bank's policy intentions can be perfectly inferred. On the other hand, in the case of $\tau = 0$, nothing is revealed about the control error, and, as will be clear below, the price setters can only relatively noisy infer the central bank's intentions, and thus, preferences and future policy.

Having presented the various building blocs of the model, the timing of events is now described in more detail — Table 1 provides a graphical presentation. Before any decisions are made, $x_0^*$ is drawn by nature. Then period 1 begins. First, the cost-push shock and the shock to the central bank's output gap target are realized. Then the central bank chooses its intentions for period 1 demand. The control error is realized, and actual demand

Table 1: Timeline of events and actions

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Period 0 : | $x_0^*$ is drawn | | | | | | |
| Period 1 : | $\varepsilon, \theta$ are realized | $x_1^I$ is chosen | $\eta$ is realized | $x_1$ materializes | $\xi$ is revealed | $\mathrm{E}\left[\pi_2 \vert I_1^P\right]$ is formed | $\pi_1$ materializes |
| Period 2 : | $x_2$ is chosen | $\pi_2$ materializes | | | | | |

is realized. After this, some part of the control error is revealed to the price setters (to a degree determined by transparency, i.e., $\tau$), who thereafter form their expectations about next period's inflation rate. After this, prices are set, thereby determining period 1 inflation. Enter Period 2, where the central bank chooses demand, and price setters set prices, thereby determining period 2 inflation.

The informational asymmetries in period 1 are crucial. Both the central bank and price setters know the structural parameters of the model and the statistical properties of shocks. At the time the central bank chooses its intentions, it has the information set $I_1^{CB} = \{x_0^*, \varepsilon, \theta\}$. The price setters' information set is $I_1^P = \{x_0^*, \varepsilon, x_1, \xi\}$. I.e., they do not know the value of the preference shock, the intended policy, and not all of the control error (except in the limit of $\tau \to 1$). From observables, they estimate $x_1^*$, and thus $x_2^*$, as this latter value is a determinant of period 2 inflation; the variable price setters need to forecast in period 1.

Before proceeding with the derivation of the equilibrium one last assumption is needed. Due to the forward-looking nature of price determination, one needs, in this finite horizon model, a terminal condition on $\mathrm{E}\left[\pi_3 | I_2^P\right]$. I will simply assume that

$$\mathrm{E}\left[\pi_3 | I_2^P\right] = (\lambda/\kappa)\, x_2^*. \tag{9}$$

The exact value of this expectation is not crucial, but as argued below, it is for various reasons a natural choice in the model. In addition, it simplifies the algebra of the solutions.

### 2.1. Equilibrium under full information about the central bank's preferences

To get a feel for the properties of the model, this section derives the equilibrium when there is full information about the central bank's preferences, i.e., $\theta \in I_1^P$. The equilibrium is derived under the assumption that the central bank acts in a discretionary fashion, i.e., that it is unable to precommit to any particular policy plan before the game starts. The model is then solved by backwards induction. In period 2 the central bank solves $\min_{x_2} \left[\lambda \left(x_2 - x_1^*\right)^2 + \pi_2^2\right]$ subject to (2) and (9). [Remember that $x_2^* = x_1^*$; cf. (6).] From the relevant first-order condition, $\lambda \left(x_2 - x_1^*\right) + \kappa \left[(\lambda/\kappa)\, x_1^* + \kappa x_2\right] = 0$, equilibrium output gap and inflation in period 2 follow as

$$x_2 = 0, \quad \pi_2 = (\lambda/\kappa)\, x_1^*. \tag{10}$$

Output will be at its natural rate while inflation will be above the socially optimal value when $x_1^* > 0$. This follows because inflation expectations [exogenously given by the terminal condition (9)] put upwards pressure on actual inflation to an extent that makes any increase in the output gap above the natural rate too expensive in terms of additional inflation. The central bank therefore refrains from expanding output, and have no choice but accepting a too high inflation rate (trying to reduce inflation is too costly in terms of the output gap decrease). The reason for the inefficiently high inflation rate is the central bank's target for output which is above the natural rate. Therefore, the equilibrium is similar to that of the well-known Barro and Gordon (1983) inflation bias model.

Output in period 2 being at the natural rate, and inflation being equal to the expected future inflation, are due to the particular choice of terminal condition for the model. Had $\mathrm{E}\left[\pi_3 | I_2^P\right]$ been assumed higher (lower), the chosen output gap would have been lower (higher). However, as period 2 is interpreted as the "long run," I find it natural to assume a value of $\mathrm{E}\left[\pi_3 | I_2^P\right]$ that implies $\pi_2 = \pi_3$ and no deviations in the output gap from its steady state. Moreover, (10) is also the time-consistent, perfect-foresight solution to an infinite horizon version of the model (see Flodén, 1996).

In period 1 the central bank solves $\min_{x_1^I} \mathrm{E}\left[\lambda \left(x_1 - x_1^*\right)^2 + \pi_1^2 | I_1^{CB}\right]$ subject to (1) and (3), and subject to the fact that by (10), $\mathrm{E}\left[\pi_2 | I_1^P\right] = (\lambda/\kappa)\, x_1^*$ since $\theta \in I_1^P$. From the relevant first-order condition, $\mathrm{E}\left[\lambda \left(x_1^I + \eta - x_1^*\right) + \kappa \left[(\lambda/\kappa)\, x_1^* + \kappa \left(x_1^I + \eta\right) + \varepsilon\right] | I_1^{CB}\right] = 0$, the equilibrium output gap and inflation in period 1 follow as

$$x_1 = -\frac{\kappa}{\lambda + \kappa^2}\varepsilon + \eta, \qquad \pi_1 = (\lambda/\kappa)\left(x_0^* + \theta\right) + \kappa\eta + \frac{\lambda}{\lambda + \kappa^2}\varepsilon. \tag{11}$$

In absence of shocks, the solution resembles that of period 2 with output being at the natural rate and inflation being inefficiently high. The shocks, however, brings the economy off the "steady state." The shock to the output target is exclusively fed into inflation, as inflation expectations change in a way deterring the central bank from attempting to realize any idiosyncratic output goal. E.g., if $\theta > 0$, inflations expectations raise, thereby neutralizing the incentive to raise the output gap as the cost of inflation becomes too high. The control error affects actual output gap by definition, and thereby also inflation. Finally, the inflation shock, due to the central bank's dislike of inflation variability, is optimally "spread out" onto the output gap and inflation. I.e., the central bank contracts output somewhat in response to a positive realization of $\varepsilon$.

