Why Central Banks Announce their Objectives: Monetary Policy with Discretionary Signalling

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Abstract

This paper analyzes the use of announcements of objectives or intentions, announcements which are common in implementation of monetary policy. To analyze such announcements, this paper uses a model in which there is asymmetric information over the central bank's objectives. This informational asymmetry is represented by a stochastic in‡ation target, upon which only the central bank can condition its actions. Thus, the scope is set for signalling, and the use of announcements can be seen as a way for a central bank to signal its type. This paper assumes that a central bank can signal at its own discretion and shows that while central banks with high in‡ation targets never use announcements, central banks with low in‡ation targets occasionally, but not always, will choose to reveal their private information through an announcement. A …rst …nding is that, contrary to what a cheap-talk equilibrium suggests, the announcements may be more precise the larger the central bank's news. Moreover, this paper shows that the frequency of announcements is unambiguously increasing in the magnitude of the central bank's news, something that goes well in line with what is typically found in actual implementation of monetary policy.

1 Introduction

A recent trend within monetary policy is to adopt an in‡ation targeting regime governing monetary policy.[1] In the past decade countries like Australia, Canada, Finland, New Zealand, Spain, Sweden, and the United Kingdom have adopted such regimes, and one can argue that the regimes governing monetary policy in Germany and the United States are similar to the more explicit in‡ation targeting regimes.[2]

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[1] When referring to the term "in‡ation targeting", this paper adopts the view put forth by Svensson [16], [17] and Rudebusch and Svensson [13], who refer to the expression "targeting the variable X" as implying that X is a variable in the central bank's objective function. Others, such as McCallum and Nelson [11], refer to targeting as part of the central bank's reaction function.

[2] For a discussion of recent in‡ation targeting, see the papers in Leiderman and Svensson [10], or for a brief discussion about the characteristics of a typical in‡ation targeting regime, see Svensson [16] and Rudebusch and Svensson [13].

One common feature among these in‡ation targeting regimes is that the countries' central bankers often state their intentions or objectives in either In‡ation Reports, public speeches or press conferences. An example of such a statement stems from the Swedish experience of in‡ation targeting. In January 1993 the Swedish Riksbank announced that the target rate for in‡ation was to be 2 percent per year from 1995, with a tolerance interval of one percentage point around this target. While the in‡ation rate had been consistent with this point target in the beginning of 1994, in‡ation had started to rise in the latter part of 1994 and had reached levels close to or just above the higher boundary of the tolerance interval in the beginning of 1995. The Riksbank's forecasts of in‡ation also pointed to an in‡ation rate between 2.5 and 3 percent for 1996 and somewhat higher for 1997.[3] The Riksbank therefore stressed in its In‡ation Reports that the target was 2 percent and that they would not be satis…ed with an in‡ation rate close to or just above the higher boundary of the tolerance interval.

Another example of where a central bank has explicitly stated their objectives and intentions comes from Canada. When the Bank of Canada introduced in‡ation targeting, they did so by …rst addressing the importance of price stability in a series of speeches in 1988. These speeches were followed in 1991 by an announcement of the central bank's in‡ation targets for subsequent few years, where the targets were to decline from 3 percent per year in 1992 to 2 percent per year in 1995. There is some empirical evidence that at least the series of speeches in 1988 was e¤ective in reducing the private sector's in‡ation expectations.[4]

The above are situations in which the central bank itself has the option of making an announcement. However, there are other situations in which a central bank always makes an announcement. This applies to the New Zealand regime where it is current practice to announce the quarterly forecast of a Monetary Conditions Index, MCI, to signal the central bank's intentions. Similarly, the German Bundesbank announces its target for the money growth rate. While discretionary announcements of the central bank are the main focus of this paper, we can think of the examples from New Zealand and Germany as being special cases of the more general model but where the central bank instead commits to announce its objectives or intentions. Thus, the paper will also have some implications for these types of announcements.

What makes these announcements interesting is that, I would argue, there is not a good theoretical basis for understanding whether they should have any e¤ects. On one hand, one could argue that announcements are nothing but examples of cheap-talk. A common result

[3] See Sveriges Riksbank [18].
[4] See Johnson [8].

from game theory is that cheap-talk should not a¤ect the equilibrium outcome unless there are multiple equilibria. In this case, cheap-talk can work as a coordination device. Stein [14] further develops the cheap-talk equilibrium concept and shows that cheap-talk also can have e¤ects in situations absent multiple equilibria. The prediction is that the more news the central bank has, the less precise its announcement should be. While such a prediction may be reasonable when it comes to the example Stein discusses, the publication of the Federal Open Market Committee minutes, it does not explain the examples discussed above, where each announcement is a precise statement of the central bank's objectives or intentions.

On the other hand, another strand of the literature deals with signalling as a means to resolve an informational asymmetry.[5] The idea is that a central bank can convince the private sector that they have certain objectives by being su¢ciently rigid in conducted policy. However, in these models the signalling device is the same as the central bank's policy instrument, usually assumed to be the in‡ation rate or the interest rate. Again, this is not quite in line with the above announcement examples.

The purpose of this paper is therefore to present a model that helps us understand how a central bank can a¤ect the economy through precise announcements of their objectives or intentions. Moreover, this paper analyzes which central banks will use these announcements and under which conditions it will choose to do so. To analyze these issues the paper uses a model that closely resembles the models …rst introduced by Kydland and Prescott [9] and extended by Barro and Gordon [2] where a time-inconsistency problem arises when the private sector faces an overambitious central bank. However, if the only informational asymmetry is over a realization of a supply shock, there is no need for the announcements. The paper therefore introduces another informational asymmetry in that the central bank, but not the private sector, knows the current objectives for monetary policy. This uncertainty over the central bank's objectives is represented by a realization of a stochastic in‡ation target, which the private sector can only observe ex post.

