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Optimal Degrees of Transparency in Monetary Policymaking

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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: *E*42; *E*52; *F*58

I. Introduction

If the definition contained in a standard dictionary is representative of the common perception about a subject, there is no doubt that being transparent is 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.

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In terms of monetary policymaking, transparency should therefore be something to strive for. For example, is "opaque" and "secretive" policymaking desirable under any circumstances? or policy conducted with a lack of "earnestness?" In policy debates, the answers to such rhetorical questions are 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:

> "... the enforcer for the ECB Opaqueness Squad."
> Willem H. Buiter on Otmar Issing in "Alice in Euroland" (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'" (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, Issing's statement is not surprising either. Therefore, most debates on transparency of monetary policy are often reduced to situations where proponents of more transparency are met by claims that the central bank is indeed aiming at high degrees of transparency.[1] Hence, a consensus about the virtues of transparency seems to prevail: transparency is a necessity in order to obtain sound monetary policy. In addition, it helps to hold independent central banks accountable for their actions, and transparency may compensate for the "democratic loss" society incurs from central bank independence.[2]

Triggered mainly by the formation of the ECB, however, analyses moving beyond simple rhetoric of the topic have emerged.[3] 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, transparency is obviously a broad concept, which illustrates openness in several dimensions, for example, with regard to operational procedures,

[1] A counterexample of a central banker's near praise of non-transparency is Federal Reserve Board chairman Alan Greenspan's famous statement: "If I've made myself too clear, you must have misunderstood me" (as quoted by *The Independent*, London, April 7, 1997).

[2] On the latter point, see e.g. Stiglitz (1998, p. 216) who states that "transparency—openness—is now recognized as a central aspect of democratic processes." Likewise, Goodfriend (1986, p. 90) advocates against secrecy as it is "inconsistent with the healthy functioning of a democracy."

[3] 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) as well as the references in Goodfriend (1986).

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policy goals, economic forecasts on which policy decisions are based, minutes from board meetings, and so forth. Here, I take a rather pragmatic stand. Transparency serves as a metaphor for any institutional feature facilitating the private sector's expectations formation about future monetary policy, and thus future economic developments.[4] The main result of the paper is that transparency need not be advantageous. Furthermore, transparency is rarely an "either/or" issue. As is the case with virtually all institutional designs, trade-offs are involved, implying here that the optimal degree of transparency may involve intermediate information disclosure.

The general intuition for this is as follows. As mentioned above, transparency facilitates private sector expectations formation and thus inference about future economic developments. In consequence, expectations react more strongly to policy changes compared with a case of little transparency. Now, when assessing the policy effects of transparency, it is of crucial importance *how and when* expectations formation affects relevant economic variables. If 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 variables more strongly due to the stronger reactions by expectations.[5] The implication can therefore be that the policymaker is induced to act excessively cautiously, because it to a greater extent becomes a "hostage of market sentiments"; see Remsperger and Worms (1999). This may be advantageous, however, if the policymaker lacks credibility and needs the "discipline of the market." On the other hand, it is undesirable if the policymaker actually has credibility, and therefore does not need to be "disciplined," but needs to perform macroeconomic stabilization without the restraints imposed by transparency. Since several aggregates of relevance for monetary policy are forward-looking, this insight may have general importance.

In this paper it is formalized in a model exhibiting the trade-off between inflation and output gap volatility featured in most analyses of monetary policy. More specifically, the model compactly describes an economy by a New Keynesian "Phillips curve," where inflation depends positively on expected *future* inflation and the current output gap; cf. Roberts (1995). That is, inflation is forward-looking. This is a variant of supply-side models,

[4] See Geraats (2000) or Winkler (2000) for frameworks distinguishing various forms of transparency.

[5] This is somewhat equivalent to the behavior of variables 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 more strongly 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.