Upon inspection of (10) and (11), it is clear that for society, the best discretionary equilibrium would be one where the central bank is characterized by $x_0^* = 0 < x^*$, as this would eliminate any systematic deviation from the inflation target.[10] I.e., having a central bank that targets the output gap at the natural rate is socially beneficial.[11]

### 2.2. Equilibrium under asymmetric information: the role of transparency

Now the model is solved for the case of asymmetric information, where transparency will be a crucial determinant for expectations formation and the central bank's decisions. Again, the model is solved by backwards induction. It is straightforward that in period 2, the decision by the central bank is the same as in the case of full information. Hence, (10) applies. The crucial matter in determining the solution is the identification of $\mathrm{E}\left[\pi_2 | I_1^P\right]$, as this is a determinant of period 1 inflation, and, hence, important for the central bank's decision in period 1. Since $\pi_2 = (\lambda/\kappa)\, x_1^* = (\lambda/\kappa)\,(x_0^* + \theta)$ this boils down to finding $\mathrm{E}\left[\theta | I_1^P\right]$.

For this purpose, conjecture that the central bank's period 1 policy intentions can be expressed as

$$x_1^I = k - k_\varepsilon \varepsilon + k_\theta \theta, \tag{12}$$

where $k$, $k_\varepsilon > 0$ and $k_\theta > 0$ are coefficients to be determined. It will subsequently be shown that if price setters believe that (12) applies, then the central bank's optimal policy will indeed be of this form. Recalling the contents of the price setters' information set, note that they can construct a "signal" variable, $s_1$, at the expectations formation stage:

$$s_1 = x_1 - \xi - k + k_\varepsilon \varepsilon. \tag{13}$$

[10] It is interesting to note that $x_0^* = 0$ does *not* result in the unconstrained optimum. In a precommitment solution, the inflation target is in absence of $\varepsilon$-shocks met in both periods. However, an inflation shock, is allowed to affect the output gap and inflation in *both* periods. This is a consequence of the forward-looking nature of inflation determination: if a contractive policy is expected to persist, lower expectations about future inflation dampen current inflation; see, e.g., Woodford (1999). I, however, refrain from an examination of precommitment here.

[11] In Appendix A it is shown that for any terminal condition $\mathrm{E}\left[\pi_3 | I_2^P\right] > 0$, having $x_0^* < x^*$ is beneficial for society.

Since (3) and (12) imply $x_1 = k - k_\varepsilon \varepsilon + k_\theta \theta + \eta$, it follows by (7) that $s_1$ can be condensed as

$$s_1 = k_\theta \theta + \upsilon. \tag{14}$$

In determining $\mathrm{E}\left[\theta | I_1^P\right]$, price setters then solve a standard signal-extraction problem. Because $\theta$ and $\upsilon$ are independently normally distributed, the conditional expectation of $\theta$ becomes

$$\mathrm{E}\left[\theta | I_1^P\right] = \mathrm{E}\left[\theta | s_1\right] = S\left(k_\theta\right) s_1, \quad S\left(k_\theta\right) \equiv \frac{k_\theta \sigma_\theta^2}{k_\theta^2 \sigma_\theta^2 + \sigma_\upsilon^2} > 0, \tag{15}$$

where $S\left(k_\theta\right)$ can be interpreted as the degree of informativeness of $s_1$ in terms of predicting $\theta$. Clearly, for a relatively high value of $\sigma_\upsilon^2$, $s_1$ provides only rather noisy information about $\theta$, whereas in the limit of $\sigma_\upsilon^2 \to 0$, the signal reveals the value of $\theta$ precisely. The price setters' inflation expectations thus follow as

$$\mathrm{E}\left[\pi_2 | I_1^P\right] = (\lambda/\kappa)\left[x_0^* + S\left(k_\theta\right) s_1\right]. \tag{16}$$

The central bank's optimal behavior in period 1 is characterized by the solution to

$$\min_{x_1^I} \mathrm{E}\left[\lambda\left(x_1 - x_0^* - \theta\right)^2 + \pi_1^2 | I_1^{CB}\right],$$

subject to (1), (3) and (16) [note that period 2 outcomes are not included in the minimand, as they are independent of period 1 policy, cf. (10)]. The first-order condition is

$$\begin{aligned} & \mathrm{E}\left[\lambda\left(x_1^I + \eta - x_0^* - \theta\right) | I_1^{CB}\right] \\ & + \mathrm{E}\left[\left((\lambda/\kappa)\left[x_0^* + S\left(k_\theta\right) s_1\right] + \kappa\left[x_1^I + \eta\right] + \varepsilon\right)\left(\kappa + (\lambda/\kappa) S\left(k_\theta\right) \frac{\partial s_1}{\partial x_1^I}\right) \middle| I_1^{CB}\right] \\ = & \ 0. \end{aligned} \tag{17}$$

