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Julian A. Parra-Polania*

Abstract

To evaluate whether transparency is beneficial, it is usual to assume that the central bank may choose one of two options, opacity versus truthful communication. However, the monetary policymaker may have incentives to misrepresent private information so as to reduce economic volatility by manipulating inflation expectations. Using a standard model, this paper points out the fact that if misrepresentation is included as a possible action there is no rational expectations equilibrium with inflation announcements. Therefore, even if transparency is preferred over secrecy the central bank cannot credibly commit to truth-telling, in contrast to what is commonly assumed in the literature on transparency.

JEL Classification: E52, E58, D82

Keywords: central bank announcements, monetary policy, transparency

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1 Introduction

Over the last two decades transparency and communication with the public have gained relevance in the conduct of monetary policy. A significant amount of theoretical and empirical research has been carried out to determine if transparency is desirable from an economic point of view.[1] On the one hand, some papers conclude that transparency is beneficial to society's welfare because it improves the predictability of monetary policy and enhances credibility (e.g. Geraats, 2005; Svensson, 2006; Demertzis and Hughes Hallett, 2007). However, another part of literature points out that transparency may be undesirable because its benefits come at the cost of flexibility, and hence the central bank's ability to stabilise the economy is reduced (e.g. Cukierman, 2001; Jensen, 2002; Gersbach, 2003).

In order to evaluate the economic impact of transparency, it has been standard to compare society's welfare when the monetary policymaker does not disclose private information versus the case in which there is partial or full transparency.[2] If transparency yields a higher level of welfare, it is concluded that society prefers it over secrecy. Nevertheless, as the present paper highlights, this result does not imply that the central bank can credibly commit to truthful communication, as has been assumed by most of the previous literature on transparency. The policymaker may have incentives to misrepresent private information so as to offset the effect of anticipated shocks, and therefore truth-telling may not be the chosen strategy. For instance, when faced with inflationary shocks, the central bank might try to deceive agents into believing that the inflation forecast is lower than it actually is, such that the effect of shocks on inflation is offset by the effect of lower inflation expectations.

Earlier literature has pointed out the existence of a credibility problem of announcements when the monetary policymaker has private information and pursues a time-inconsistent goal (e.g. Canzoneri, 1985; Stein, 1989; Garfinkel and Oh, 1995). The present paper, instead, assumes that central bank preferences are not time inconsistent (i.e. there is no inflation bias) and extends the analysis to incorporate the possibility that rational agents may try to extract some information from inflation announcements, even if the policymaker acts strategically.

[1]See Eijffinger and Van der Cruijsen (2010) for a survey of literature on central bank transparency.

[2]Examples of partial transparency can be found in Jensen (2002) and Walsh (2007). The former sets up a model in which the control error of monetary policy is partially revealed. The latter assumes that the central bank announces in a manner such that just a fraction of firms receives the information. Misrepresentation is not considered in any of these papers.

In a standard model with a stochastic expectations augmented Phillips curve, the paper shows that there is no equilibrium under rational expectations when the central bank communicates inflation targets or forecasts and misrepresentation of private information is included as a possible strategy. The intuition behind this result is as follows. If private agents use the announcement to extract information about the central bank's intentions, then the best response of the policymaker is to misrepresent private information so as to offset the effect of anticipated shocks on inflation. As rational agents foresee this situation, they incorporate the inflation announcement into their information set but take into account the intention of the central bank to misrepresent. Given this reaction, the policymaker's best response is to increase the degree of misrepresentation. But again, private agents also anticipate this and adjust their inflation expectations accordingly... and so on, without convergence to a rational expectations equilibrium with inflation announcements.

This seems to be just a theoretical problem since in practice central banks make announcements an presumably an equilibrium exists (although it might be a bounded-rational expectations equilibrium). However, there is also empirical evidence of the fact that rather than announcing their actual inflation forecasts, central banks misrepresent private information and make strategic announcements, as shown by Gomez-Barrero and Parra-Polania (2011). Their model predicts that if the central bank is announcing strategically, a negative correlation should be observed between inflation forecasts announced by the monetary policymaker and their corresponding forecast errors. Furthermore their model also predicts that the strength of such evidence should vary according to the forecast horizon length, due to the availability of private information on future shocks. These predictions were validated by their empirical analysis. The appendix of the present paper updates Gomez-Barrero and Parra-Polania's database (for four central banks: England, Hungary, New Zealand and Sweden) and confirms their results.

The remainder of the paper is organised as follows. Section 2 gives further details about previous literature and the credibility problem of central bank announcements. Section 3 presents the model. Equilibrium is discussed in Section 4. Section 5 examines some possible ways in which this credibility problem might be solved and points out some drawbacks of each solution. Section 6 concludes.

2 Credibility problem of announcements

Canzoneri (1985) was the first to call attention to the lack of credibility of monetary policy announcements when the central bank has private information. In Canzoneri's model, the policymaker's forecast of the money demand shock is not observed by private agents. Therefore, they are unable to know with certainty whether an expansionary policy is a result of a perceived increase in money demand or an attempt to stimulate output above potential. As a result, monetary policy announcements cannot be trusted because the central bank has incentives to lie in order to achieve better outcomes.

Similarly, Stein (1989) and Garfinkel and Oh (1995) point out the inability of the central bank to credibly communicate its intentions by making precise announcements despite the fact that it would be better off by truthfully revealing its private information as opposed to being completely opaque. The problem is that if central bank announcements were believed by the public, the optimal strategy for the policymaker would be misleading private sector expectations.

A common feature in the three above-mentioned papers is that one of the monetary authority's goals is inconsistent with the steady-state level, and hence there is time inconsistency as described originally by Kydland and Prescott (1977) and Barro and Gordon (1983). The presence of time inconsistency is, in all of these papers, a necessary condition for the credibility problem of announcements to arise. In contrast, in the present paper the central bank does not pursue any time-inconsistent goal and, despite this fact, it is still unable to credibly communicate its intentions. The source of the problem, as mentioned above, is the fact that the central bank intends to offset volatility that stems from economic shocks by manipulating inflation expectations. In this way, the paper points out the existence of difficulties with regard to credibility of inflation announcements even when there is no inflation bias in central bank preferences. Moreover, the present paper extends the analysis to formally incorporate the possibility that the public tries to extract some information from central bank announcements, even if the policymaker acts strategically and misrepresents information.

In the recent literature about transparency, it has become common practice to overlook the credibility problem of central bank announcements. Three exceptions are Walsh (1999), Mahadeva and Sterne (2002) and Hoerova et al. (2009). These papers take into account the possibility that the central bank strategically sets the level of the announcement.

The first two papers solve the credibility problem by assuming that the policymaker is exogenously penalised for the deviation of actual inflation from the announcement.[3] In contrast, no exogenous penalisations are assumed in the present paper and all of the incentives that make transparency desirable or undesirable arise endogenously from the model.