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which have become standard in recent monetary policy analyses; see e.g. the contributions in Taylor (1999) and the references therein.[6]

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 (2001). Nor can the private sector observe a "control error" in policy-making. 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 more strongly, the more the latter is believed to be the case, since this implies that the central bank will also act relatively expansively in the future. Following Faust and Svensson (2001), I then model transparency as the central bank's release of information about the control error. The greater the amount of information revealed, the easier it is for the private sector to infer the true policy intentions of the central bank—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. For the central bank, this means that the marginal cost of demand at the planning stage (in terms of inflation) increases, because inflation expectations, and thus current inflation, respond more strongly. As a consequence, more transparency induces the central bank to pay greater attention to its inflation target relative to its output gap target. This is beneficial if the bank has poor inflation credibility. If, on the other hand, the central bank enjoys low-inflation credibility, transparency will just be a policy-distorting straitjacket: when attempting to strike an optimal balance between output gap and inflation variability, the central bank will be 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.[7]

As is evident, my analysis draws on a number of aspects of Faust and Svensson (2001). The results differ substantially, however, as their main message is that a high degree of transparency is beneficial. The difference

[6]Forward-looking behavior in price setting has found empirical support in e.g. Galí and Gertler (1999) and Rudebusch (2002) on US data, and Galí, Gertler and López-Salido (2001) and Smets (2000) on data for Euroland.

[7]As pointed out by the referees, the results are therefore supportive of Alan Greenspan's apparent preference for non-transparency; cf. footnote 1. Since he is usually considered to enjoy a great deal of credibility, my results indeed suggest that transparency would be harmful for the Federal Reserve.

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arises because they adopt a Lucas-style supply function, where inflation expectations are formed at the *beginning* of any period. As more transparency makes inflation expectations more sensitive to policy actions, current policy decisions affect inflation expectations in the future. This has no implications for current aggregates as none are forward-looking. Transparency thus introduces a constant marginal cost of loose monetary policy, which is beneficial given that the central bank is aiming at an output level above the natural level, resulting in a Barro and Gordon (1983) inflation bias. Moreover, it implies that stabilization policy is efficient.[8]

The economic benefits of transparency are also examined in Geraats (2000) who, in a two-period model, finds that transparency puts downward pressure on inflation expectations, thereby mitigating excessive equilibrium inflation. The main intuition for this result is related to that of Faust and Svensson (2001). Her results, however, are cast in a different model and transparency is concerned with release of information about shocks hitting the economy before policy implementation.[9] Furthermore, she shows how the implementation of full transparency corresponds to the publication of conditional forecasts of inflation (and output). In an extension, focusing on an output and inflation variability trade-off, she finds that stabilization policy is best under a regime of full transparency. The reason is that private sector expectation errors in period 2 lead to both output and inflation variability. A regime of full transparency minimizes such errors and allows the central bank to respond efficiently to economic shocks in period 1 without worrying about the effects on period 2 expectations. Her model, however, does not feature forward-looking variables. Hence, the results differ from mine as the intra-temporal output and inflation variability tradeoff is unaffected by transparency in her model, whereas it becomes distorted in mine.

Another recent paper of relevance is Cukierman (2001), who—as I do—points to potential drawbacks of transparency. He presents two models. One features a stochastic Lucas-supply function, where transparency is synonymous with full information about supply shocks to the private sector before inflation expectations are formed. In consequence, monetary policy loses the ability to stabilize these shocks, since an informational advantage is needed in order to perform efficient stabilization policy. A highly related result is found by Gersbach (1998). In Cukierman's second model, the central bank affects demand through nominal interest rates. Again, transparency is synonymous with full information about shocks. Monetary policy does not become

[8]Transparency in their model therefore works analogously to a linear inflation contract; cf. Walsh (1995). This incentive mechanism indeed eliminates excessive inflation without distorting shock stabilization.
[9]In Jensen (2000), I also consider a case where transparency concerns such shocks. Within my framework I find that transparency distorts stabilization policy in this case as well.

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ineffective, however, but inflation expectations become more sensitive to policy actions. To attain a desired change in the real interest rate, larger changes in the nominal interest rate are therefore needed. If society dislikes changes in the nominal interest rate *per se*, transparency is thus disadvantageous.

The remainder of the paper is organized as follows. The model is introduced in Section II, and the solution in the case of no informational asymmetries is provided. This section also derives the equilibrium in the case of asymmetric information and describes the main implications of transparency. Section III reports numerical analyses illustrating how the structural features of the model economy affect the optimal degrees of transparency. Section IV addresses the difference between full information and full transparency. Section V concludes. Some proofs are in the Appendix.