From (3) and (13), it follows that $\partial s_1 / \partial x_1^I = 1$. Also, note by (14) that $\mathrm{E}\left[s_1 | I_1^{CB}\right] = k_\theta \theta$. Using these insights, and taking the relevant conditional expectation, (17) reduces to

$$\lambda\left(x_1^I - x_0^* - \theta\right) + \left((\lambda/\kappa)\left[x_0^* + S\left(k_\theta\right) k_\theta \theta\right] + \kappa x_1^I + \varepsilon\right)\left(\kappa + (\lambda/\kappa) S\left(k_\theta\right)\right) = 0. \tag{18}$$

From this, the optimal period 1 policy intentions emerge as

$$x_1^I = -\frac{(\lambda/\kappa)^2 x_0^* S\left(k_\theta\right)}{\lambda + \kappa^2 + \lambda S\left(k_\theta\right)} - \frac{\kappa + (\lambda/\kappa) S\left(k_\theta\right)}{\lambda + \kappa^2 + \lambda S\left(k_\theta\right)} \varepsilon + \frac{\lambda\left[1 - S\left(k_\theta\right) k_\theta\left(1 + \left(\lambda/\kappa^2\right) S\left(k_\theta\right)\right)\right]}{\lambda + \kappa^2 + \lambda S\left(k_\theta\right)} \theta, \tag{19}$$

which verifies the form of the conjecture (12). It is then straightforward to establish by (12) and (19) that the unknown coefficients satisfy

$$\begin{aligned} k_\theta &= \frac{\lambda}{\lambda + \left(\kappa + (\lambda/\kappa)\, S(k_\theta)\right)^2} \equiv F(k_\theta) > 0, \qquad (20) \\ k_\varepsilon &= \frac{\kappa + (\lambda/\kappa)\, S(k_\theta)}{\lambda + \kappa^2 + \lambda S(k_\theta)} > 0, \qquad (21) \\ k &= -\frac{(\lambda/\kappa)^2\, x_0^* S(k_\theta)}{\lambda + \kappa^2 + \lambda S(k_\theta)} \lesseqgtr 0. \qquad (22) \end{aligned}$$

Remark the recursive structure of the system (20)-(22): $k_\theta$ is determined by (20), and in Appendix B it is proven that a unique solution to $k_\theta$ exists. Given this solution, $k_\varepsilon$ and $k$ are uniquely determined by (21) and (22), respectively. Hence, for any realization of $\varepsilon$ and $\theta$, equilibrium policy of the linear form (12) is unique.

Before proceeding with the numerical analysis, a case offering a closed-form solution is worthy of investigation in order to obtain some intuition of the characteristics of the equilibrium. In the limiting case of full transparency, $\tau \to 1$, everything about the control error is revealed, and therefore, by (8), $\sigma_v^2 = (1-\tau)\,\sigma_\eta^2 \to 0$. In consequence, $S(k_\theta) \to 1/k_\theta$, cf. (15). It then follows from (20) that $k_\theta \to 0$, and, thus, $S(k_\theta) \to \infty$. Examining (21) and (22) then reveals that $k_\varepsilon \to 1/\kappa$ and $k \to -(\lambda/\kappa^2)\, x_0^*$. Collecting this information, provides the equilibrium solution for the output gap and inflation in period 1 as

$$x_1|_{\tau\to 1} = \eta - \left(\lambda/\kappa^2\right) x_0^* - (1/\kappa)\,\varepsilon, \qquad \pi_1|_{\tau\to 1} = (\lambda/\kappa)\,\theta + \kappa\eta. \qquad (23)$$

Approaching full transparency, inflation expectations are extremely sensitive to the actions of the central bank, who therefore is induced to give inflation stabilization highest priority in policymaking and thus act in isolation of political pressures for a particular output target.

In effect, only control errors and realized political pressure shocks cause deviations of inflation from target. To meet this end, however, the central bank must (in case of $x_0^* > 0$) perform a contractive policy so as to squeeze out inflation of the economy — except for the part accruing from the price setters' perfect forecast of the preference shock's influence on period 2 policy and inflation. Such a contractive policy may be unacceptable to a society putting a non-negligible weight on the output gap, and is one downside of a high degree of transparency to be considered. Furthermore, due to the priority given to inflation stabilization, any inflationary shock will exclusively be transmitted onto the output gap. In effect, the balance between output gap and inflation variability becomes unacceptable from a social point of view. [Cf. the optimal balance as shown by (11).]

This example shows some of the trade-offs involved in the determination of the optimal degree of transparency. By making expectations more sensitive to policy actions, the central bank is induced to pay more attention to inflation stabilization. Hence, the more transparency in policymaking, the closer will inflation be to its preferred value on average. Transparency is thus good if credibility of the inflation target is lacking. The flip-side of the coin to this, however, is that the period 1 output gap may reach an unacceptable low average value, and exhibit too high inflation-shock driven variability. These trade-offs and their influence on the optimal value of $\tau$ from the point of view of society are examined more thoroughly in the next section.

## 3. The optimal degrees of transparency

The criterion for evaluating the optimal degrees of transparency will be the value of society's loss in the equilibrium described above. Inserting (10) and (12) into (4) [and recalling (1), (3) and 16], society's equilibrium loss can be written as

$$\begin{aligned} L^S &= 2\lambda x^{*2} + 2\left(\lambda/\kappa\right)^2 x_0^{*2} + \left(\lambda + \kappa^2\right)\sigma_\eta^2 + \left(\lambda/\kappa\right)^2 \sigma_\theta^2 \\ &\quad + \left(\lambda + \kappa^2\right) k^2 + 2\lambda k \left(x_0^* - x^*\right) + \left[\lambda k_\varepsilon^2 + \left(1 - \kappa k_\varepsilon\right)^2\right]\sigma_\varepsilon^2 \\ &\quad + \left(\lambda/\kappa\right)^2 S\left(k_\theta\right)^2 \left(1-\tau\right)\sigma_\eta^2 + \left[\lambda + \left(\kappa + \left(\lambda/\kappa\right) S\left(k_\theta\right)\right)^2\right] k_\theta^2 \sigma_\theta^2, \end{aligned} \tag{24}$$

where I have used that $\sigma_\upsilon^2 = (1-\tau)\,\sigma_\eta^2$, which must also be remembered in the definition of $S\left(k_\theta\right)$.