Hoerova et al. (2009) set up a model in which the central bank receives a private signal of investment profitability. The policymaker has an incentive to misrepresent this signal so as to reduce dispersion in investment decisions across individuals. It is pointed out that there is no equilibrium in which the central bank announces its actual signal and investors make use of this announcement. These authors also show that credible information transmission can be achieved through changes in the interest rate. By observing these changes private investors can infer the central bank's private signal of investment profitability. Although this solves the inability of the central bank to credibly communicate its private information, announcements become redundant because all of the information is transmitted by changing the interest rate. Moreover, since the monetary instrument is changed, transmitting information has a cost due to the monetary distortion created.

3 The Model

The model is a game between the central bank and the public. The former minimises inflation and output volatility and the latter intends to forecast inflation as accurately as possible. Every period, the central bank makes an announcement θ_t and picks the monetary instrument m_t so as to minimise the expected value of the loss function

$$\Gamma_t = \lambda y_t^2 + (\pi_t - \pi_t^*)^2 \tag{1}$$

where y_t is the output gap, π_t is inflation, π_t^* is the implicit short-run inflation target, $\lambda > 0$ is the relative weight on output stabilisation and the subscript t denotes the time period. As can be seen, (1) implies no inflation bias in the central bank's intentions. Uncertainty about central bank preferences is modelled as uncertainty about the implicit target as it has been done in some previous literature about transparency (e.g. Tarkka and Mayes, 1999; Geraats, 2005; Carboni and Ellison, 2011). The implicit

[3] More details about this solution are given in Section 5.

short-run target changes over time as follows

$$\pi_t^* = \alpha\pi_{t-1}^* + (1-\alpha)\,\pi_0^* + \eta_t \tag{2}$$

where π_0^* is the long-run inflation target, which is exogenously given, $\alpha \in [0,1)$ and η_t is iid with $E[\eta_t] = 0$ and $Var[\eta_t] = \sigma_\eta^2$. η_t is drawn at the beginning of the period and is only known to the central bank. For simplicity it is assumed that η_t is uncorrelated with other disturbances in the model. Equation (2) captures the empirical evidence that, as shown by Mahadeva and Sterne (2002), in countries with moderate to high inflation there is persistence in short-run inflation targets. It also includes the particular case (when $\alpha = 0$) in which the short-run inflation target is equal to the long-run target plus some noise particular to period t ($\pi_t^* = \pi_0^* + \eta_t$). This case may be more appropriate to model countries with low and stable inflation.

Aggregate supply is described by an expectations-augmented Phillips equation:

$$\pi_t = \pi_t^e + y_t + s_t \tag{3}$$

where π_t^e represents inflation expectations and s_t is an aggregate supply shock. Aggregate demand is equal to the monetary instrument m_t plus a demand shock d_t:

$$y_t = m_t + d_t \tag{4}$$

The variable m_t can be regarded as related to the negative of the interest rate or, alternatively, to the growth rate of the money supply. Aggregate shocks $\varepsilon_t \in \{s_t, d_t\}$ are separated into three different components, ε_t^p which is anticipated by both the central bank and the public, ε_t^b which is anticipated only by the central bank, and ε_t^u which is unanticipated, where $\varepsilon_t = \varepsilon_t^p + \varepsilon_t^b + \varepsilon_t^u$. Each component is independently distributed with zero mean and $Var\left[\varepsilon_t^k\right] = \sigma_{\varepsilon^k}^2$, for $k \in \{p,\ b,\ u\}$. This separation allows for the analysis of different situations as particular cases of the model. For instance, when the central bank has perfect information $\varepsilon_t^u = 0, \forall t$ and $\sigma_{\varepsilon^u}^2 = 0$; and when both the central bank and the public are equally informed $\varepsilon_t^b = 0, \forall t$ and $\sigma_{\varepsilon^b}^2 = 0$. For ease of exposition, sometimes we collect the part of aggregated shocks that is anticipated by the central bank into a single term, such that $\varepsilon_t^{cb} = \varepsilon_t^p + \varepsilon_t^b$ and $\sigma_{\varepsilon^{cb}}^2 = \sigma_{\varepsilon^p}^2 + \sigma_{\varepsilon^b}^2$.

The timing for every period t is as follows: Before the period starts η_t is drawn. It is only known to the central bank. (i) The central bank makes an inflation announcement θ_t for period t. (ii) Private agents form inflation expectations π_t^e. (iii) The central bank sets the monetary instrument m_t. (iv) Shocks s_t, d_t and inflation π_t are realised.

4 Equilibrium

The model is solved by backward induction. In the third stage, the central bank sets the monetary instrument so as to minimise its expected loss function (1) subject to (3) and (4) and taking private sector inflation expectations as given. The solution to this problem implies

$$m_t = \frac{1}{1+\lambda}\left(\pi_t^* - \pi_t^e - s_t^{cb}\right) - d_t^{cb} \tag{5}$$

This is a standard result. The central bank intends to completely offsets anticipated demand shocks but just partially offsets anticipated supply shocks because it is also concerned about output volatility ($\lambda > 0$). Substituting (3), (4) and (5) into (1) we can express the loss function as follows:

$$\Gamma_t = \left(s_t^u + d_t^u\right)^2 + \lambda\left(d_t^u\right)^2 + \frac{\lambda}{1+\lambda}\left[\left(\pi_t^* - \pi_t^e - s_t^{cb}\right)^2 - 2s_t^u\left(\pi_t^* - \pi_t^e - s_t^{cb}\right)\right] \tag{6}$$

Furthermore, substituting (4) and (5) into (3) and using the fact that private agents form rational expectations, i.e. $\pi_t^e \equiv E\left[\pi_t \mid I_t^p\right]$[4], we can obtain

$$\pi_t^e = E\left[\pi_t^* \mid I_t^p\right] + \lambda E\left[s_t^{cb} \mid I_t^p\right] \tag{7}$$

where I_t^p denotes the information set of private agents when they form inflation expectations. Note that if no additional information is given by the central bank to private agents then $I_t^p \equiv \left\{\lambda,\ \alpha,\ \pi_0^*,\ E\left[\eta_t\right],\ \sigma_\eta^2,\ \varepsilon_t^p,\ E\left[\varepsilon_t^k\right],\ \sigma_{\varepsilon^k}^2,\ \pi_{t-l},\ y_{t-l},\ m_{t-l}\right\}$ for $\varepsilon \in \{s, d\}$, $k \in \{p,\ b,\ u\}$ and $l \in \{1, 2, ..., t-1\}$.