II. A Simple Model of Monetary Policy

The model describes a closed economy in two periods, 1 and 2. Loosely, period 1 may be regarded as the present and period 2 as the future. In accordance with this view, decisions taken in period 1 will be of primary 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 to existing literature on transparency in monetary policymaking, the supply side of the economy is modeled by a simple variant of the so-called New Keynesian "Phillips curve" emphasizing forward-looking behavior; cf. Roberts (1995). Prices are set by monopolistically competitive firms, and assuming staggered price setting along the lines of Calvo (1983), it can be shown that optimal price setting approximately results in the following inflation dynamics; see e.g. Rotemberg and Woodford (1998):

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

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

where π_i is the inflation rate in period i and x_i is the output gap, here measured as the log output deviation from the log of the natural rate of output. Inflation in period 1 is subject to a disturbance ε assumed to have zero mean and variance σ_ε^2, a "cost-push" shock; cf. Clarida, Galí and Gertler (1999).[10] $E[\cdot | I_i^P]$ is the expectations operator and I_i^P is the information set of

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

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the price setters. Forward-looking behavior in (1)–(2) arises because firms that are "allowed" to change prices today, know that they 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.[11]

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

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

where, along the lines of Faust and Svensson (2001), x_1^I is the central bank's *intention* for the output gap in period 1, and where $\eta \sim N(0, \sigma_\eta^2)$. Although x_1^I is treated below 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 modeling of the demand side.[12] The shock η could represent a control error, or disturbances to demand and technology which the central bank is unable to counteract for various reasons (say, due to informational problems). For convenience, however, I refer to η 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:

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

This is 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.) Due to the underlying assumption of imperfect competition, the natural rate of output is inefficient, thus

[11]In most empirical analyses, including those mentioned in footnote 6, inflation typically exhibits persistence; i.e., lagged inflation is a significant determinant of current inflation. Here, however, I adopt a purely forward-looking specification for analytical tractability. As long as expected future inflation is of importance, the qualitative statements relating to transparency remain valid under inflation persistence as well.

[12]If the policy instrument were 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.

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explaining a positive target value for the output gap. The choice of zero as the preferred rate of inflation is a convenient normalization.

The conduct of monetary policy is delegated, before period 1 begins, 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 (2001), and can be interpreted as capturing political pressure 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). The loss function of the central bank is therefore given as

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

where

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

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 decisions in period 1, I assume away a shock to the output target in period 2.

To model transparency formally, I follow Faust and Svensson (2001) and assume that after monetary policy has been conducted in period 1, the price setters will get some information about the shock, η. 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. This information may be interpreted as stemming from public statements or reports by the central bank in 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 η. By assumption, the revelation of ξ 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, the output gap. Policymaking of the central bank becomes more *transparent* as its intentions to a larger extent *can be distinctly seen*. Formally, this is modeled as

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

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Table 1. *Timeline of events and actions*

Period 0:	x_0^* is drawn						
Period 1:	ε, θ are realized	x_1^I is chosen	η is realized	x_1 materializes	ξ is revealed	$E[\pi_2 \vert I_1^P]$ is formed	π_1 materializes
Period 2:	x_2 is chosen	π_2 materializes					

where $0 \leqslant \tau < 1$ is an index of transparency. For instance, as $\tau \to 1$, 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 price setters can only relatively noisily infer the central bank's intentions, and thus, future policy.

The timing of events may now be 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 is realized. After this, some part of the control error is revealed to the price setters (to a degree determined by transparency, i.e., τ), 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 $I_1^P = \{x_0^*, \varepsilon, x_1, \xi\}$. That is, 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, this finite horizon model needs a terminal condition on $E[\pi_3|I_2^P]$. I assume that

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

The exact value of this expectation is not crucial but, as argued below, it is

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for various reasons a natural choice in the model. In addition, it simplifies the algebra of the solutions.

Equilibrium under Full Information about the Central Bank's Preferences

To get a feel for the properties of the model, I now derive 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 discretionarily, i.e., that it is unable to commit to any particular policy plan before the game starts. The model is then solved by backwards induction. In period 2 the central bank solves $\min_{x_2}[\lambda(x_2 - x_1^*)^2 + \pi_2^2]$ subject to (2) and (9). Recall that $x_2^* = x_1^*$; cf. (6). From the relevant first-order condition, $\lambda(x_2 - x_1^*) + \kappa[(\lambda/\kappa)x_1^* + \kappa x_2] = 0$, equilibrium output gap and inflation in period 2 follow as

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

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 upward 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 has no choice but to accept a too high inflation rate (reducing inflation is too costly in terms of the output gap loss). 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.