The objective of the remainder of this section is to identify the value of $\tau$, which minimizes (24) for various parameter constellations. I will mainly focus on the optimal degrees of transparency when three key concepts vary in importance. First, *initial credibility* as quantified by $x_0^*$. E.g., a value of $x_0^*$ equal to the natural rate (zero) will, as shown above, lead to the most favorable outcome, as inflationary expectations will match the inflation target. This case will therefore be considered synonymous with a central bank with good credibility, whereas cases of $x_0^* > 0$ will be cases of a bank with initial credibility problems. Second, *independence* as quantified through $\sigma_\theta^2$. The idea being that high values of $\sigma_\theta^2$ describe a bank subject to much pressure in terms of shifting its output objective. In contrast, low values of $\sigma_\theta^2$ represents a bank who is most likely to stick to its initial goal for output. Thirdly, the *stabilization need* as quantified by $\sigma_\varepsilon^2$; within the model framework this represents a relatively strong need for active monetary stabilization policy.

The numerical exercises will thus cover changes in $x_0^*$, $\sigma_\theta^2$ and $\sigma_\varepsilon^2$. The remaining

Table 2: Optimal degrees of transparency

| $\sigma_\theta^2 = 0.05$ | $x_0^* = 0.00$ | $x_0^* = 1.00$ | $x_0^* = 2.00$ | $x_0^* = 3.00$ | $x_0^* = 4.00$ |
|---|---|---|---|---|---|
| $\sigma_\varepsilon^2 = 0.00$ | 0.999 | 0.000 | 0.000 | 0.964 | 0.984 |
| $\sigma_\varepsilon^2 = 0.50$ | 0.016 | 0.000 | 0.000 | 0.963 | 0.983 |
| $\sigma_\varepsilon^2 = 1.00$ | 0.004 | 0.000 | 0.000 | 0.962 | 0.983 |
| $\sigma_\varepsilon^2 = 2.00$ | 0.000 | 0.000 | 0.000 | 0.960 | 0.983 |

| $\sigma_\theta^2 = 0.50$ | $x_0^* = 0.00$ | $x_0^* = 1.00$ | $x_0^* = 2.00$ | $x_0^* = 3.00$ | $x_0^* = 4.00$ |
|---|---|---|---|---|---|
| $\sigma_\varepsilon^2 = 0.00$ | 0.999 | 0.000 | 0.000 | 0.663 | 0.843 |
| $\sigma_\varepsilon^2 = 0.50$ | 0.988 | 0.000 | 0.000 | 0.656 | 0.841 |
| $\sigma_\varepsilon^2 = 1.00$ | 0.896 | 0.000 | 0.000 | 0.645 | 0.837 |
| $\sigma_\varepsilon^2 = 2.00$ | 0.001 | 0.000 | 0.000 | 0.625 | 0.833 |

| $\sigma_\theta^2 = 1.00$ | $x_0^* = 0.00$ | $x_0^* = 1.00$ | $x_0^* = 2.00$ | $x_0^* = 3.00$ | $x_0^* = 4.00$ |
|---|---|---|---|---|---|
| $\sigma_\varepsilon^2 = 0.00$ | 0.999 | 0.000 | 0.000 | 0.367 | 0.699 |
| $\sigma_\varepsilon^2 = 0.50$ | 0.999 | 0.000 | 0.000 | 0.354 | 0.692 |
| $\sigma_\varepsilon^2 = 1.00$ | 0.975 | 0.000 | 0.000 | 0.337 | 0.683 |
| $\sigma_\varepsilon^2 = 2.00$ | 0.792 | 0.000 | 0.000 | 0.290 | 0.674 |

| $\sigma_\theta^2 = 2.00$ | $x_0^* = 0.00$ | $x_0^* = 1.00$ | $x_0^* = 2.00$ | $x_0^* = 3.00$ | $x_0^* = 4.00$ |
|---|---|---|---|---|---|
| $\sigma_\varepsilon^2 = 0.00$ | 0.999 | 0.000 | 0.000 | 0.004 | 0.440 |
| $\sigma_\varepsilon^2 = 0.50$ | 0.999 | 0.000 | 0.000 | 0.004 | 0.433 |
| $\sigma_\varepsilon^2 = 1.00$ | 0.999 | 0.000 | 0.000 | 0.004 | 0.425 |
| $\sigma_\varepsilon^2 = 2.00$ | 0.950 | 0.000 | 0.000 | 0.000 | 0.407 |

The optimal values of $\tau$ for the case of $\lambda = 1.00$, $x^* = 2.00$, $\kappa = 1.0$ and $\sigma_\eta^2 = 1.00$.

parameters are kept fixed at the following values: $x^* = 2.0$, $\lambda = 1.0$, $\kappa = 1.0$ and $\sigma_\eta^2 = 1.0$. For each exercise, $\tau$ is varied from 0 to 0.999 with a grid of 0.001. The value of $\tau$ yielding the lowest value of $L^S$ [as given by (24)] is then taken as the optimal degree of transparency. Table 2 reports the optimal degrees of transparency for all combinations of $x_0^* \in [0.00, 1.00, 2.00, 3.00, 4.00]$, $\sigma_\varepsilon^2 \in [0.00, 0.50, 1.00, 2.00]$ and $\sigma_\theta^2 \in [0.05, 0.50, 1.00, 2.00]$.