4.1 Symmetric information

As a benchmark, the model is first solved for the case in which private information held by the central bank is truthfully revealed to the public and hence I_t^p includes π_t^*, s_t^b and d_t^b. Consequently, from equation (7) we know that $\pi_t^e = \pi_t^* + \lambda s_t^{cb}$. Substituting this expression into (6) and taking the unconditional expected value we find that for any

[4] Appendix B.1 shows that the main result of this paper (i.e. the absence of equilibrium with inflation announcements) also applies to a Phillips Curve with forward-looking inflation expectations i.e. $\pi_t = \pi_{t+1|t}^e + y_t + s_t$ where $\pi_{t+1|t}^e \equiv E\left[\pi_{t+1} \mid I_t^p\right]$

period t, the expected loss function for the symmetric information (SI) case is

$$E\left[\Gamma_t^{SI}\right] = (1+\lambda)\left(\sigma_{d^u}^2 + \lambda\sigma_{s^{cb}}^2\right) + \sigma_{s^u}^2 \tag{8}$$

The expected loss is increasing in the economic volatility associated with the variance of the unanticipated demand shock and the variance of all the components of the aggregate supply shock. It can also be seen that for this case $\pi_t^{SI} = \pi_t^* + \lambda s_t^{cb} + s_t^u + d_t^u$ and $y_t^{SI} = -s_t^{cb} + d_t^u$.

4.2 Asymmetric information

This section analyses two different scenarios. The first one corresponds to the model with no inflation announcements. By comparing this case to the one with symmetric information, we can find a sufficient condition under which transparency is preferred over secrecy. The second scenario incorporates inflation announcements into the model and shows that there is no rational expectations equilibrium when misrepresentation of private information is included as a possible strategy for the central bank.

4.2.1 No inflation announcements

With no announcements (NA), information from the past becomes relevant for private agents, and therefore a two-period setup is analysed. In the second period, since private agents do not know π_2^*, they have to estimate its value from their information set I_2^p. Using equation (2) for periods one and two, it can be seen that $\pi_2^* = \pi_0^* + \alpha\eta_1 + \eta_2$, and hence from (7) $\pi_2^e = \pi_0^* + \alpha\widehat{\eta}_{1|2} + \lambda s_2^p$ where $\widehat{\eta}_{1|2} \equiv E\left[\eta_1 \mid I_2^p\right]$. Substituting this expression into (6) and taking the unconditional expected value we find that

$$E\left[\Gamma_2^{NA}\right] = (1+\lambda)\left(\sigma_{d^u}^2 + \lambda\sigma_{s^p}^2\right) + \sigma_{s^u}^2 + \frac{\lambda}{1+\lambda}\left(\sigma_{s^b}^2 + \sigma_\eta^2 + \alpha^2\mu_1\right) \tag{9}$$

where μ_1 is the mean square error of $\widehat{\eta}_{1|2}$, i.e. $\mu_1 \equiv E\left[\left(\widehat{\eta}_{1|2} - \eta_1\right)^2\right]$. Note that the public estimates η_1 using three different signals that can be constructed from three variables observed in period one, namely the inflation outcome π_1, the monetary instrument m_1 and the output gap y_1.[5] Comparing (8) to (9) and recalling that $\sigma_{s^{cb}}^2 = \sigma_{s^p}^2 + \sigma_{s^b}^2$ it can

[5]The public cannot perfectly infer η_1 from I_2^p because the problem implies a system of three equations, one from each variable π_1, y_1 and m_1 in five unknowns s_1^b, s_1^u, d_1^b, d_1^u and η_1. Assuming that shocks η_1 and ε_1^k for $\varepsilon \in \{s,d\}$ and $k \in \{b,u\}$ are normally distributed, this represents a standard signal extraction problem.

be seen that, under asymmetric information, uncertainty about the short-run implicit target $(\sigma_\eta^2 + \alpha^2 \mu_1)$ increases the expected loss but the effect of the supply shock s_2^b on economic volatility is mitigated. The final result of these two contrary effects on the expected loss is formally analysed below, in Proposition 1.

In period one, the central bank takes into account that its policy instrument m_1 affects the estimator of the implicit target in period two. For this reason, the central bank picks m_1 with two purposes; first, to reduce the volatility that stems from shocks in the same period, and second, to reduce uncertainty about its intentions in period two. The fact that these two purposes are not entirely compatible implies that the central bank restrains its stabilisation efforts to make the monetary instrument a better signal of its intentions.

In the third stage of period one, the problem for the central bank is minimising

$$E\left[\Gamma_1 + \beta\Gamma_2 \mid I_{1(3)}^{cb}\right] \tag{10}$$

with respect to m_1, where $\beta \in (0,1)$ is the discount factor and $I_{1(3)}^{cb}$ represents the information set of the central bank in period one at the moment of deciding upon the monetary instrument, i.e. in the third stage.[6]

Proposition 1 *When there is asymmetric information about both the implicit target π_t^* and the supply shock s_t^b,*

(i) If volatility that stems from uncertainty about the implicit target shock η_t is large enough relative to volatility caused by the effect on inflation expectations of revealing the supply shock s_t^b, the central bank's loss under symmetric information is lower than that with no announcements. Therefore, the central bank prefers full transparency to secrecy. Formally, $E\left[\Gamma_t^{NA}\right] > E\left[\Gamma_t^{SI}\right]$ for $t \in \{1,2\}$, if

$$\lambda\,(2+\lambda)\,\sigma_{s^b}^2 < \sigma_\eta^2 \tag{11}$$

(ii) For the limiting case in which there is no uncertainty about the implicit target shock ($\sigma_\eta^2 = 0$), it is better for the policymaker to be opaque i.e. $E\left[\Gamma_t^{NA}\right]_{\sigma_\eta^2=0} \leq E\left[\Gamma_t^{SI}\right]$ for $t \in \{1,2\}$.

[6] Solving the model implies cumbersome algebra which does not add much to the purpose of this paper. It can be shown that in the no announcements (NA) case, neither expected inflation nor the expected output gap are affected with respect to the symmetric information case, i.e. $E\left[\pi_t^{NA}\right] = E\left[\pi_t^{SI}\right] = \pi_0^*$ and $E\left[y_t^{NA}\right] = E\left[y_t^{SI}\right] = 0$ for $t \in \{1,2\}$.

Proof. First notice that since $E\left[\Gamma_t^{SI}\right]$ does not depend on decisions from previous periods then (8) applies to any period t. Also recall that $\sigma^2_{s^{cb}} = \sigma^2_{s^p} + \sigma^2_{s^b}$.