Thus, the scope is set for signalling. However, for signalling to have any e¤ects it must be that the signal is perceived as costly to the informed agent, in this case the central bank. This paper therefore adopts a view similar to the view put forth by Guthrie and Wright [7], who discuss the e¤ects of "open mouth operations" in New Zealand, where an open mouth operation simply refers to the announcement of a numerical value of the MCI. The reason why

[5] See for instance Backus and Dri¢ll [1], Persson and Tabellini [12] and Vickers [19].

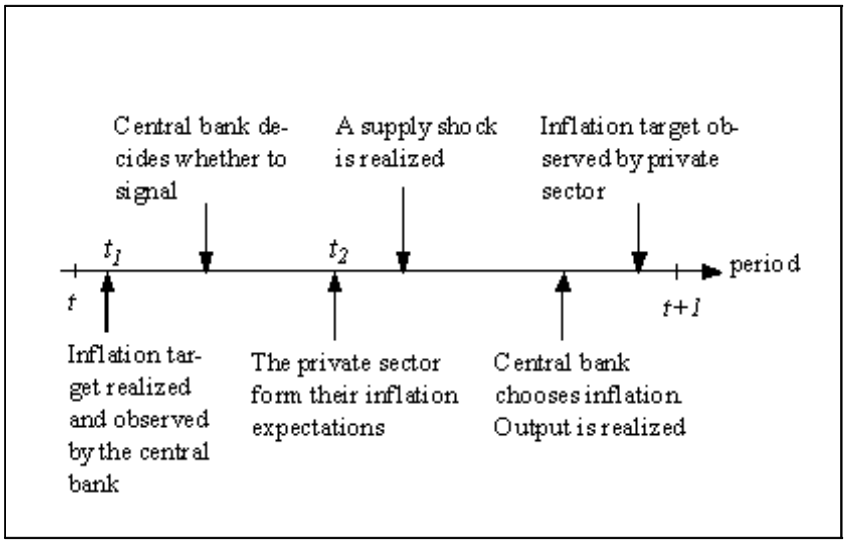
the announcement is perceived as costly to the central bank is that the central bank looses some ‡exibility by committing to using an open market operation to bring the MCI in line with the announcement when the announcement itself does not do so.

This paper di¤ers from Guthrie and Wright [7] in the following ways. By explicitly modeling the central bank's preferences and introducing an informational asymmetry over the central bank's objectives, the paper gives a rationale for why the private sector's expectations may di¤er from the central bank's. In Guthrie and Wright this di¤erence is simply assumed, and if one assumes rational expectations there is no way that these expectations can di¤er. Also, where they assume that the signalling cost is exogenous this paper derives the value of the signalling cost endogenously. However, the most important di¤erence is that this paper assumes that the central bank has discretion in the signalling. The added bene…t from such an assumption is that it is possible to derive the conditions under which a central bank will choose to reveal their private information.

The paper shows that even though the announcement of the objectives or intentions is perceived as costly the central bank may choose to reveal its private information. Also, contrary to the results of Stein [14], the paper shows that the signal may be more precise when the central bank has more news to reveal. Regarding which types of central banks will use the announcements and when they will do so, this paper shows that: (i) only central banks with ambitious objectives will reveal their private information through an announcement, and (ii) the more news the central bank has to reveal the more frequently they will use the announcements. These results seem consistent with the two examples of announcements given above in that in both cases the central banks used announcements in an early stage of in‡ation targeting, when the uncertainty over the central bank's objectives was large – or at least larger than what would occur after a couple of years under the in‡ation targeting regimes.

The paper is organized as follows: Section 2 describes the basic assumptions of the model. Section 3 uses the assumption that the central bank commits to signalling to derive the values of the signalling cost in equilibrium. Section 4 assumes that signalling is discretionary and analyzes when a central bank would use the signalling device and how the equilibrium strategies would be a¤ected by changes in the informational asymmetry. Finally, Section 5 concludes.

Figure 2.1: Timing of the game with discretion



2 The Model

The assumed timing of events is shown in Figure 2.1. First, the central bank's in‡ation target for period t is realized and observed by the central bank but not by the private sector. Conditional upon the realization of the in‡ation target the central bank determines whether to signal; that is, whether to announce their target for the period. Then, the private sector form its in‡ation expectations, conditional on the possible signal. After the private sector's in‡ation expectations are formed a supply shock is realized and observed by everyone, whereupon the central bank chooses which in‡ation rate to implement. The central bank's choice of in‡ation also determines the output for the period. Finally, at the end of each period, the central bank's in‡ation target is observed by the private sector.[6] The same sequence of events is repeated for the following period.

Since expectations operators will be used frequently it is worth noting how they are de…ned. An expectations operator of the form $E_{t\,i\,1}X_t$ refers to the central bank's expectations, whereas an expectations operator of the form $X_{tjt\,i\,1}$ refers to the private sector's expectations. Moreover, the expectations will be conditioned on two di¤erent information sets, denoted by t_1 and t_2 in Figure 2.1. As an example, the private sector's in‡ation expectations are thus denoted $¼_{tjt_2}$.