The fact that output in period 2 is at the natural rate, and inflation equals the expected future inflation, is due to the particular choice of terminal condition for the model. Had $E[\pi_3|I_2^P]$ 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 $E[\pi_3|I_2^P]$ that implies $\pi_2 = \pi_3$ and no deviations in output from the natural rate. 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 $\min_{x_1^I} E[\lambda(x_1 - x_1^*)^2 + \pi_1^2|I_1^{CB}]$ subject to (1) and (3), and subject to the fact that by (10), $E[\pi_2|I_1^P] = (\lambda/\kappa)x_1^*$ since $\theta \in I_1^P$. From the relevant first-order condition,

$$E[\lambda(x_1^I + \eta - x_1^*) + \kappa[(\lambda/\kappa)x_1^* + \kappa(x_1^I + \eta) + \varepsilon]|I_1^{CB}] = 0,$$

the equilibrium output gap and inflation in period 1 follow as

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

In the absence of shocks, the solution is similar to that of period 2. The shocks, however, bring 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. For example, if $\theta > 0$, inflation expectations raise, thereby neutralizing the incentive to raise the output gap as the cost of inflation becomes too high. The control error affects the 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. That is, the central bank contracts output somewhat in response to a positive realization of ε.

On 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.[13] That is, having a central bank that targets the output gap at the natural rate is socially beneficial.[14]

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. For period 1, the crucial matter is the identification of $E[\pi_2|I_1^P]$, as this is a determinant of π_1 and, hence, important for the central bank's decision. Since $\pi_2 = (\lambda/\kappa)x_1^* = (\lambda/\kappa)(x_0^* + \theta)$, this boils down to finding $E[\theta|I_1^P]$. To do this, conjecture that the central bank's period 1 policy intentions can be expressed as

[13] Note that $x_0^* = 0$ does not result in the unconstrained optimum. In a commitment solution, an inflation shock is allowed to affect the output gap and inflation in *both* periods. That is, if a contractive policy is expected to persist, lower expectations about future inflation dampen current inflation, thereby improving the output–inflation trade-off; see e.g. Woodford (1999). Here, however, I refrain from examining commitment.

[14] In an Appendix (available on request), it is shown that for any terminal condition $E[\pi_3|I_2^P] \geqslant 0$, having $x_0^* < x^*$ is beneficial for society.

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

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:

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

As (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 $\mathrm{E}[\theta | I_1^P]$, price setters solve a standard signal-extraction problem. Because θ and υ are independently normally distributed, the conditional expectation of θ becomes

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

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

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

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

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

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

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

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

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

From this, the optimal period 1 policy intentions emerge as

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

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

$$k_\theta = \frac{\lambda}{\lambda + (\kappa + (\lambda/\kappa)S(k_\theta))^2} \equiv F(k_\theta) > 0, \quad (20)$$

$$k_\varepsilon = \frac{\kappa + (\lambda/\kappa)S(k_\theta)}{\lambda + \kappa^2 + \lambda S(k_\theta)} > 0, \quad (21)$$

$$k = -\frac{(\lambda/\kappa)^2 x_0^* S(k_\theta)}{\lambda + \kappa^2 + \lambda S(k_\theta)} \lesseqgtr 0. \quad (22)$$

Note the recursive structure of the system (20)–(22): k_θ is determined by (20), and in the Appendix it is proven that a unique solution to k_θ exists. Given this solution, k_ε and k are uniquely determined by (21) and (22), respectively. Hence, for any realization of ε and θ, 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 about the characteristics of the equilibrium. In the limiting case of full

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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. equation (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

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

Approaching full transparency, inflation expectations are extremely sensitive to the actions of the central bank, which is therefore induced to give inflation stabilization highest priority and thus act in isolation of political pressure 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 has to (in case of $x_0^* > 0$) implement a contractive policy so as to squeeze inflation out 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 that assigns a non-negligible weight to the output gap, and is one downside of a high degree of transparency to be taken into consideration. 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 illustrates 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, however, is that the period 1 output gap may reach an unacceptably low average value, and exhibit too high inflation-shock driven variability. These trade-offs and their influence on the optimal value of τ from the point of view of society are examined more thoroughly in the next section.