Part (i): Assume that (11) holds. By comparing (8) and (9), $E\left[\Gamma_2^{NA}\right] > E\left[\Gamma_2^{SI}\right]$. To compare the expected loss in period one, let m_1^o be the solution to the minimisation of (10) when the central bank does not care about the future (i.e. $\beta = 0$). For this particular case,

$$E\left[\Gamma_1^{NA}\left(m_1^o\right)\right] = (1+\lambda)\left(\sigma^2_{d^u} + \lambda\sigma^2_{s^p}\right) + \sigma^2_{s^u} + \frac{\lambda}{1+\lambda}\left(\sigma^2_{s^b} + \sigma^2_{\eta}\right) \tag{12}$$

By definition $E\left[\Gamma_1^{NA}\left(m_1^o\right)\right] \leq E\left[\Gamma_1^{NA}\right]$. Comparing (12) to (8), we can see that $E\left[\Gamma_1^{NA}\left(m_1^o\right)\right] > E\left[\Gamma_1^{SI}\right]$ (if and only if (11) holds). Therefore, $E\left[\Gamma_1^{NA}\right] > E\left[\Gamma_1^{SI}\right]$.

Part (ii): Note that since private agents know $E\left[\eta_t\right]$, by making $\sigma^2_\eta = 0$ we are eliminating uncertainty about π_t^*, and therefore information from the past is no longer useful to private agents. Solving the one-period model is enough to obtain the solution for any period. The expected loss is

$$E\left[\Gamma_t^{NA}\right]_{\sigma^2_\eta = 0} = (1+\lambda)\left(\sigma^2_{d^u} + \lambda\sigma^2_{s^p}\right) + \sigma^2_{s^u} + \frac{\lambda}{1+\lambda}\sigma^2_{s^b} \tag{13}$$

The statement in the proposition follows from comparing (13) to (8). ■

Part (i) of Proposition 1 points out that if the informational advantage of the central bank about the supply shock is small relative to uncertainty about the central bank's intentions (and hence $\sigma^2_{s^b}$ is small relative to σ^2_η), it is better for the policymaker to be transparent because the cost of disclosing her private information about the supply shock would be smaller than the benefit from communicating the implicit inflation target. Since condition (11) is sufficient but not necessary, we cannot directly state that if it is not satisfied then secrecy outperforms transparency. However, as remarked by part (ii), when the variance of the implicit target shock η_t approaches zero, the central bank prefers secrecy over full transparency.

So far, to analyse the impact of inflation announcements on economic volatility we have assumed that the central bank either commits to truthfully reveal all of its private information or discloses nothing. However, using the results above, we can show that partial transparency is preferred to both secrecy and full transparency. It is not difficult to see that if we assume that η_t (but not s_t^b) is revealed to the public, the expected loss is equal to that for the case in which $\sigma^2_\eta = 0$, and hence equal to the right-hand side of (13). Therefore, using part (ii) of Proposition 1 we can state that it is a better strategy for the policymaker to commit to reveal only the implicit target rather than all of its private information because the latter includes information about the supply shock which increases inflation expectations volatility. This is in the spirit of Geraats (2007) who concludes that the optimal communication strategy for the central bank is to be clear about the inflation target but ambiguous about supply shocks. Furthermore, in order to see that revealing only the implicit target is also preferred over secrecy it can be verified that $E\left[\Gamma_t^{NA}\right]_{\sigma_\eta^2=0} \leq E\left[\Gamma_t^{NA}\right]$ for $t \in \{1,2\}$ by comparing (13) to (9) and (12).

4.2.2 Announcements

Using the model described in Section 3, the present section analyses the credibility problem of announcements that arises when misrepresentation is included as a possible action for the central bank. It is also incorporated the possibility that the public tries to extract some information from the inflation announcement, even if it deviates from the truth. Private agents will not take the announcement at face value, but they can still try to use it to enhance their information set. The result obtained, as shown below, is that there is no rational expectations equilibrium for the model with inflation announcements. The intuition behind this result is as follows. Since the central bank knows the private sector's reaction, the policymaker adjusts the announcement accordingly, so as to be able to still deceive private agents; but they also foresee this new adjustment and the central bank again anticipates their new reaction and so on, ad infinitum and without convergence to an equilibrium with inflation announcements.[7]

In order to distinguish the case in which there are announcements from that in which there are not, the next definition indicates when a public statement provides useful information to forecast inflation, and hence can be regarded as an inflation announcement.

Definition 1. *A public statement made by the central bank in period t is an inflation announcement θ_t only if it is correlated with any piece of information that is not known to private agents but is relevant to forecast inflation in the same period or in future periods.*

[7] Note that these changes of each player's strategy occur in notional time, and therefore only the final result is observed in the model's solution, that there is no equilibrium.

If, for instance, the policymaker announced s_t^p, it would be equivalent to the case with no announcements as s_t^p is already known by private agents, and hence publishing its value does not provide any additional information in forecasting inflation. Given Definition 1, we look for an answer to the question whether there is a rational expectations equilibrium in the model with announcements.

Let us first express the general idea in the following way. π_t^e is a function of the available information, which includes θ_t. In the first stage the central bank minimises (1) with respect to θ_t, which affects the loss function through its effect on inflation expectations. From (6) and taking the expected value conditional on the information set of the central bank yields

$$E\left[\Gamma_t \mid I_{t(1)}^{cb}\right] = (1+\lambda)\,\sigma_{d^u}^2 + \sigma_{s^u}^2 + \frac{\lambda}{1+\lambda}\left(\pi_t^e - \pi_t^* + s_t^{cb}\right)^2 \tag{14}$$

where $I_{t(1)}^{cb}$ represents the information set of the central bank in the first stage. Minimising with respect to θ_t implies:

$$\frac{2\lambda}{1+\lambda}\left(\pi_t^e - \pi_t^* + s_t^{cb}\right)\frac{d\pi_t^e}{d\theta_t} = 0$$

If θ_t is an inflation announcement (recall *Definition 1*) and private agents are rational it must be the case that π_t^e depends on θ_t, and hence $d\pi_t^e/d\theta_t \neq 0$. The best response for the central bank is to announce an inflation forecast θ_t such that $\pi_t^e = \pi_t^* - s_t^{cb}$. This is inconsistent with private agents objective of forecasting inflation as accurately as possible, in (7), unless $s_t^{cb} = 0$. Furthermore, using $\pi_t^e = \pi_t^* - s_t^{cb}$ and equations (3)-(5) we obtain $\pi_t = \pi_t^* + s_t^u + d_t^u$. From this analysis we can see that the announcement θ_t intends to influence inflation expectations in such a way that their effect on inflation offsets the effect of the anticipated supply shock s_t^{cb} and realised inflation deviates from the implicit target only as a result of unanticipated shocks.