The private sector is characterized by two equations. First, output is given by the supply

[6] The assumption that the private sector can observe the in‡ation target at the end of each period could be relaxed at the cost of added algebraic complexity.

curve

$$y_t = \alpha(\pi_t - \pi_t^e) + \varepsilon_t, \tag{2.1}$$

where y_t is the (log of) output in period t (measured as deviations from trend and normalized around zero), π_t is the inflation rate in period t, π_t^e is the private sector's inflation expectations for period t, $\alpha > 0$ is the impact of surprise inflation on current output, and ε_t is a serially uncorrelated supply shock with mean zero and variance σ_ε^2. Second, the private sector's inflation expectations are assumed to be formed rationally, that is

$$\pi_t^e = \pi_{t|t-2}. \tag{2.2}$$

The central bank is assumed to choose the inflation rate so as to minimize an intertemporal loss-function, which in the beginning of period t is given by

$$V_t = E_{t-1}\left[\sum_{j=t}^{\infty} \beta^{j-t} L_j\right], \tag{2.3}$$

where $\beta \in (0;1)$ is the discount factor, and L_j is the central bank's period loss-function, which in period t is

$$L_t = \frac{1}{2}\left[(\pi_t - \pi_t^{CB})^2 + \lambda (y_t - y^n)^2\right] + S(a). \tag{2.4}$$

In the period loss-function, $y^n > 0$ denotes the optimal level of output and, $\lambda > 0$ denotes the weight attached to output stabilization relative to inflation stabilization. π_t^{CB} denotes the central bank's inflation target in period t;and S(a) denotes the cost of sending signal a. The following subsections discuss the central bank's inflation target and the signalling cost in more detail.[7]

2.1 The Central Bank's Inflation Target

The central bank's inflation target is assumed to be the private information of the central bank and follows a first-order Markov chain with two possible states so that

$$\pi_t^{CB} \in \{\underline{\pi}, \overline{\pi}\}, \tag{2.5}$$

[7] The model will not be used for making judgements about the optimality of different policies, so there is no need to introduce a social welfare function. Independently of how the social welfare function is specified, the optimal policy for the central bank remains the same. However, we can think of the private sector as having the same loss-function as the central bank (2.4), with the only difference being that from the private sector's view the optimal level of inflation (denoted by π^n) is constant and equal to the unconditional mean of the Markov chain. Thus, the central bank's preferences coincide on average with the private sector's preferences.

where $\underline{\pi} < \bar{\pi}$, and the transition matrix between the states is

$$\Theta = \begin{bmatrix} \alpha & 1-\alpha \\ 1-\alpha & \alpha \end{bmatrix}. \tag{2.6}$$

Thus, the probability that the target remains unchanged is denoted by α, where it is assumed that $\alpha \geq \frac{1}{2}$. Similarly, the probability of a switch in the target is then $1-\alpha \leq \frac{1}{2}$.[8]

The assumption that the central bank has private information about the inflation target can be justified the following way. If we instead assume that the central bank has private information over the output target, as in Faust and Svensson [5], it can be shown that the gain from resolving the informational asymmetry always is smaller than the perceived signalling cost. Consequently, under the assumption that the central bank has private information over the output target, the central bank prefers never to use an announcement, which seems to be at odds with the examples of announcements given in the introduction.

Moreover, the assumption of a time-varying inflation target can be justified in the following manner. Consider instead a model where the central bank's preferences are drawn from a discrete distribution in the beginning of the game, but once the preferences are determined they remain constant, as in Backus and Driffill [1], Persson and Tabellini [12], and Vickers [19]. Under these assumptions a central bank with a low inflation target would have a large incentive to resolve the informational asymmetry in the first period of the game. Once this is done, the model reduces to the traditional discretionary (or committed) equilibrium (depending on how we assume monetary policy is conducted) in each of the following periods; that is, there would be no scope for further signalling once the informational asymmetry is resolved.

Thus, both the assumption that the central bank has private information over the inflation target and the assumption that the target varies over time are necessary to generate an equilibrium in which the central bank sometimes, but not always, announces its objectives. While these two arguments both are technical in nature, I prefer to interpret them the following way. The central bank's policy group consists of different members with possibly different views of the current economic stance and thus different views of the current optimal policy. These views may also change over time. When deciding upon which policy to conduct, these possibly different and changing views must be aggregated. Thus, the assumptions that (i) the inflation target is stochastic, and (ii) this target is the central bank's private information are just assumptions

[8] The assumption of a stochastic inflation target is similar to the assumptions made by Faust and Svensson [5] and Cukierman and Meltzer [4]. The former assume that the central bank's output target is stochastic and follows an AR(1)-process whereas the latter assume that it is the central bank's willingness to trade higher inflation for more stimulation that is stochastic and follows an AR(1)-process.

made to reflect the idea that the private sector does not fully know the central bank's objectives.

2.2 The Signalling Cost

For signalling to have any effects it must be perceived as costly to the informed agent, in this case the central bank. The term $S(a)$ in the loss-function (2.4), where $a \in \mathbb{R}_+ \setminus \{f, g\}$, represents this perceived cost of signalling.[9] If the central bank chooses to announce its objectives, we assume that such an announcement is associated with a fixed cost, f.[10] Given the assumption of a fixed cost it is convenient to let the cost-function be of the form

$$S(a) = \begin{cases} f + a; & \text{for } a \in \mathbb{R}_+ \\ 0; & \text{for } a \in \{f, g\} \end{cases}; \tag{2.7}$$

where the fixed cost, f, is assumed to be exogenous, whereas the variable cost, a, is a decision variable of the central bank.

The two different components of the signalling cost can be thought of in the following way. The fixed cost, f, represents an actual cost, for example the cost of incorporating the announcement in an inflation report, giving a speech to the public, or holding a press conference. On the other hand, the variable cost, a, can be thought of as a cost in the sense that it allows less flexibility in future monetary policy, which arises because the central bank commits to conducting a policy which brings the private sector's beliefs in line with the announcement if the announcement itself does not achieve this.[11] The variable cost can also be thought of as capturing a reputational loss in that the central bank cannot use announcements in the future if the private sector can verify that the central bank did not announce its true objectives. Thus, a seemingly cheap announcement may very well be perceived as fairly costly from the central bank's point of view.

3 Equilibrium with Commitment in Signalling

While we ultimately are interested in finding the equilibrium in which the central bank itself can choose if and when to signal, it is still useful to start with a simpler version of the model. Thus, we temporarily assume that the central bank commits to announcing its objectives. However, the choice of which monetary policy to conduct is assumed to be discretionary throughout the

[9] In Backus and Driffill [1], Persson and Tabellini [12], and Vickers [19], the signalling cost is represented by the increased loss from conducting a more restrictive policy than would have been the case absent an informational asymmetry.