III. 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 in Section II for the case of asymmetric information. Inserting (10) and (12) into (4), and recalling (1), (3) and (16), society's equilibrium loss can be written as

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$$L^S = \lambda(k - x^*)^2 + (\lambda + \kappa^2)\sigma_\eta^2 + [\lambda + (\kappa + (\lambda/\kappa)S(k_\theta))^2]k_\theta^2\sigma_\theta^2$$
$$+ [(\lambda/\kappa)x_0^* + \kappa k]^2 + [(\lambda/\kappa)^2 S(k_\theta)^2 + 2\lambda S(k_\theta)](1-\tau)\sigma_\eta^2$$
$$+ [\lambda k_\varepsilon^2 + (1 - \kappa k_\varepsilon)^2]\sigma_\varepsilon^2 + \lambda x^{*2} + (\lambda/\kappa)^2 x_0^{*2} + (\lambda/\kappa)\sigma_\theta^2, \qquad (24)$$

where I have used that $\sigma_v^2 = (1-\tau)\sigma_\eta^2$, which also applies in the definition of $S(k_\theta)$.

The result that stabilization of inflation shocks is worsened by transparency follows immediately by (24). To see this, note that the effect of σ_ε^2 on the social loss is minimized when $k_\varepsilon = \kappa/(\lambda + \kappa^2)$, the output response to inflation shocks under full information. Under asymmetric information, however, (21) reveals that $k_\varepsilon > \kappa/(\lambda + \kappa^2)$ since $S(k_\theta) > 0$. Moreover, as $\partial S(k_\theta)/\partial\tau > 0$, because more transparency increases the informativeness of the private sector's "signal" (see the Appendix), it follows that k_ε increases with τ as $\partial k_\varepsilon/\partial S(k_\theta) > 0$. In other words, more transparency increases the social loss from σ_ε^2 , and the optimal degree of transparency will therefore be decreasing in σ_ε^2 (whenever the value of τ minimizing L^S is interior).

The remainder of this section is devoted to identifying numerically the value of τ, which minimizes (24) for various parameter constellations. I focus mainly on the optimal degrees of transparency when three key concepts vary in importance. The first is *initial credibility* as quantified by x_0^*. For instance, a value of x_0^* equal to the natural rate (zero) will, as shown above, lead to the most favorable outcome, as the unconditional expectation of inflation in both periods will match the inflation target. This case is therefore regarded as synonymous with a credible central bank, whereas in the cases of $x_0^* > 0$, the bank has credibility problems as expected inflation is above target. The second concept is *independence* as quantified through (the inverse of) σ_θ^2, the idea being that a high σ_θ^2 describes a bank subject to much pressure in terms of shifting its output objective. The third is a *stabilization need* as quantified by σ_ε^2.

The numerical exercises therefore cover variations in x_0^*, σ_θ^2 and σ_ε^2. The remaining parameters were kept fixed at a baseline of $\lambda = 1.0$, $x^* = 1.0$, $\kappa = \frac{2}{3}$ and $\sigma_\eta^2 = 1.0$. For each exercise, τ was varied from 0 to 0.999 with a grid of 0.001. The value of τ yielding the lowest value of L^S, as given by (24), is the optimal degree of transparency. Table 2 reports the optimal degrees for all combinations of $x_0^* \in [0.00, 1.00, 2.00, 3.00]$, $\sigma_\varepsilon^2 \in [0.00, 0.50, 1.00, 2.00]$ and $\sigma_\theta^2 \in [0.05, 0.50, 1.00]$. Deviations from the baseline values of λ, κ and σ_η^2, are reported in an Appendix (available on request), and discussed below.

As mentioned above, a central bank is assumed to enjoy initial credibility, the more compatible are its output and inflation targets. In such a case,

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transparency mainly serves to insulate policy from variability induced by political pressure, i.e., from variability in θ. Average inflation is not an issue in institutional design. Not surprisingly, therefore, the optimal degree of transparency is higher, the higher is σ_θ^2. In conformity with the discussion above, note that for a given σ_θ^2 the optimal τ is decreasing in the need for stabilization. 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 maximal. In the presence of inflation shocks of increasing variance, however, the optimal degree of transparency falls significantly. The optimal reduction in transparency induced by stabilization needs becomes smaller, the higher is σ_θ^2. This follows because for high values of σ_θ^2, the main source of macroeconomic variability is political pressure. Inflation shocks—of whatever variance—contribute only relatively little to the overall social loss.