As mentioned, a central bank is assumed to enjoy initial credibility, the more compatible are its output and inflation targets. In such a case, transparency mainly serves to insulate policy from macroeconomic variability induced by political pressure, i.e., from variability in $\theta$; average inflation is not going to be an issue in institutional design. Not surprisingly, therefore, the optimal degree of transparency is higher the higher is $\sigma_\theta^2$. Note, however, that in conformity with the discussion in Section 2.2, for a given $\sigma_\theta^2$, this degree is decreasing in the need for stabilization need. This is most evident in the case of very small chances of a "divergent" output goal, i.e., when $\sigma_\theta^2 = 0.05$. There, in the absence of any inflation shocks, transparency should be at the maximum. In presence of inflation shocks of increasing variance, however, the optimal degree of transparency falls dramatically. The optimal reduction in transparency induced by stabilization needs, becomes smaller the higher is $\sigma_\theta^2$. This follows because for high values of $\sigma_\theta^2$, the main source of macroeconomic variability is that arising from political pressures. Inflation shocks — of whatever variance — contribute only little to the overall social loss. In conclusion, a central bank with good initial credibility, a high degree of de facto independence, and with a need for performing active stabilization policy does not have to be transparent, as transparency will merely distort macroeconomic stabilization.

A central bank with less perfect initial credibility, $x_0^* > 0$, will, as discussed above, ceteris paribus conduct a monetary policy leading to inflation above target. Immediately, one would conjecture that this would necessitate transparency, so as to induce the central bank to pay more attention to its inflation target. The results of Table 2, however, does not unambiguously confirm this assertion. For central banks with "moderate" credibility problems, $x_0^* = 1.00$ and $x_0^* = 2.00$, the optimal degrees of transparency are in fact zero no matter the degree of independence and stabilization need. The explanation for this result is that the positive average inflation rate resulting from the credibility problem is not of overwhelming magnitude. Hence, by introducing transparency, the central bank will be induced to conduct a contractive policy sending the economy into a recession. This loss of output cannot outweigh the gain from reduced inflation, when credibility problems are relatively moderate.

When credibility problems are worse, the intuition about a need for transparency becomes valid. As evident, when $x_0^* = 3.00$ and $x_0^* = 4.00$, equilibrium inflation will be excessive to a degree that the loss in output induced by transparency is outweighed by the gain in terms of lower inflation. In these cases, excessive inflation is thus the prime concern in institutional design, and transparency should be substantive. Political pressures do not play a dominant role *per se*. They mainly serve the role of enabling changes in transparency to have macroeconomic effects through inflation expectations formation. E.g., if $\sigma_\theta^2$ is low, it requires a relatively high degree of transparency to attain a given marginal effect of policy on inflation expectations. The reason being that in such a case there is relatively much noise in the signal-extraction problem, and the private sector reacts — for given transparency — little to changes in policy actions (these changes are most likely to have arisen from a control error rather than from a change in the output goal). On the other hand, if $\sigma_\theta^2$ is high, transparency need not be so high, as the noise is relatively low, and the private sector will therefore react more strongly to policy changes. This explains why in the cases of $x_0^* = 3.00$ and $x_0^* = 4.00$ the optimal degree of transparency, all things equal, decreases with $\sigma_\theta^2$; in contrast in the situation where it was political pressures *per se*, which were the main problem (as in the case of $x_0^* = 0$).

Note also that increased stabilization needs will in all cases reduce the optimal degree of transparency as the distortion created by transparency becomes more costly.[12] From the Table, however, it is evident that the sensitivity of the optimal degree of transparency with respect to $\sigma_\varepsilon^2$ is rather small. This is because when credibility problems are severe, the (optimal) recession induced by transparency is severe, making the main social cost the loss of output. Variability induced by inflation shocks play a relatively minor role, and the design of transparency is therefore less sensitive to changes in $\sigma_\varepsilon^2$.

This last aspect points to an important quantitative qualifier concerning the results presented in this paper. Note that the model is interpreted as period 1 being the short run, and period 2 as the long run. But in the evaluation of the social loss, they are given the same weight. Clearly then, if the model is extended (say, to an infinite horizon model), the short run losses of output contractions will be given relatively small weight when evaluating the social loss of various degree of transparency. This will most likely change the results of the table in two dimensions. First, even for moderate credibility problems ($x_0^* = 1.00$ and $x_0^* = 2.00$) some transparency will be optimal, as the output contraction causing the optimality of zero transparency in Table 2 will contribute rather little to the overall social loss. Secondly, and more importantly, the sensitivity of the optimal degree of transparency with respect to $\sigma_\varepsilon^2$ will probably become much higher in the cases of $x_0^* = 3.00$ and $x_0^* = 4.00$. The reason being that the initial output contractions, as mentioned, will contribute less to the social loss, whereas the distortion in stabilization policy is present in every period. So, if $\sigma_\varepsilon^2$ increases, it would be optimal to reduce $\tau$ by more that what is reflected by Table 2 where, as mentioned, the main determinant of the optimal $\tau$ is the gain of reduced inflation versus the loss of output. In an infinite horizon version of model, the trade-off between gain of credibility and loss of flexibility in the determination of transparency would therefore probably feature much stronger (this conjecture is the subject of current research). In any case, the results obtained in this simple model illustrates this and other important trade-offs in the determination of the optimal degree of transparency.

[12] The result can easily be shown analytically. From (24), it follows that the effect of $\sigma_\varepsilon^2$ on the social loss is minimized for $k_\varepsilon = \kappa / \left(\lambda + \kappa^2\right)$; the response to inflation shocks under full information. In equilibrium, however, it follows by (21) that $k_\varepsilon > \kappa / \left(\lambda + \kappa^2\right)$ since $S\left(k_\theta\right) > 0$. Furthermore, in Appendix C it is shown that $\partial S\left(k_\theta\right) / \partial \tau > 0$, which implies that $k_\varepsilon$ increases with $\tau$ because $\partial k_\varepsilon / \partial S\left(k_\theta\right) > 0$. In other words, more transparency unambiguously increases the social loss from $\sigma_\varepsilon^2$, so an increase in $\sigma_\varepsilon^2$ implies a lower optimal degree of transparency.