[10] The fixed cost will, in equilibrium, distinguish the signal of a central bank with a high target from no signal at all.

[11] This interpretation is the same as the interpretation in Guthrie and Wright [7].

paper. Thus, the assumption of commitment in signalling is just a special case of the timing shown in Figure 2.1 and may be used to explain the consequences of signalling that are conducted in New Zealand and Germany.

The equilibrium concept in this signalling game is the least cost separating Perfect Bayesian Equilibrium, PBE; that is, an equilibrium where the central bank reveals its objectives by its action, each agent acts in its own interest given its beliefs, beliefs are consistent with Bayes' rule along the equilibrium path, and the signalling itself is e¢cient. There are multiple equilibria in this model as well as in most other models with signalling. However, this paper restricts its attention to only one of these equilibria: the least cost separating PBE, since this equilibrium is the only equilibrium consistent with the Intuitive Criterion, IC.[12] Thus, the central bank's signal completely resolves the informational asymmetry. Moreover, the size of the signalling cost is as small as possible.

3.1 Optimal Choice of In‡ation Given the Signal

The assumption that everything is observable at the end of each period together with the speci…cation of the supply curve in (2.1) simpli…es the solution of this model. Since there are no endogenous state variables the problem of …nding the optimal choice of in‡ation reduces to a static optimization problem. Still, there are quite a few di¤erent cases that need to be considered when …nding the optimal choice of in‡ation. The central bank's in‡ation target may be low or high, and the target may or may not have switched since the previous period. However, no matter which of these cases we are considering, the central bank's choice of which in‡ation rate to implement is always the solution to the same …rst-order condition.[13] This is because all that the signalling and switching in the target do is to alter the in‡ation expectations, and these in‡ation expectations are taken as given when the central bank chooses which policy to implement.

Thus, given the signal and given the private sector's in‡ation expectations, the optimal choice

[12] The Intuitive Criterion (IC) is a re…nement of the set of equilibria in signalling games. For a formal de…nition of the IC see either the original reference, which is Cho and Kreps [3], or for a somewhat more accessible treatment see Fudenberg and Tirole [6], section 11.2. The IC takes into account the beliefs that support a given equilibrium and asks which of these beliefs are reasonable. Intuitively, the IC supposes that one agent deviates from the proposed equilibrium strategy and then gives the following speech: "I admit that I have deviated, but does this mean that I am weak? No, for had I actually been weak this deviation would not have been bene…cial for me; only if I am tough would this deviation make me strictly better o¤. Thus, you should not think that I am weak when my deviation only makes sense if I am tough." Typically, the IC suggests that only the least-cost separating equilibrium is supported by reasonable beliefs.

[13] As shall soon become clear, the choice of in‡ation expressed as a function of the in‡ation expectations remains the same. However, given that the in‡ation expectations alter between the possible cases, the actual in‡ation will vary.

of in‡ation is the solution to the …rst-order condition

$$\left(\pi_t - \pi_t^{CB}\right) + \beta\left(y_t - y^{\natural}\right) = 0; \tag{3.1}$$

which is obtained by di¤erentiating the loss-function (2.4) with respect to current in‡ation and using $\frac{\partial y_t}{\partial \pi_t} = \beta$ from the supply-curve (2.1). The …rst term in this …rst-order condition represents the current marginal loss from increasing in‡ation slightly and the second term represents the marginal indirect gain in terms of increased output following an increase in the in‡ation rate. At the margin these two terms should exactly o¤set each other. Inserting the supply curve from equation (2.1) into the above expression gives the actual outcomes in terms of the parameters and the in‡ation expectations as

$$\pi_t = \frac{1}{1+\beta^2\alpha}\left[\beta\alpha y^{\natural} + \pi_t^{CB} + \beta^2\alpha\pi_t^{e} - \beta\alpha\varepsilon_t\right]; \text{ and} \tag{3.2}$$

$$y_t = \frac{\beta}{1+\beta^2\alpha}\left[\beta\alpha y^{\natural} + \pi_t^{CB} - \pi_t^{e} + \frac{1}{\beta}\varepsilon_t\right]: \tag{3.3}$$

The in‡ation expectations are found as the conditional expectations of (3.2). Note that for the private sector all that can alter its expectations is a signal from the central bank. Thus, in terms of the private sector's beliefs about the in‡ation target, the in‡ation expectations are given by

$$\pi_t^{e} = \beta\alpha y^{\natural} + \pi_{t|t_2}^{CB}; \tag{3.4}$$

where the term $\pi_{t|t_2}^{CB}$ denotes the private sector's beliefs about the central bank's in‡ation target, which in turn depends on the signal. Substituting the in‡ation expectations into (3.2) and (3.3) gives the dynamics of in‡ation and output as

$$\pi_t = \beta\alpha y^{\natural} + \frac{1}{1+\beta^2\alpha}\pi_t^{CB} + \frac{\beta^2\alpha}{1+\beta^2\alpha}\pi_{t|t_2}^{CB} - \frac{\beta\alpha}{1+\beta^2\alpha}\varepsilon_t; \text{ and} \tag{3.5}$$

$$y_t = \frac{\beta}{1+\beta^2\alpha}\left[\pi_t^{CB} - \pi_{t|t_2}^{CB}\right] + \frac{1}{1+\beta^2\alpha}\varepsilon_t: \tag{3.6}$$