Let us now explain more formally the absence of equilibrium for the case in which shocks are normally distributed. In the third stage, the central bank minimises (1) with respect to the monetary instrument m_t. As has been already shown, it implies that m_t follows (5) and that, in the second stage, private agents form inflation expectations following (7). The inflation announcement θ_t is incorporated into I_t^p so we need to distinguish the private agents' estimator before and after knowing θ_t. Let $\widehat{\pi}_{t(0)}^*$ be the estimator of the implicit inflation target conditional on the information set available to the public in period t, before knowing θ_t i.e. before the first stage. Taking into account the private sector's information set and for analytical convenience, we can express π_t^e in the following form:

$$\pi_t^e = \widehat{\pi}_{t(0)}^* + E\left[\pi_t^* - \widehat{\pi}_{t(0)}^* \mid \theta_t\right] + \lambda\left(s_t^p + E\left[s_t^b \mid \theta_t\right]\right) \tag{15}$$

We do not yet know the explicit functional form of (15). Assuming that $\pi_t^* - \widehat{\pi}_{t(0)}^*$ and s_t^b are normally distributed it is shown below that, if θ_t is an inflation announcement, $E\left[\pi_t^* - \widehat{\pi}_{t(0)}^* \mid \theta_t\right]$ and $E\left[s_t^b \mid \theta_t\right]$ are linear functions in θ_t, $\widehat{\pi}_{t(0)}^*$ and s_t^p. Therefore, we can consistently assume that minimising (14) implies a solution for θ_t that is linear in π_t^*, s_t^b, s_t^p and $\widehat{\pi}_{t(0)}^*$ and that, accordingly, π_t^e takes the form

$$\pi_t^e = a_0 + a_\theta \theta_t + a_s s_t^p + a_{\pi^*} \widehat{\pi}_{t(0)}^* \tag{16}$$

where a_i for $i \in \{0, \theta, s, \pi^*\}$ are constants to be determined. Substituting (16) into (14) and minimising with respect to θ_t implies

$$\theta_t = \frac{-a_0 - (1 + a_s)\, s_t^p + (1 - a_{\pi^*})\, \widehat{\pi}_{t(0)}^* + \left(\pi_t^* - \widehat{\pi}_{t(0)}^*\right) - s_t^b}{a_\theta} \tag{17}$$

for $a_\theta \neq 0$. Equation (17) shows that θ_t is correlated with both the forecast error $\pi_t^* - \widehat{\pi}_{t(0)}^*$ and s_t^b which are unobserved variables to the public, and hence from *Definition 1* we can state that θ_t is an inflation announcement.

In order to determine parameters in equation (16) we proceed as follows. Since private agents know that the central bank announces θ_t following (17), they can construct a signal $x(\theta_t)$,

$$x(\theta_t) \equiv a_0 + a_\theta \theta_t + (1 + a_s)\, s_t^p - (1 - a_{\pi^*})\, \widehat{\pi}_{t(0)}^* = \pi_t^* - \widehat{\pi}_{t(0)}^* - s_t^b \tag{18}$$

The right-hand side of the equality represents a noisy signal of $\pi_t^* - \widehat{\pi}_{t(0)}^*$ and s_t^b because private agents are not able to perfectly separate one variable from the other. The left-hand side provides the way in which this signal can be constructed by using variables that are known to the public. Finding $E\left[\pi_t^* - \widehat{\pi}_{t(0)}^* \mid \theta_t\right]$ and $E\left[s_t^b \mid \theta_t\right]$ represents a signal extraction problem as described by Harvey and De Rossi (2006). Note that since the forecast error $\pi_t^* - \widehat{\pi}_{t(0)}^*$ only depends on η_t and past information, it is uncorrelated with s_t^b. From a standard lemma on the multivariate normal distribution (Harvey, 1989,

p. 165), the estimators are

$$\begin{aligned} E\left[\pi_t^* - \widehat{\pi}_{t(0)}^* \mid \theta_t\right] &= \gamma x(\theta_t) \\ E\left[s_t^b \mid \theta_t\right] &= -(1-\gamma)\, x(\theta_t) \end{aligned} \quad (19)$$

where $\gamma = \left(MSE\left[\widehat{\pi}_{t(0)}^*\right]/\sigma_{s^b}^2\right)\left(1 + MSE\left[\widehat{\pi}_{t(0)}^*\right]/\sigma_{s^b}^2\right)^{-1} \in (0,1)$. $MSE\left[\widehat{\pi}_{t(0)}^*\right]$ is the mean square error of the estimator $\widehat{\pi}_{t(0)}^*$ and $MSE\left[\widehat{\pi}_{t(0)}^*\right]/\sigma_{s^b}^2$ can be interpreted as a signal-to-noise ratio. The higher (lower) the variance $\sigma_{s^b}^2$ relative to the $MSE\left[\widehat{\pi}_{t(0)}^*\right]$, the noisier (better) the signal $x(\theta_t)$ for estimating $\pi_t^* - \widehat{\pi}_{t(0)}^*$ but the better (noisier) for estimating s_t^b. Substituting (18)-(19) into (15) and comparing the result to (16) we obtain the following system of equations: $a_0 = a_0 C, a_\theta = a_\theta C$, $a_s = \lambda + (1 + a_s) C$ and $a_{\pi^*} = 1 + (a_{\pi^*} - 1) C$ where $C \equiv \gamma - \lambda(1-\gamma)$.

The only equilibrium to the above system requires that $a_\theta = 0$, which implies that, from (17), θ_t is undefined.[8] Setting $a_\theta = 0$ means that agents do not include θ_t as a relevant variable to forecast inflation. Taking into account *Definition 1*, this only occurs when there is no inflation announcement, and therefore it does not exist a rational expectations equilibrium with inflation announcements in this monetary policy game.[9] This result draws attention to the fact that, for theoretical models, it is not innocuous to assume that when the central bank makes an inflation announcement it is revealing its actual private information because truthful communication may not be the optimal strategy.

With regard to the robustness of the result obtained in this section, it is important to remark that:

1. It does not require the central bank to have more information than private agents about both s_t and π_t^*. If we assume $s_t^b = 0$ for every t, $x(\theta_t)$ becomes a precise signal of $\pi_t^* - \widehat{\pi}_{t(0)}^*$. Then $\gamma = 1$ ($C = 1$) and the system of equations above has no solution since it implies $a_s = \lambda + 1 + a_s$. If, instead, we assume $\widehat{\pi}_{t(0)}^* = \pi_t^*$ for every t, $x(\theta_t)$ becomes a precise signal of s_t^b. Then $\gamma = 0$ ($C = -\lambda$) and the solution to the system of equations above requires $a_\theta = -\lambda a_\theta$ ($a_\theta = 0$).

[8] Note that since $\gamma \in (0,1)$ and $\lambda > 0$ then $C < 1$.