A central bank with less perfect initial credibility, $x_0^* > 0$, will as discussed above conduct a policy leading to excessive average inflation. Immediately, it could be conjectured that this would necessitate transparency, so as to induce the central bank to pay more attention to its inflation target. Table 2, however, does not unambiguously confirm this. For a central bank

Table 2. *Optimal degrees of transparency*

$\sigma_\theta^2 = 0.05$	$x_0^* = 0.00$	$x_0^* = 1.00$	$x_0^* = 2.00$	$x_0^* = 3.00$
$\sigma_\varepsilon^2 = 0.00$	0.999	0.002	0.921	0.953
$\sigma_\varepsilon^2 = 0.50$	0.868	0.002	0.918	0.952
$\sigma_\varepsilon^2 = 1.00$	0.652	0.000	0.914	0.951
$\sigma_\varepsilon^2 = 2.00$	0.181	0.000	0.907	0.949
$\sigma_\theta^2 = 0.50$	$x_0^* = 0.00$	$x_0^* = 1.00$	$x_0^* = 2.00$	$x_0^* = 3.00$
$\sigma_\varepsilon^2 = 0.00$	0.999	0.001	0.402	0.578
$\sigma_\varepsilon^2 = 0.50$	0.978	0.001	0.378	0.567
$\sigma_\varepsilon^2 = 1.00$	0.909	0.001	0.345	0.558
$\sigma_\varepsilon^2 = 2.00$	0.691	0.000	0.289	0.538
$\sigma_\theta^2 = 1.00$	$x_0^* = 0.00$	$x_0^* = 1.00$	$x_0^* = 2.00$	$x_0^* = 3.00$
$\sigma_\varepsilon^2 = 0.00$	0.999	0.172	0.076	0.246
$\sigma_\varepsilon^2 = 0.50$	0.995	0.032	0.037	0.234
$\sigma_\varepsilon^2 = 1.00$	0.956	0.000	0.000	0.210
$\sigma_\varepsilon^2 = 2.00$	0.818	0.000	0.000	0.172

Note: The optimal values of τ for the case of $\lambda = 1.00$, $x^* = 1.00$, $\kappa = \frac{2}{3}$ and $\sigma_\eta^2 = 1.00$.

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with a "moderate" credibility problem, $x_0^* = 1.00$, the optimal degrees of transparency are virtually zero regardless of the degree of independence and need for stabilization. The explanation is that average inflation is not of an overwhelming magnitude. Hence, by introducing transparency, the central bank is 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. For example, when $x_0^* = 2.00$ and $x_0^* = 3.00$, 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 such cases, excessive inflation is the prime concern in institutional design, and transparency becomes necessary. Note, however, that when σ_θ^2 is relatively high, the need for transparency is relatively small. The reason is as follows. With substantive political pressure, inflation expectations react strongly to the actions of the central bank, because the actions are then good indicators of future policy (the noise in the private sector's signal-extraction problem is relatively small). In consequence, the central bank is—irrespective of the degree of transparency—induced to pay more attention to the inflation target. This reduces the credibility problem and thus the need for transparency.[15]

Note that increased stabilization needs in all cases reduce the optimal degree of transparency (whenever interior) as shown above. However, the sensitivity of the optimal degree of transparency with respect to σ_ε^2 is often rather small. This is because when credibility problems are severe, the (optimal) recession induced by transparency is severe, making the loss of output the main social cost. Variability induced by inflation shocks play a relatively minor role, and the choice of transparency is therefore less sensitive to σ_ε^2.

This aspect points to an important quantitative qualifier concerning the results. Note that the model is interpreted as period 1 representing the short run, and period 2 the long run. In the evaluation of the social loss, however, they are given the same weight. If the model is extended to an infinite horizon model, the short-run losses of output contractions will be given relatively small weight when evaluating various degrees of transparency. This will most likely change the results in two dimensions. First, even for moderate credibility problems ($x_0^* = 1.00$), some transparency will be optimal, as the output contraction causing the optimality of zero transparency in Table 2 will contribute rather little to the social loss. Second, the

[15]This contrasts with the situation where political pressure *per se* is the main problem (as in the case of $x_0^* = 0$), and the optimal degree of transparency increases with σ_θ^2.