The central bank chooses which signal to send based on the expected loss, which can be found by substituting equations (3.5) and (3.6) into the central bank's loss-function (2.4) and taking the conditional expectation as of time t_1. This yields

$$\begin{aligned} E_{t_1}\left[L_t\left(\pi_{t|t_2}^{CB}\right)\right] = {} & \frac{1}{2}\left[1+\beta^2\alpha\right]\left(y^{\natural}\right)^2 + \frac{\beta^2\alpha}{1+\beta^2\alpha}\left(\pi_t^{CB} - \pi_{t|t_2}^{CB}\right)^2 \\ & + \frac{\alpha}{1+\beta^2\alpha}\sigma_{\varepsilon}^2 - 2\beta\alpha y^{\natural}\left(\pi_t^{CB} - \pi_{t|t_2}^{CB}\right) + S(a). \end{aligned} \tag{3.7}$$

To get some intuition for how the private sector's beliefs about the central bank's in‡ation target a¤ect this expected loss, it is helpful to look at the derivative

$$\frac{@E_{t_1}\left[L_t\left(\pi_{t|t_2}^{CB}\right)\right]}{@\pi_{t|t_2}^{CB}} = \alpha\left[\frac{\alpha}{1+\alpha^2}\left(\pi_{t|t_2}^{CB} - \pi_t^{CB}\right) + y^*\right]. \tag{3.8}$$

A central bank with a low in‡ation target faces a situation where the private sector's beliefs about the target are higher than or equal to the true target. Thus, the derivative in (3.8) is unambiguously positive for such a bank, and moreover the value of the derivative is increasing in $\pi_{t|t_2}^{CB}$. Thus, as one might expect, a central bank with a low in‡ation target always has an incentive to reduce the private sector's beliefs about the target.

The situation facing a central bank with a high in‡ation target is somewhat di¤erent. Since the private sector's beliefs about the target are always less than or equal to the true target, the sign of the derivative in (3.8) is ambiguous. If the derivative is positive, which arises when $\pi_{t|t_2}^{CB} > \pi_t^{CB} - \frac{1+\alpha^2}{\alpha}y^*$, the central bank would like to reduce the private sector's beliefs about the in‡ation target. Thus, absent a time-inconsistency problem (i.e., when $y^* = 0$) a central bank with a high in‡ation target will never try to mimic a central bank with a low in‡ation target. The intuition is that when $y^* = 0$ and the central bank truthfully reveals its target, the outcomes in terms of in‡ation and output will on average be on their …rst best levels.[14] If such a central bank is successful in reducing the private sector's beliefs about the target, such a policy would reduce the in‡ation and increase output, both of which are costly to the central bank. Therefore, under these conditions, such a central bank has incentives to reveal its target truthfully. On the other hand, if the derivative in (3.8) is negative, which arises when $\pi_{t|t_2}^{CB} < \pi_t^{CB} - \frac{1+\alpha^2}{\alpha}y^*$, the central bank with a high in‡ation target has an incentive to increase the private sector's beliefs about the target through signalling.

Since we will frequently look at the di¤erence in losses between two alternative signals, it is worthwhile to …nd a general expression for this di¤erence. This di¤erence in losses can be expressed as

$$\begin{aligned} & E_{t_1}\left[L_t\left(\pi_{t|t_2}^{CB}\right)\right] - E_{t_1}\left[L_t\left(\pi_{t|t_2}^{CB}\right)\right] \\ = & \frac{1}{2}\left[\frac{\alpha^2}{1+\alpha^2}\left(\pi_t^{CB} - \pi_{t|t_2}^{CB}\right)^2 - \left(\pi_t^{CB} - \pi_{t|t_2}^{CB}\right)^2 + 2\alpha y^*\left(\pi_{t|t_2}^{CB} - \pi_{t|t_2}^{CB}\right)\right] \\ & + S(a) - S(\hat{a}). \end{aligned} \tag{3.9}$$

[14] The actual outcomes in terms of in‡ation and output will depend on the realization of the supply shock.

where $\pi^{CB}_{t|t_2}$ denotes the private sector's beliefs about the inflation target when the signal a is sent, and $\pi^{CB}_{t|t_2}$ denotes the beliefs when an alternative signal $\hat{a}$ is sent.

3.2 The Value of the Signalling Cost

Since there are only two types of central banks in the model, the equilibrium outcome will only contain two levels of the signalling cost, denoted $\underline{a}$ and $\bar{a}$: To get separation, one will have to find a value of the difference between $\underline{a}$ and $\bar{a}$ such that no type has an incentive to deviate and mimic the other type. The least cost separating PBE then naturally implies that one of these values is zero. As we saw earlier in equation (3.8), a central bank with a low inflation target always has an incentive to try to decrease the private sector's beliefs about the target. Denoting the signalling cost that such a bank is willing to bear by $\underline{a}$, the least cost separating PBE implies that $\bar{a} = 0$. Thus, all that remains is to find the value of $\underline{a}$ that ensures that a central bank with a high target does not want to mimic a central bank with a low target.

The private sector's beliefs, denoted by μ, are a probability distribution over the possible signals and are given by

$$\begin{aligned} \mu\left(\pi^{CB}_t = \underline{\pi} \mid a = \underline{a}'\right) &= 1; \text{ and} \\ \mu\left(\pi^{CB}_t = \bar{\pi} \mid a \neq \underline{a}'\right) &= 1: \end{aligned} \tag{3.10}$$

That is, the private sector believes that the inflation target is low if and only if it sees the signal $\underline{a}$ and high otherwise.