[9] The same result applies for a multi-period setup. Assume, instead, that there exists values for a_i, $i \in \{\theta, s, \pi^*\}$, such that there is an equilibrium for an either finite or infinite period model. By following (17), the minimum expected loss for every single period t (i.e. $E\left[\Gamma_t \mid I_t^{cb}\right] = (1+\lambda)\,\sigma_{d^u}^2 + \sigma_{s^u}^2$) is attainable without affecting the same possibility for future periods. Therefore the value function is independent of past decisions and the equilibrium for the multi-period setup must be equal to that for the one-period case.

2. It also applies to a Phillips Curve with forward-looking inflation expectations i.e. $\pi_t = E\left[\pi_{t+1} \mid I_t^p\right] + y_t + s_t$, as it is explained in more detail in Appendix B.1.

3. It is not particular to models in which opacity is preferred to transparency on supply shocks. Notice that in this paper the central bank has no incentives to reveal information about supply shocks because it reduces the possibility to stabilise the economy. This is a common feature in the literature on transparency about real shocks (e.g. Cukierman, 2001; Gersbach, 2003; Eijffinger and Tesfaselassie, 2007; Geraats, 2007). However, by modelling the behaviour of wage setters more explicitly, Laskar (2010) points out that when the nominal wage responds to supply shocks, which helps to stabilisation, transparency on such shocks may be preferred to opacity. Appendix B.2 shows that in spite of this feature, if misrepresentation is included in Laskar's model as a possible action for the central bank, there is no equilibrium with inflation announcements.

5 Some possible solutions

Based on some ideas (or solutions to similar problems) from the previous literature on central bank announcements, this section briefly discusses some possible ways in which the credibility problem might be solved. It also remarks why none of them is a completely satisfactory solution to the problem described in the previous section.

5.1 Canzoneri's solutions

Canzoneri (1985) proposes two different approaches to solve the credibility problem of central bank announcements (see section 2), the legislative approach and the reputational one. The former approach gives an active role to the government. For instance, the congress might take into account ex-post information about the money demand shock to legislate incentive compatible rules for monetary policy. These rules would contribute to stabilisation but require the government to be able to observe demand shocks of previous periods with high accuracy. Of course, the ability of the government to collect ex-post information on economic shocks should not depend on the central bank because we would return to the problem of misrepresentation.

On the other hand, the reputation-building approach suggests that a solution can be found without the action of a third party. In Canzoneri's model, as mentioned above, the public does not know with certainty whether a high growth rate of the money supply is a result of a perceived increase in money demand or an attempt to stimulate output. However, they know that the higher the growth rate of money the higher the probability that the policymaker deviated from the low-inflation policy. Based on this fact, Canzoneri proposes that the private sector follows a simple rule and punishes the central bank by reverting to the inflationary strategy (i.e. expecting high inflation in the future) whenever the money growth of the previous period exceeds an upper-limit value. This value has to be small enough to ensure that the central bank has no incentive to misrepresent its money demand forecast. The adoption of this rule by private agents also implies that even if the central bank is always running the ideal policy and announcing its actual money demand forecast, there will still be occasional inflationary periods associated with large negative central bank forecasts' errors.

Unfortunately this approach does not work as a rational expectations solution for the model in the present paper due to an important difference between the timing of these two models. In Canzoneri's model, private agents may punish the central bank without hurting themselves because their inflation forecast accuracy is independent of the punishment strategy.[10] This feature depends crucially on the assumption that private sector inflation expectations are formed before the central bank announcement. Quite the opposite, the present paper assumes that the inflation announcement precedes inflation expectations formation, giving a central role to the influence of announcements on the public's expectations.

5.2 Imprecise announcements

Stein (1989) and Garfinkel and Oh (1995) show that truthful communication is possible when the central bank announces the range in which its private information lies, rather than announcing a precise value. If the ranges from which the policymaker picks the one to announce are large enough, the central bank prefers revealing the actual range rather than increasing the degree of its misrepresentation significantly. In other words, if the central bank wants to misrepresent information it has to tell a big lie (small lies are not possible due to the size of the ranges), and therefore telling the truth is preferable to lying.

By means of a simple example, we can see why the credibility problem can be

[10]When the private sector can punish the central bank without hurting itself the threat to punish is credible and it is easy to support an equilibrium by implementing trigger strategies.

overcome, in Stein's model, when the central bank can only change its announcement by a discrete amount. Although the example refers to precise announcements, it gives us the intuition behind the case in which the central bank has to pick an interval to announce. In Stein's model, the central bank target for the (log) real exchange rate, say $E > 0$ (the analysis for $E < 0$ is analogous), is unknown to the public and inconsistent with its steady state level (zero). The credibility problem arises from the fact that the optimal policy for the central bank is making a monetary injection M equal to $E/2$ but, at the same time, it would like to manipulate private agents' expectations M^e so as to reduce the deviation $(M^e - E)^2$. Suppose that the central bank can choose the target to announce only among three possible values, E, E' and E'' ($E'' < E < E'$). A necessary and sufficient condition for the central bank to announce E (the truth) is that E' be large enough relative to E ($E' \geq 3E$), because then $M^e = E/2$ is closer to E than $E'/2$ or $E''/2$.

Now another simple example helps us to understand why this would be an impractical solution to the credibility problem when misrepresentation of private information is related to the size of the supply shock. From Section 4.1 we know that the truthful inflation forecast announcement is $\theta = \pi^* + \lambda s^{cb}$ but from equation (14) we know that the central bank wants to minimise $\left(\pi^e - \pi^* + s^{cb}\right)^2$. Suppose, as above, that there are only three possible announcements, θ, θ' and θ'' ($\theta'' < \theta < \theta'$) and there is an inflationary shock ($s^{cb} > 0$, the analysis for a deflationary shock is analogous). A necessary and sufficient condition for the central bank preferring to announce θ (the truth) is that $\theta'' \leq \pi^* - (2 + \lambda)\, s^{cb}$ i.e. the cost of telling the truth, $(1 + \lambda)^2 \left(s^{cb}\right)^2$, is less than that of lying. Ranges for this case would have to be very large because the central bank has incentives to try to deceive agents into believing that an inflationary shock is, instead, deflationary and much bigger in absolute value. In contrast, in Stein's model even in extreme cases in which the monetary policymaker is very limited to reveal information (e.g. E is large in absolute value), the central bank can be counted on to tell the truth at least about whether its real exchange rate target is positive or negative.

5.3 Communication through policy actions

As mentioned in Section 2, Hoerova et al. (2009) show that credible information can be transmitted through changes in the policy interest rate. Private investors observe these changes and infer the central bank's private information. As remarked before, this solves the inability of the central bank to credibly communicate with the public but makes inflation announcements completely unnecessary because all the information is communicated through the policy rate. This resembles the analysis presented in Geraats (2000), for a central bank that operates under opaqueness, or in the present paper for the model with no announcements (Section 4.2.1). In these cases, transmitting information has a cost due to the fact that the policymaker restrains its stabilisation efforts to make the monetary instrument a better signal of its intentions.