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sensitivity of the optimal degree of transparency with respect to σ_ε^2 will probably become higher in the cases of $x_0^* = 2.00$ and $x_0^* = 3.00$. The reason is 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 σ_ε^2 increases, it would be optimal to reduce τ by more than what is reflected by Table 2. In such an extension of the model, the trade-off between gain of credibility and loss of flexibility in the determination of transparency would therefore probably feature much more strongly.

Sensitivity analyses confirm the qualitative nature of the results in Table 2, and show how the optimal τ changes with λ, κ and σ_η^2. Specifically, a higher concern for output fluctuations (higher λ) will decrease the optimal degrees of transparency. This follows because the losses of transparency, lower and too unstable output, are given more weight. The optimal degrees of transparency become higher if the sensitivity of inflation to output increases (i.e., κ becomes higher). This is because any reduction in inflation can be achieved through a smaller output loss, and because the trade-off in inflation shock stabilization is then relatively favorable. Hence, less is lost by high degrees of transparency. Finally, a higher variance of the control error (higher σ_η^2) implies that more transparency is optimal, because this compensates for the increased noise in information.

IV. Full Information or Full Transparency?

It is of interest to contemplate what other forms of information disclosure are possible within the model. Transparency, as defined here, makes it easier for price setters to *infer* the true intentions of the central bank, and it is due to this inference problem that inflation expectations respond to the central bank's actions. 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 (i.e., the realization of θ is revealed). In this case, however, there will be no linkage between what the central bank does and what the private sector expects: when forming inflation expectations, the private sector knows with perfection policy in period 2. Hence, expectations about period 2 inflation will be *in*sensitive to the central bank's actions in period 1. Full transparency and full information thus differ markedly in terms of how the incentives of the central bank are affected.

This is also the reason for what may appear paradoxical about my results. Under full transparency, why is it that the private sector will not "allow" efficient shock stabilization, as all that it observes is merely what it expects to see? The reason is precisely that the private sector is *inferring* the preferences of the central bank, not observing them. Under full transparency, the public expects the central bank to behave as if inflation stabilization is

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the overriding objective for monetary policy, and it does indeed see what it expects. Any other action of the bank, say a slightly more expansive policy, would lead inflation expectations to soar, as a huge positive output preference shock would be inferred. In anticipation of this, the bank would never consider such action, and would stick to its "inflation is all that matters" policy. If instead the private sector directly *observed* the preference shock, expectations would not react to the central bank's actions at all (cf. above) and the bank would not be trapped in the straitjacket of full inflation stabilization.

This marked difference between full information and full transparency also features in Faust and Svensson (2001), where full information about central bank preferences leads to the worst of all outcomes. Essentially, their model would then feature an inflation bias, which is otherwise reduced under full transparency due to the "inflation discipline" that expectations induce. In my model, however, such discipline distorts stabilization policy as emphasized above. In contrast, under full information, inflation shocks are stabilized optimally (when the central bank operates under discretion; cf. footnote 13). Hence, it may be the case that when the central bank enjoys good initial credibility (i.e., excessive inflation is not a problem), and there is a need for stabilization, a regime of full information is preferable to a regime of full transparency. To examine this formally, note that the social loss under full information is readily found by using (11) and (4) as

$$L^S|_{\mathit{full\ info}} = 2\lambda x^{*2} + 2(\lambda/\kappa)^2 x_0^{*2} + 2(\lambda/\kappa)^2 \sigma_\theta^2 + (\lambda + \kappa^2)\sigma_\eta^2 + \frac{\lambda}{\lambda + \kappa^2}\sigma_\varepsilon^2. \tag{25}$$

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

$$\begin{aligned} L^S|_{\mathit{full\ trans}} = {} & 2\lambda x^{*2} + [(1/\kappa^2) + \lambda](\lambda/\kappa)^2 x_0^{*2} + 2(\lambda/\kappa)^2 x_0^* x^* \\ & + 2(\lambda/\kappa)^2\sigma_\theta^2 + (\lambda + \kappa^2)\sigma_\eta^2 + \lambda(1/\kappa)^2\sigma_\varepsilon^2. \end{aligned} \tag{26}$$