## 4. Concluding remarks

From a semantic and democratic point of view, full transparency in the policy conduct of a politically independent central bank is obviously a must. The results of this paper demonstrate in a simple model emphasizing forward-looking behavior that this conclusion is debatable from an economic point of view. Most importantly, the results point to trade-offs in the optimal degree of transparency, of which the main one is well known in the literature on monetary policymaking. Namely that between credibility and flexibility. More transparency leads to a more "disciplined" policy of the bank, which is good if it lacks credibility, but which is bad if stabilizing the economy against shocks is of importance. This trade-off is absent in other formal analyses of transparency, as these ignore the importance of forward-looking economic variables. They may then underestimate that the response of market expectations to monetary policy actions comes quickly and with immediate impact on current aggregates, thereby hampering stabilization efforts.

The results are, of course, not conclusive for how central bank regulations should be designed with respect to a complex concept like transparency, which has been modelled here in just one of possible many ways. The identification of various trade-offs, however, emphasizes strongly that it is generally inappropriate to consider transparency as a "free lunch." Or as the opposite for that matter.[13]

It is of interest to contemplate what other forms of information disclosure are possible within this model framework. Transparency, in this paper, makes it easier for the price setters to *infer* the true intentions of the central bank. Now, an obvious alternative to this form of transparency is a case where price setters are directly informed about the preferences of the central banker. In this case of full information, however, the incentive correcting mechanism of transparency vanishes: when forming inflation expectations, the private sector knows with perfection policy in period 2. Hence, inflation expectations will be *in*sensitive to the central bank's actions.

In the model of Faust and Svensson (2000), such full information about the goals of the central bank leads to the worst of all outcomes (essentially, the model then features an inflation bias like in Barro and Gordon, 1983). In my model, however, the incentive correcting mechanism of transparency distorts shock stabilization as emphasized above. In contrast, under full information, inflation shocks are stabilized optimally (when the central bank operates under discretion; conform Footnote 10). Hence, it may be the case that when

[13] It is worthwhile stressing that the analysis points to disadvantages of transparency in an "ideal" environment where there are no problems in terms of sending and receiving information — problems that otherwise may complicate the implementation of transparency in practice as argued by Winkler (2000).

the central bank enjoys good credibility, and the need for stabilization is relatively large, a regime of full information is preferable to a regime of full transparency. This conjecture is indeed verified in Appendix D (from where it also follows that if credibility is sufficiently poor, full information is inferior for basically the same reason as in Faust and Svensson, 2000). This implies that in an economy with a need for macroeconomic stabilization, transparency in the sense of facilitating inference about the characteristics of the central bank is a straitjacket, which can be loosened if, instead, preferences are revealed directly.

From an implementation point of view, transparency as modelled in this paper could, as mentioned, be achieved through the release of various forecasts and reports making it easier for the public to estimate future policy. The feasibility of the full information case is, however, rather questionable. It is unclear which mechanisms could completely eliminate preference uncertainty. Note also that even when preference uncertainty is very limited (i.e., $\sigma_\theta^2$ is small), the identified trade-offs in the optimal design of transparency are still important as evident from Table 2 for the case of $\sigma_\theta^2 = 0.05$. It thus appears that a proper modelling of openness is one that acknowledges some uncertainty about preferences, and view transparency as a means to facilitating expectations formation.

# Appendix

## A. Solution for an arbitrary terminal condition in case of full information

Instead of assuming (9), assume that $\mathrm{E}\left[\pi_3|I_2^P\right] = T$. In period 2 the central bank then solves $\min_{x_2}\left[\lambda\left(x_2 - x_1^*\right)^2 + \pi_2^2\right]$ subject to (2) and $\mathrm{E}\left[\pi_3|I_2^P\right] = T$. The relevant first-order condition is $\lambda\left(x_2 - x_1^*\right) + \kappa\left(T + \kappa x_2\right) = 0$ from which the period 2 solution emerges as

$$x_2 = \frac{\lambda x_1^* - \kappa T}{\lambda + \kappa^2}, \quad \pi_2 = \frac{\lambda\left(\kappa x_1^* + T\right)}{\lambda + \kappa^2}. \tag{A.1}$$

In finding the solution for period 1, assume that $\theta = \eta = 0$, and thus $x_1^* = x_0^*$. This is inconsequential, as the main issue is to demonstrate when a value of $x_0^*$ lower than $x^*$ is beneficial. Allowing for a $\theta$-shock only adds an independent source of fluctuations. Likewise, the way the control error affects the outcomes is orthogonal to the issue at hand. Hence, period 1 equilibrium is found by solving $\min_{x_1}\left[\lambda\left(x_1 - x_0^*\right)^2 + \pi_1^2\right]$ subject to (1) and $\mathrm{E}\left[\pi_2|I_1^P\right] = \lambda\left(\kappa x_0^* + T\right)/\left(\lambda + \kappa^2\right)$. The first-order condition is $\lambda\left(x_1 - x_0^*\right) + \kappa[\lambda\left(\kappa x_0^* + T\right)/\left(\lambda + \kappa^2\right) + \kappa x_1 + \varepsilon] = 0$ implying

$$x_1 = \frac{\lambda\left(\lambda x_0^* - \kappa T\right)}{\left(\lambda + \kappa^2\right)^2} - \frac{\kappa}{\lambda + \kappa^2}\varepsilon, \quad \pi_1 = \frac{\lambda\left[\kappa\left[2\lambda + \kappa^2\right]x_0^* + \lambda T\right]}{\left(\lambda + \kappa^2\right)^2} + \frac{\lambda}{\lambda + \kappa^2}\varepsilon. \tag{A.2}$$