5.4 Exogenous reputation cost

As mentioned in Section 2, Walsh (1999) and Mahadeva and Sterne (2002) solve the credibility problem in their models by assuming that the policymaker is exogenously penalised for the deviation of actual inflation from the announcement. This penalisation represents a reputation loss which is included in the central bank's loss function. Equation (1) becomes $\Gamma_t = \lambda_1 y_t^2 + \lambda_2(\pi_t - \pi_t^*)^2 + \lambda_3 (\pi_t - \theta_t)^2$. With this loss function, despite the fact that the central bank still announces strategically, the monetary policy game of the present paper converges to an equilibrium point because the exogenous penalisation imposes a limit on the optimal degree of misrepresentation. Although this solves the problem described in Section 4.2.2, the solution comes from assuming this exogenous cost. However one would expect that, unless the action of a third party may be required, all of the incentives that make transparency desirable or undesirable should arise endogenously from the model.

In a similar way, one could solve the credibility problem by assuming, as Cukierman (2000) does, that there are two types of central bank, one which makes dependable inflation target announcements and another one which acts in an opportunistic way. The public is uncertain about the type of the policymaker in office. In this case, there is an equilibrium because in order to reduce the probability of its identity being revealed, the opportunistic type emulates the announcements and policy actions of the dependable one. Nevertheless, this solution does not explain why there would exist a dependable central bank which always chooses to tell the truth despite the fact that there are incentives to manipulate inflation expectations so as to reduce economic volatility.

6 Conclusion

The increased interaction between the central bank and the public has brought attention to the effect of policy announcements on private sector expectations. To assess the economic desirability of monetary policy transparency it is common practice to compare two scenarios; one in which the monetary authority reveals its private information, fully or partially, and another one in which there is full opacity.

The present paper complements earlier work by analysing the scenario in which the policymaker chooses the level of inflation announcements (e.g. inflation forecasts) taking into account that they have an effect on inflation expectations. The paper points out that even if the monetary policymaker prefers partial or full transparency over secrecy this fact does not rule out misrepresentation. The central bank may find it optimal to attempt to misguide inflation expectations so as to reduce economic volatility and, since private agents are aware of this situation, a credibility problem arises. It is shown that, for a very standard setup with a stochastic expectations augmented Phillips curve, there is no equilibrium under rational expectations with inflation announcements.

Based on previous literature about central bank announcements, the paper discusses some alternative ways in which the credibility problem might be solved; however, each of them has important drawbacks and it seems that we still need to find a more satisfactory solution. In conclusion, theoretical literature on transparency should not regard as established the fact that the central bank can credibly commit to truthfully reveal its private information, even in the absence of inflation-biased preferences.

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APPENDIX

A Empirical evidence on strategic forecasting

Gomez-Barrero and Parra-Polania (2011) set up a model in which the policymaker may make strategic announcements but faces an exogenous reputation cost like that described in section 5.4. Their model predicts that, under the presence of strategic announcements, we should find a negative correlation between central bank inflation forecasts and their corresponding forecast errors. Evidence of such negative correlation should be especially stronger for intermediate forecast horizons. The intuition behind this implication is as follows. For long horizons the central bank does not have much information about future shocks and, as a result, it does not have strong incentives to manipulate expectations. For very short horizons, it has more information but most of the relevant expectations have been already formed, then lying implies small benefits.

By conducting a hypothesis test on the correlation between inflation forecasts and their corresponding forecast errors ($\rho_{i,k} \equiv corr\,[\pi_i - \theta_{i,k}\ ,\ \theta_{i,k}]$, where $k = 1, 2, ..., 8$ refers to horizons -lag in quarters- and i refers to countries) Gomez-Barrero and Parra-Polania find evidence consistent with their model predictions. This appendix updates their database and conducts the same test ($H_0 : \rho_{i,k} = 0$ vs. $H_1 : \rho_{i,k} < 0$) using data from four inflation targeters: England, Hungary, New Zealand and Sweden (note that all of them are in the top seven list of transparent central banks according to the index of transparency constructed by Dincer and Eichengreen, 2009).

The estimates of $\rho_{i,k}$ are reported in Table A.1. In all cases the estimated coefficient is negative.

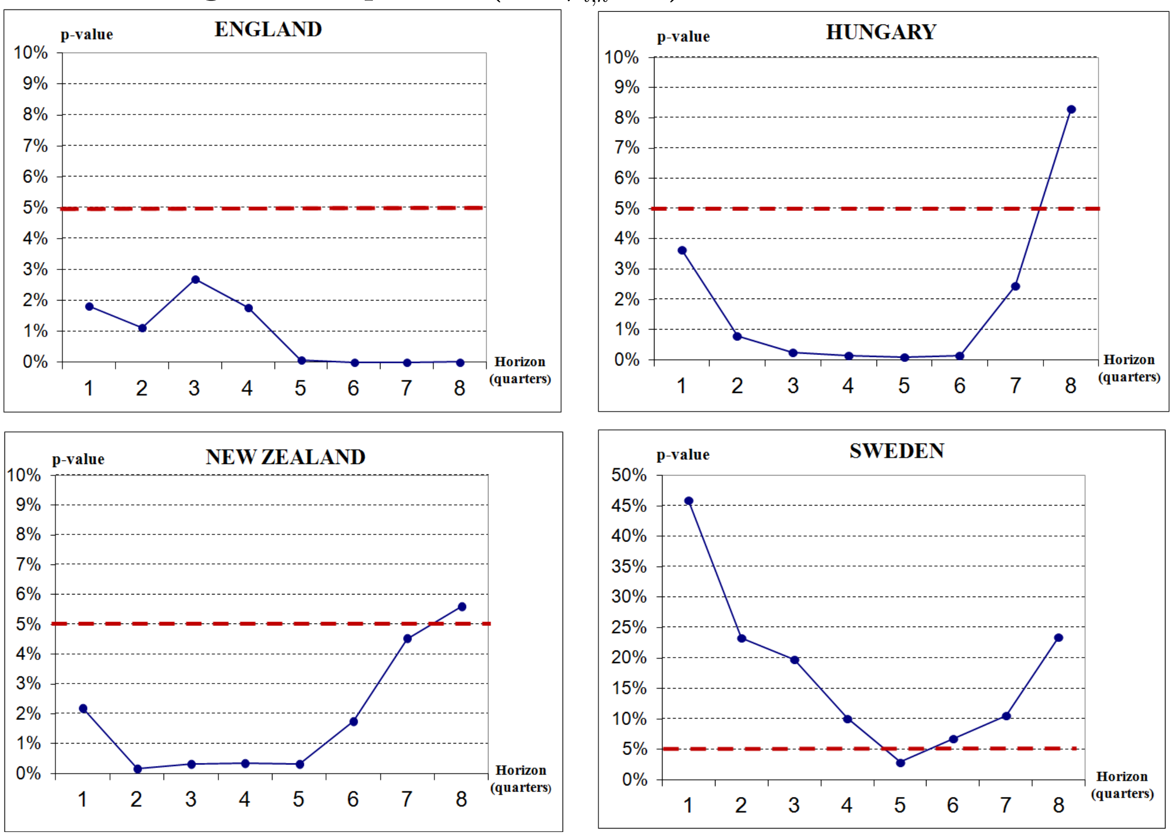
Table A.1. Estimated correlation coefficients