By simple comparison of (25) and (26) it follows that a regime of full information is preferable to a regime of full transparency if

$$\frac{1}{\lambda + \kappa^2}\sigma_\varepsilon^2 > 2(x_0^* - x^*)x_0^* - (1/\kappa^2 + \lambda)x_0^{*2}. \tag{27}$$

This is always fulfilled if $x_0^* = 0$, thus confirming the assertion made above. If credibility problems are severe (x_0^* is sufficiently high), however, the

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condition may not hold as inflation becomes too excessive under full information, as in Faust and Svensson (2001).[16]

From an implementation point of view, transparency as modeled 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, an open question as it is unclear which mechanisms could eliminate preference uncertainty entirely. Issuance of detailed inflation reports as practiced by many inflation-targeting central banks, or publication of minutes from board meetings could clearly be instrumental in this respect,[17] but whether such information disclosure can eliminate *any* uncertainty about future policy conduct could be questionable.

Note also that preference uncertainty needs only to be infinitesimal in order for the identified trade-offs in the optimal design of transparency to be important; cf. Table 2 for the case of $\sigma_\theta^2 = 0.05$. It thus appears that a proper modeling of openness acknowledges some uncertainty about preferences, and view transparency as a means to facilitate expectations formation, not to eliminate all uncertainties completely.

V. 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. In a simple model emphasizing forward-looking behavior, this paper demonstrates that this conclusion is debatable from an economic point of view. Most importantly, it points to trade-offs in the optimal degree of transparency, of which the main one is well known in the literature on monetary policymaking: the trade-off 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 they ignore the importance of forward-looking economic variables. They may then underestimate that the response of market expecta-

[16]The above only compares full information with full transparency. As there are cases where partial transparency is better than full transparency, partial transparency may sometimes be better than full information. For sufficiently large σ_ε^2, however, this cannot be the case as inflation shocks are inefficiently stabilized even under partial degrees of transparency

[17]Another example is the procedure in the United Kingdom, where the Bank of England, in the event inflation breaches a target threshold, is required to formally explain to the government the speed at which it expects inflation to return to target. This reveals information about the central bank's preferences for output versus inflation variability.

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tions to monetary policy actions comes quickly and with immediate impact on current aggregates, thereby hampering stabilization efforts.[18]

The results are, of course, not conclusive regarding how central bank regulations should be designed with respect to a complex concept like transparency, which has been modeled here in just one of many possible 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.

Appendix

Proof of Existence and Uniqueness of k_θ

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_θ 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 LHS 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

$$F'(k_\theta) = -\frac{2\lambda^2[1 + (\lambda/\kappa^2)S(k_\theta)]}{[\lambda + (\kappa + (\lambda/\kappa)S(k_\theta))^2]^2} S'(k_\theta) < 1 \tag{A1}$$

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

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

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

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

and thus

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

[18]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 may otherwise complicate the implementation of transparency in practice, as argued by Winkler (2000).

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

$$4\lambda^2[1+(\lambda/\kappa^2)S(k_\theta)]S(k_\theta)^2$$
$$< [\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2]^2 + 2\lambda[1+(\lambda/\kappa^2)S(k_\theta)]S(k_\theta)[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2],$$

and thus

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

which always holds.

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 using the implicit function theorem. Totally differentiating the expression for $S(k_\theta)$, (15), yields

$$\mathrm{d}S(k_\theta) = \frac{\sigma_\theta^2(\sigma_v^2 - k_\theta^2\sigma_\theta^2)}{(k_\theta^2\sigma_\theta^2+\sigma_v^2)^2}\mathrm{d}k_\theta - \frac{k_\theta\sigma_\theta^2}{(k_\theta^2\sigma_\theta^2+\sigma_v^2)^2}\mathrm{d}\sigma_v^2. \tag{A2}$$

Totally differentiating (20) yields

$$\mathrm{d}k_\theta = -\frac{2\lambda^2(1+(\lambda/\kappa^2)S(k_\theta))}{[\lambda+(\kappa+(\lambda/\kappa)S(k_\theta))^2]^2}\mathrm{d}S(k_\theta), \tag{A3}$$

which inserted back into (A2) yields

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

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

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

or,

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

By nature of S, it follows that this corresponds to

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

This is exactly condition equation (A1), which was proven to hold above.

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