As the response to the inflation shock is invariant to $x_0^*$, we can ignore it when assessing the set of desirable values of $x_0^*$. Society's loss from a policy leading to (A.1)-(A.2) is then simply given by

$$\begin{aligned} L^S &= \lambda \left( \frac{\lambda \left( \lambda x_0^* - \kappa T \right)}{\left( \lambda + \kappa^2 \right)^2} - x^* \right)^2 + \left( \frac{\lambda \left[ \kappa \left[ 2\lambda + \kappa^2 \right] x_0^* + \lambda T \right]}{\left( \lambda + \kappa^2 \right)^2} \right)^2 \\ &+ \lambda \left( \frac{\lambda x_0^* - \kappa T}{\lambda + \kappa^2} - x^* \right)^2 + \left( \frac{\lambda \left( \kappa x_0^* + T \right)}{\lambda + \kappa^2} \right)^2 . \end{aligned}$$

One then finds that

$$\begin{aligned} \frac{\partial L^S}{\partial x_0^*} &= 2\lambda \left( \frac{\lambda \left( \lambda x_0^* - \kappa T \right)}{\left( \lambda + \kappa^2 \right)^2} - x^* \right) \frac{\lambda^2}{\left( \lambda + \kappa^2 \right)^2} + 2 \left( \frac{\lambda \left[ \kappa \left[ 2\lambda + \kappa^2 \right] x_0^* + \lambda T \right]}{\left( \lambda + \kappa^2 \right)^2} \right) \frac{\lambda \kappa \left[ 2\lambda + \kappa^2 \right]}{\left( \lambda + \kappa^2 \right)^2} \\ &+ 2\lambda \left( \frac{\lambda x_0^* - \kappa T}{\lambda + \kappa^2} - x^* \right) \frac{\lambda}{\lambda + \kappa^2} + 2 \left( \frac{\lambda \left( \kappa x_0^* + T \right)}{\lambda + \kappa^2} \right) \frac{\lambda \kappa}{\lambda + \kappa^2}, \qquad \text{(A.3)} \end{aligned}$$

and as $\partial^2 L^S / \partial x_0^{*2} > 0$ it follows that $\partial L^S / \partial x_0^* = 0$ characterizes the value of $x_0^*$ securing the lowest social loss. We find that this must satisfy

$$\begin{aligned} & \lambda \left( \frac{\lambda \left( \lambda x_0^* - \kappa T \right)}{\left( \lambda + \kappa^2 \right)^2} - x^* \right) \frac{\lambda}{\lambda + \kappa^2} + \left( \frac{\lambda \left[ \kappa \left[ 2\lambda + \kappa^2 \right] x_0^* + \lambda T \right]}{\left( \lambda + \kappa^2 \right)^2} \right) \frac{\kappa \left[ 2\lambda + \kappa^2 \right]}{\lambda + \kappa^2} \\ & + \lambda \left( \frac{\lambda x_0^* - \kappa T}{\lambda + \kappa^2} - x^* \right) + \frac{\lambda \kappa \left( \kappa x_0^* + T \right)}{\lambda + \kappa^2} \\ = \; & 0. \end{aligned}$$

If the left hand side evaluated at $x_0^* = x^*$ is positive, then it follows that a value $x_0^* < x^*$ is preferable to society. This is the case if

$$\begin{aligned} & \lambda \left( \frac{\lambda \left( \lambda x^* - \kappa T \right)}{\left( \lambda + \kappa^2 \right)^2} - x^* \right) \frac{\lambda}{\lambda + \kappa^2} + \left( \frac{\lambda \left[ \kappa \left[ 2\lambda + \kappa^2 \right] x^* + \lambda T \right]}{\left( \lambda + \kappa^2 \right)^2} \right) \frac{\kappa \left[ 2\lambda + \kappa^2 \right]}{\lambda + \kappa^2} \\ & + \lambda \left( \frac{\lambda x^* - \kappa T}{\lambda + \kappa^2} - x^* \right) + \frac{\lambda \kappa \left( \kappa x^* + T \right)}{\lambda + \kappa^2} \\ > \; & 0, \end{aligned}$$

which after tedious manipulation reduces to

$$x^* \kappa \left( 2\lambda + \kappa^2 \right) + T\lambda > 0.$$

This always holds for $T > 0$.

## B. Proof of existence and uniqueness of $k_\theta$

*Existence.* Since $S(0) = S(\infty) = 0$, cf. (15), it follows from (20) that $F(0) = F(\infty) = \lambda/(\lambda+\kappa^2)$. For $0 < k_\theta < \infty$, $S(k_\theta) > 0$, and it then follows from (20) that $F(k_\theta) < \lambda/(\lambda+\kappa^2)$. A solution for $k_\theta$ therefore belongs to $[0, \lambda/(\lambda+\kappa^2)]$, and at least one solution obviously exists since $F$ is continuous.