	Horizon (quarters)							
Country	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
England	−0.38 (31)	−0.42 (30)	−0.36 (29)	−0.40 (28)	−0.58 (27)	−0.77 (26)	−0.74 (25)	−0.67 (24)
Hungary	−0.31 (35)	−0.41 (34)	−0.48 (33)	−0.51 (32)	−0.53 (31)	−0.53 (30)	−0.38 (27)	−0.30 (23)
N.Zealand	−0.30 (46)	−0.43 (45)	−0.41 (44)	−0.41 (43)	−0.42 (42)	−0.33 (41)	−0.27 (40)	−0.26 (39)
Sweden	−0.02 (47)	−0.11 (46)	−0.13 (45)	−0.20 (44)	−0.29 (43)	−0.23 (42)	−0.20 (41)	−0.12 (40)

Number of observations are reported in parentheses.

The corresponding p-values are reported in Figure A.1. The dotted line marks the 5% level of significance. For three of the four analysed countries (all but Sweden) there is evidence that, in general, the correlation coefficient $\rho_{i,k}$ is negative. Furthermore, for three countries (all but England) the estimated values follow a u-shaped curve, which implies that evidence is weaker for very short or for long horizons.

Figure A.1. p-value ($H_0 : \rho_{i,k} = 0$) vs. forecast horizon



In order to increase the statistical power of these tests, we follow the same procedure as described by Gomez-Barrero and Parra-Polania. Although not shown here, it is verified that the above data are poolable and only one test may be conducted for each lag. In this case similar results are obtained: at the 5% significance level, there is evidence (for all forecast horizons) that there exists negative correlation between central bank inflation forecasts and their corresponding forecast errors and the estimated values follow a u-shape such that this evidence is stronger for intermediate horizons.

B Alternative Phillips curves

B.1 Forward-looking expectations

The same result obtained in Section 4.2.2 can be obtained for a Phillips curve of the form $\pi_t = \pi^e_{t+1|t} + y_t + s_t$ where $\pi^e_{t+1|t} \equiv E\left[\pi_{t+1} \mid I^p_t\right]$. This equation replaces (3). It can be verified that now the solution for inflation, in terms of expectations, is $\pi_t = (1+\lambda)^{-1}\left(\pi^*_t + \lambda\left(\pi^e_{t+1|t} + s^{cb}_t\right)\right) + s^u_t + d^u_t$ and also that $\pi^e_{t+1|t} = \delta_1\left(\delta_2\pi^*_0 + \alpha E\left[\pi^*_t \mid I^p_t\right]\right)$ where $\delta_1 = (1+\lambda(1-\alpha))^{-1}$ and $\delta_2 = (1-\alpha)(1+\lambda)$. The latter result can be expressed as

$$E\left[\pi_{t+1} \mid I^p_t\right] = \delta_1\delta_2\pi^*_0 + \delta_1\alpha\left(\widehat{\pi}^*_{t(0)} + E\left[\pi^*_t - \widehat{\pi}^*_{t(0)} \mid \theta_t\right]\right)$$

where, as in Section 4.2.2, $\widehat{\pi}^*_{t(0)}$ is the estimator of the implicit inflation target conditional on the information set available to the public before knowing θ_t. This equation replaces (15). The rest of the argument is similar to the one presented in Section 4.2.2 but note that $E\left[s^b_t \mid \theta_t\right]$ is not relevant for expectations formation. In equations (14) and (16) π^e_t must be substituted by $\pi^e_{t+1|t}$. The final system of equations is: $a_0 = \delta_1\delta_2\pi^*_0 + \delta_1\alpha\gamma a_0$, $a_\theta = \delta_1\alpha\gamma a_\theta$, $a_s = \delta_1\alpha\gamma(1+a_s)$ and $a_{\pi^*} = \delta_1\alpha(1-\gamma(1-a_{\pi^*}))$. The only equilibrium requires that $a_\theta = 0$.

B.2 Laskar's (2010) model

Laskar's (2010) reduced model is given by two equations: the central bank loss, $L = \lambda y^2 + \pi^2$ and the Phillips curve, $y = \tau_1(\pi - \pi^e + s - \tau_2 E[s \mid \theta])$ where coefficients τ are positive constants ($0 < \tau_2 < 1$), which depend on the parameters of the structural equations. Original notation has been changed so as to make it similar to that in the present paper. Minimising the loss function with respect to π and using the result and the fact that private agents are rational, we can express

$$\pi^e = -\tau_1^2(1-\tau_2)\lambda E[s \mid \theta]$$

and

$$L = \frac{\lambda\tau_1^2}{1+\lambda\tau_1^2}\left[\left(\tau_2 - \lambda\tau_1^2(1-\tau_2)\right)E[s \mid \theta] - s\right]^2 \qquad \text{(A.1)}$$

When there is full opacity (no announcements, NA) $E^{NA}[s \mid \theta] = 0$, since the private sector cannot anticipate the shock. In contrast, under a transparent (T) regime $E^T[s \mid \theta] = s$. Transparency on supply shocks is preferred to opacity when $L^{NA} > L^T$

which happens if (and only if) $1 > (1-\tau_2)^2 (1+\lambda\tau_1^2)^2$. This condition is satisfied when, in Laskar's model, the weight given by trade unions to employment (in their loss function) is greater than the weight given to the same objective by the central bank (in its loss function). In this case the private sector lets the nominal wage strongly responds to the shock which helps to stabilise employment. In contrast, under opacity there is no response since the private sector cannot anticipate the shock. This is why transparency may be preferable to opacity.

Now let us assume that the central bank announces θ, taking into consideration its final objective, minimising L. Private agents anticipate this situation and form expectations following $E[s \mid \theta] = a\theta$ where a is a constant to be determined. Then minimising (A.1) with respect to θ, solving for s and using the undetermined coefficients method we obtain the following equation: $a = (\tau_2 - \lambda\tau_1^2 (1-\tau_2))\, a$. Since $\tau_2 < 1$, the only equilibrium requires that $a = 0$.