Suppose that the central bank plays the proposed equilibrium strategy; that is, each type of central bank chooses the signal that reveals its inflation target. This implies that the private sector's beliefs are[15]

$$\pi^{CB}_{t|t_2} = \pi^{CB}_t: \tag{3.11}$$

To sustain this outcome as an equilibrium we need to see what happens when a central bank deviates. Since the optimal choice of inflation still is the solution to the same first-order condition as before, the only way a central bank can possibly gain by deviating in this model is by changing its signal and making the private sector believe that it is a central bank of a different type than its true type. Hence, if a central bank deviates and chooses the alternative signal, the private

[15] Note that when the central bank plays according to this proposed equilibrium strategy, the outcomes in terms of inflation and output are exactly the same as the discretionary outcome in a model where the central bank is simply assigned an inflation target, π^{CB}_t, as suggested by Svensson [15].

sector's beliefs about the inflation target are

$$\pi^{CB}_{t|t_2} = \pi^{CB}_t; \tag{3.12}$$

where $\pi^{CB}_{t|t_2}$ denotes private sector beliefs when the central bank deviates, and π^{CB}_t denotes the target of a type other than the central bank's true type. To prevent a central bank from deviating, the expected loss must be smaller when the central bank truthfully reveals its target than when it deviates. This condition implies that the difference in losses in (3.9) must be non-positive when substituting for the private sector's beliefs from (3.11) and (3.12). Therefore, the smallest value of the signalling cost that prevents a central bank with a high inflation target from mimicking a central bank with a low target is given by

$$\underline{a} = \beta\left(\pi^H - \underline{\pi}\right)\left[y^* - \frac{\beta}{1+\beta^2}\frac{\left(\pi^H - \underline{\pi}\right)}{2}\right]. \tag{3.13}$$

Given that $\underline{a}$ is as in (3.13), a central bank with a high inflation target cannot gain from trying to convince the private sector that it is a central bank with a low inflation target.[16] The results regarding the variable part of the signalling cost are summarized in the following proposition.

Proposition 3.1. With regard to the size of the variable component of the signalling cost, the following applies:

1. For sufficiently small values of the output target, y^*, the variable component of the signalling cost is zero.
2. The effect on the variable component of the signalling cost from an increase in $\pi^H - \underline{\pi}$ is ambiguous.

Proof. Part (1) follows directly from equation (3.13). The variable component of the signalling cost is non-negative if and only if

$$y^* \geq \frac{\beta}{1+\beta^2}\frac{\left(\pi^H - \underline{\pi}\right)}{2}. \tag{3.14}$$

Part (2) follows from differentiating (3.13) with respect to $(\pi^H - \underline{\pi})$, which yields

$$\frac{\partial \underline{a}}{\partial\left(\pi^H - \underline{\pi}\right)} = \beta\left[y^* - \frac{\beta}{1+\beta^2}\left(\pi^H - \underline{\pi}\right)\right]; \tag{3.15}$$

[16] To get some feeling for how large the signaling cost must be, let us look at the following numerical example. Assume that the parameters have the values $\beta = \gamma = \frac{1}{2}$, $y^* = 1$, $\pi^H = 3$, and $\underline{\pi} = 1$. This yields a signalling cost $\underline{a} = \frac{5}{18}$, but how large is this? Consider the situation facing a central bank with a low inflation target. If the central bank signals, the average inflation equals 1:25, and the average output equals zero. Thus, for such a bank to be indifferent between signaling and not signaling the private sector must believe that the central bank's inflation target is approximately 1:92 if the central bank doesn't signal. So, if such a central bank does not signal, the average inflation will be 1:35, and the average output will be ¡0:4, which implies that an increase in inflation of 0:1 and a decrease in output of 0:4 gives rise to a loss as large as the signaling cost $\underline{a} = \frac{5}{18}$.

the sign of which is ambiguous. ■

The intuition for Part (1) of Proposition 3.1 hinges on equation (3.8), where a central bank with a high in‡ation target has no incentive to deviate absent a time-inconsistency problem. Furthermore, when y^{α} is close to zero, the gains from deviating are of second order, and thus a central bank with a high in‡ation target only has incentive to try to reduce the private sector's beliefs about the target when y^{α} is su¢ciently high. This result shows that when the informational asymmetry stems from an uncertainty over the policymaker's objectives, signalling may sometimes, but not always, be costless and still have the desired e¤ects on the private sector's expectations.

Part (2) of Proposition 3.1 shows that for su¢ciently large values of y^{α} the signalling cost is increasing in $\pi - \underline{\pi}$, whereas for small values of y^{α} the signalling cost is decreasing in $\pi - \underline{\pi}$. The intuition for this result hinges on the in‡ationary bias, which arises in an equilibrium where the central bank reveals its target truthfully. This in‡ation bias is increasing in the output target. Thus, for small values of y^{α}, this in‡ation bias is also small, so a central bank that deviates may induce an average in‡ation that is below the target. If uncertainty about the target increases, the incentives to deviate decrease, so the signalling cost necessary for separation decreases. Conversely, if the in‡ation bias is su¢ciently large, an increase in uncertainty about the policymaker's preferences increases the incentives to deviate so that the signalling cost in this case increases.

The result in Part (2) of Proposition 3.1 can be interpreted as contrary to the results in Stein [14], where a cheap-talk equilibrium implies that the bigger the central bank's news, the less precise its announcement should be. Within this framework, it is natural to think that the central bank's news is bigger when $(\pi - \underline{\pi})$ is large. Furthermore, $\underline{a}$ is assumed to capture the loss of ‡exibility that the central bank incurs by announcing it's objectives. It seems reasonable that the more precise the announcement, the greater the loss of this ‡exibility. Thus, the result that there is an ambiguous e¤ect of an increase in $(\pi - \underline{\pi})$ on the variable component of the signalling cost is contrary to the results of Stein.

4 Equilibrium with Discretionary Signalling

We now drop the assumption that the central bank always announces its objectives and instead turn to a model where the central bank can decide if and when it wants to signal. Since an equilibrium with discretionary signalling is di¤erent from what is typical in models with

signalling, we …rst de…ne the equilibrium.

De…nition 4.1. An equilibrium with discretionary signalling is de…ned as a situation where:

1. The central bank plays the strategy consistent with the least cost separating Perfect Bayesian Equilibrium (PBE) if it chooses to signal.
2. The central bank chooses to signal if it …nds it bene…cial to do so.
3. The private sector's beliefs are consistent with Bayes' rule along the equilibrium path.