*Uniqueness.* Since the slope of the left hand side of (20) is 1, it follows that if the slope of $F$ in a solution is smaller than 1, the solution is unique. This is the case if

$$F'(k_\theta) = -\frac{2\lambda^2\left[1+(\lambda/\kappa^2)S(k_\theta)\right]}{\left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2}S'(k_\theta) < 1 \tag{B.1}$$

holds in a solution. Using the expression for $S'(k_\theta)$ this is rewritten as

$$-\frac{2\lambda^2\left[1+(\lambda/\kappa^2)S(k_\theta)\right]}{\left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2}\frac{\sigma_\theta^2\left(\sigma_\upsilon^2-k_\theta^2\sigma_\theta^2\right)}{\left(k_\theta^2\sigma_\theta^2+\sigma_\upsilon^2\right)^2} < 1$$

Using the characterization of a solution, (20), and the definition of $S$, (15), this can after some manipulation be further rewritten as

$$-\frac{2\lambda\left[1+(\lambda/\kappa^2)S(k_\theta)\right]S(k_\theta)}{\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2}\left(1-2\frac{k_\theta^2\sigma_\theta^2}{k_\theta^2\sigma_\theta^2+\sigma_\upsilon^2}\right) < 1$$

and thus

$$-\frac{2\lambda\left[1+(\lambda/\kappa^2)S(k_\theta)\right]S(k_\theta)}{\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2}\left(1-2\frac{\lambda S(k_\theta)}{\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2}\right) < 1$$

by use of (20) and (15). This is equivalent of

$$\begin{aligned} & 4\lambda^2\left[1+\left(\lambda/\kappa^2\right)S(k_\theta)\right]S(k_\theta)^2 \\ < \; & \left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2 + 2\lambda\left[1+\left(\lambda/\kappa^2\right)S(k_\theta)\right]S(k_\theta)\left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right], \end{aligned}$$

and thus

$$-2\lambda\left[1+\left(\lambda/\kappa^2\right)S(k_\theta)\right]S(k_\theta)\left\{\lambda+\kappa^2+(\lambda/\kappa)^2S(k_\theta)^2\right\} < \left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2,$$

which always holds.

### C. Proof that $\partial S(k_\theta)/\partial\tau > 0$

Since $\sigma_v^2 = (1-\tau)\sigma_\eta^2$, proving that $\partial S(k_\theta)/\partial\sigma_v^2 < 0$ is equivalent. I do this by use of the Implicit Function Theorem. Totally differentiating the expression for $S(k_\theta)$, (15), yields

$$\mathrm{d}S(k_\theta) = \frac{\sigma_\theta^2\left(\sigma_v^2 - k_\theta^2\sigma_\theta^2\right)}{\left(k_\theta^2\sigma_\theta^2+\sigma_v^2\right)^2}\mathrm{d}k_\theta - \frac{k_\theta\sigma_\theta^2}{\left(k_\theta^2\sigma_\theta^2+\sigma_v^2\right)^2}\mathrm{d}\sigma_v^2. \tag{C.1}$$

Totally differentiating (20) yields

$$\mathrm{d}k_\theta = -\frac{2\lambda^2\left(1+(\lambda/\kappa^2)S(k_\theta)\right)}{\left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2}\mathrm{d}S(k_\theta), \tag{C.2}$$

which inserted back into (C.1) yields

$$\left[\left(k_\theta^2\sigma_\theta^2+\sigma_v^2\right)^2 + \frac{2\lambda^2\left(1+(\lambda/\kappa^2)S(k_\theta)\right)\sigma_\theta^2\left(\sigma_v^2-k_\theta^2\sigma_\theta^2\right)}{\left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2}\right]\mathrm{d}S(k_\theta) = -k_\theta\sigma_\theta^2\mathrm{d}\sigma_v^2.$$

A sufficient condition securing $\partial S(k_\theta)/\partial\sigma_v^2 < 0$ is therefore

$$\left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2\left(k_\theta^2\sigma_\theta^2+\sigma_v^2\right)^2 + 2\lambda^2\left(1+\left(\lambda/\kappa^2\right)S(k_\theta)\right)\sigma_\theta^2\left(\sigma_v^2-k_\theta^2\sigma_\theta^2\right) > 0,$$

or,

$$-\frac{2\lambda^2\left(1+(\lambda/\kappa^2)S(k_\theta)\right)\sigma_\theta^2\left(\sigma_v^2-k_\theta^2\sigma_\theta^2\right)}{\left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2\left(k_\theta^2\sigma_\theta^2+\sigma_v^2\right)^2} < 1.$$

By nature of $S$, it follows that this corresponds to

$$-\frac{2\lambda^2\left(1+(\lambda/\kappa^2)S(k_\theta)\right)}{\left[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2\right]^2}S'(k_\theta) < 1.$$

This is exactly condition (B.1), which was proven to hold in Appendix B.

### D. Full information or full transparency?

The social loss under full information, is readily found by use of (11) and (4) as

$$L^S\big|_{full\ info} = 2\lambda x^{*2} + 2(\lambda/\kappa)^2 x_0^{*2} + 2(\lambda/\kappa)^2\sigma_\theta^2 + \left(\lambda+\kappa^2\right)\sigma_\eta^2 + \frac{\lambda}{\lambda+\kappa^2}\sigma_\varepsilon^2. \tag{D.1}$$

The loss under full transparency is then found using (23) and (4) as

$$L^S\big|_{full\ trans} \quad = \quad 2\lambda x^{*2} + \left(\left(1/\kappa^2\right)+\lambda\right)(\lambda/\kappa)^2 x_0^{*2} + 2(\lambda/\kappa)^2 x_0^* x^*$$

$$+2\left(\lambda/\kappa\right)^2\sigma_\theta^2+\left(\lambda+\kappa^2\right)\sigma_\eta^2+\lambda\left(1/\kappa\right)^2\sigma_\varepsilon^2. \tag{D.2}$$

By simple comparison, it therefore follows by use of (D.1) and (D.2) that a regime of full information is preferable to a regime of full transparency if

$$\frac{1}{\lambda+\kappa^2}\sigma_\varepsilon^2>2\left(x_0^*-x^*\right)x_0^*-\left(1/\kappa^2+\lambda\right)x_0^{*2}. \tag{D.3}$$

This condition is always fulfilled if $x_0^*=0$, thus confirming the assertion made in the main text. If $x_0^*>0$, the condition may not hold, but all things equal it follows that the larger is the stabilization need, i.e., $\sigma_\varepsilon^2$, the more likely is (D.3) satisfied.

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