Thus, if a central bank chooses to signal, it plays the strategy described in the preceding section, and the results in Proposition 3.1 remain valid whenever the central bank chooses to signal. What remains is to solve for the outcome when a central bank chooses not to signal, and correspondingly to determine if and when it will signal. The following subsections describe these steps in detail.

4.1 Equilibrium when the Central Bank does not Signal

When the central bank does not signal, the private sector can base their in‡ation expectations on the past realization of the central bank's in‡ation target and on the fact that the central bank did not signal. The private sector's beliefs about the target when the central bank does not signal can be described by

$$\pi^{CB}_{t|t_2} = q\pi^{CB}_{t-1} + (1-q)\theta^{CB}_{t-1} \tag{4.1}$$

where q is the private sector's probability assessment that the central bank's in‡ation target did not change, and θ^{CB}_{t-1} denotes the in‡ation target of a central bank of the other type. For both types of central banks there are four possible signalling strategies; (i) always signal, (ii) never signal, (iii) signal if the target remains unchanged but not if it has switched, and (iv) signal if the target has switched but not if it remains unchanged.[17]

There are only three possible values for the probabilities that can be consistent with Bayes' rule, , $q \in \{0; Á; 1\}$. To see this, consider the case where the private sector sees no signal but does know that the central bank's in‡ation target in the preceding period was low. If a central bank whose in‡ation target was low in the preceding period never signals, then $q = Á$ is the only probability assessment that is consistent with Bayes' rule. However, if the same central bank always signals when the target has switched but never when it remains unchanged, then

[17] The possibility of a mixed strategy in the signalling is excluded.

no signal implies that the target has remained unchanged, so $q = 1$ is the only probability assessment that is consistent with Bayes' rule. Finally, if such a central bank always signals when the target remains unchanged but never when it has switched, then $q = 0$ is the only probability assessment that is consistent with Bayes' rule.

By substituting these beliefs into equations (3.5) and (3.6), we have a complete description of the dynamics of in‡ation and output when there is no signal. Thus, all that remains is to determine if and when a central bank will use the signalling device and when it will keep the informational asymmetry.

4.2 When Will the Central Bank Signal?

For both types of central bank, the decision about whether to signal is based on the di¤erence in losses between two alternative strategies, given by (3.9). Here, the private sector's beliefs under the alternative strategy are from (4.1) with its respective probabilities, and the signalling cost is given by (2.7), where $\underline{a}$ is as in (3.13). The central bank will choose a proposed equilibrium strategy if this di¤erence in losses is non-positive and will deviate otherwise. Note that the size of the signalling cost in (3.13) prevents a central bank from trying to mimic the other type. Thus, a deviation exclusively refers to the choice of whether to signal. As an example, if the proposed strategy is to never signal, a central bank can deviate by either signalling if the target remains unchanged or signalling if it has switched. Thus, there are two possible deviations for this signalling strategy, and this holds for the other signalling strategies as well. Then, for a strategy to be an equilibrium, the central bank should not deviate independently of the current realization of the in‡ation target.

Which of these four signalling strategies that actually are equilibria depends on the …xed cost, f. As an example, it is easy to understand that if the …xed cost is su¢ciently large the strategy to never signal will be an equilibrium strategy. The private sector then rationally will believe that the probability that the central bank's in‡ation target has remained unchanged is Á, which is consistent with Bayes' rule.

Since there are two possible deviations for each signalling strategy, there are two restrictions on the value of the …xed cost for each of these four strategies. For a strategy to actually be an equilibrium, the …xed cost must satisfy both of these restrictions. Table 4.1.a shows the restrictions on the …xed cost such that the four candidate signalling strategies are possible equilibria for a central bank whose in‡ation target in the preceding period is low, and Table

4.1.b shows the corresponding values for a central bank whose in‡ation target in the preceding period is high. There are two constants in these tables, de…ned as $\pm = \circledR(\bar{\pi} - \underline{\pi})$, and $\circ = \frac{1}{1+\circledR^2}$. In both tables a restriction that implies negative …xed cost is marked by a zero.[18]

Table 4.1.a. Restrictions on the …xed cost for a central bank with $\pi_{t-1}^{CB} = \underline{\pi}$.

Row	Signalling strategy	Value of q	Current In‡ation Target	
			$\pi_t^{CB} = \underline{\pi}$	$\pi_t^{CB} = \bar{\pi}$
1.	Always signal	Á	$f \cdot \pm, \quad (1-Á)^2 + 1 \quad \frac{\pm\circ}{2} - y^{\natural}Á$	$f < 0$
2.	Never signal	Á	$f \geq \pm, \quad (1-Á)^2 + 1 \quad \frac{\pm\circ}{2} - y^{\natural}Á$	$f \geq 0$
3.	Don't signal if $\pi_t^{CB} = \pi_{t-1}^{CB}$, Signal if $\pi_t^{CB} \neq \pi_{t-1}^{CB}$	1	$f \geq 0$	$f \cdot 0$
4.	Signal if $\pi_t^{CB} = \pi_{t-1}^{CB}$, Don't signal if $\pi_t^{CB} \neq \pi_{t-1}^{CB}$	0	$f \cdot \pm\circ^2$,	$f \geq 0$

Notes: The central bank will play the proposed equilibrium strategy for values of the …xed cost, f, that satisfy the constraints in the table. The constants are de…ned as $\pm = \circledR(\bar{\pi} - \underline{\pi})$ and $\circ = \frac{1}{1+\circledR^2}$.

The results regarding which strategies are equilibria are summarized in the following proposition.

Proposition 4.2. In a game with discretionary signalling, each type of central bank has only two equilibrium strategies.

1. Never signal.
2. Signal if the current realization of the in‡ation target is low; do not signal if it is high.

Proof. That the strategy to always signal never is an equilibrium follows from the …rst row of Table 4.1.a - 4.1.b. If the current realization of the in‡ation target is high the central bank requires a negative …xed cost to play that strategy. Thus, this cannot be an equilibrium. Note that any belief, q, is consistent with Bayes' rule given this strategy, since if the central bank plays this strategy there will always be a signal, and thus Bayes' rule does not apply to these beliefs. However, it can be shown that independent of these beliefs there is no equilibrium in

[18] When deriving these values, the central bank's output target is assumed to satisfy (3.14), which ensures that $\underline{a} \geq 0$. Although the values in Tables 4.1.a - 4.1.b change when $\underline{a} = 0$; the qualitative results remain unchanged. It can be shown that the values corresponding to Tables 4.1.a - 4.1.b always are larger when $\underline{a} = 0$.

Table 4.1.b. Restrictions on the …xed cost for a central bank with $¼_{t¡1}^{CB} = \bar{¼}$.

Row	Signalling strategy	Value of q	Current In‡ation Target	
			$¼_t^{CB} = \underline{¼}$	$¼_t^{CB} = \bar{¼}$
1.	Always signal	Á	$f \cdot \pm_3^3 Á^2 + 1 \frac{\pm°}{2} ¡ (1 ¡ Á) y^¤$	$f < 0$
2.	Never signal	Á	$f ¸ \pm_3^3 Á^2 + 1 \frac{\pm°}{2} ¡ (1 ¡ Á) y^¤$	$f ¸ 0$
3.	Don't signal if $¼_t^{CB} = ¼_{t¡1}^{CB}$, Signal if $¼_t^{CB} 6= ¼_{t¡1}^{CB}$	1	$f \cdot \pm^{2°}$	$f ¸ 0$
4.	Signal if $¼_t^{CB} = ¼_{t¡1}^{CB}$, Don't signal if $¼_t^{CB} 6= ¼_{t¡1}^{CB}$	0	$f ¸ 0$	$f \cdot 0$

Notes: The central bank will play the proposed equilibrium strategy for values of the …xed cost, f, thatsatisfy the constraints in the table. The constants are de…ned as $\pm = ®(\bar{¼} ¡ \underline{¼})$ and $° = \frac{1}{1+®^2}$.

which the central bank always signals. Moreover, that the strategies that involve signalling when the current in‡ation target is high are not equilibria follows from row 3 of Table 4.1.a and row 4 of Table 4.1.b. Again, for these strategies to be equilibria a central bank whose current in‡ation target is high requires a negative …xed cost to play them.

That the strategy to never signal is an equilibrium for a central bank with $¼_{t¡1}^{CB} = \underline{¼}$ follows from row 2 of Table 4.1.a. For values of the …xed cost that satisfy $f ¸ \pm_3^3 (1 ¡ Á)^2 + 1 \frac{\pm°}{2} ¡ y^¤Á$ such a central bank prefers not to signal independently of the current realization of the target. Thus, the private sector rationally believes that the probability that the target has remained unchanged is Á, which is consistent with Bayes' rule. The same argument applies for a central bank whose target in the preceding period was high. From row 2 of Table 4.1.b it follows that never signal is an equilibrium for such a bank for …xed costs $f ¸ \pm_3^3 Á^2 + 1 \frac{\pm°}{2} ¡ (1 ¡ Á) y^¤$.

That the strategies that involve signalling when the current realization of the in‡ation target is low are equilibria follows from row 4 of Table 4.1.a and row 3 of Table 4.1.b., respectively. These strategies are equilibria for …xed costs $0 \cdot f \cdot \pm^{2°}$, where the private sector rationally believes that no signal implies that the current realization of the target is high, which is consistent with Bayes' rule. ■

The intuition for why the strategies that involve signalling if the current target is high but not if it is low are not equilibrium strategies is the following. A central bank whose current

in‡ation target is high will be perceived as a central bank with a high target independent of whether it signals. Thus, it will not pay a …xed cost when the current target is high to resolve an informational asymmetry which also would be resolved by not signalling.

Proposition 4.2 thus establishes the result that any equilibrium that involves signalling implies that only central banks whose current in‡ation target is low undertake signalling. Thus, the …rst prediction from this model is that only central banks with ambitious objectives engage in signalling.

Moreover, it is interesting to note that there is a possibility of multiple equilibria. If the …xed cost is larger than $\pm^2 \circ$, the unique equilibrium is to never signal. However, for smaller values of f both equilibria may exist at the same time. This is most easily seen by noting that for y¤ su¢ciently large the strategy to never signal is always an equilibrium, and for $f \cdot \pm^2 \circ$ the strategy that involves signalling if the current target is low is also an equilibrium. Thus, whenever the two equilibria coexist, the traditional coordination problem applies; that is, how do the central bank and the private sector know which equilibrium strategy to play? It seems reasonable that history and reputation may play an important role as such a coordination device.

It it also interesting to see how these equilibrium strategies are a¤ected by changes in the parameters. Of particular interest are changes in $\pi - \underline{\pi}$ and Á, since they both relate to the central bank's private information and thus the news the central bank has to reveal. De…ne the frequency of signalling as being the number of equilibria that involve signalling divided by the total number of equilibria. Then, the results regarding the frequency of signalling are given in Proposition 4.3.

Proposition 4.3. The frequency of signalling has the following characteristics.

1. It is non-decreasing in $\pi - \underline{\pi}$.
2. It is non-increasing in Á for a central bank with $\pi^{CB}_{t-1} = \underline{\pi}$ and non-decreasing in Á for a central bank with $\pi^{CB}_{t-1} = \pi$.

Proof. Part (1) of this proposition follows from studying the restrictions on the …xed costs from Tables 4.1.a - 4.1.b. Each of the relevant restrictions satisfy $\frac{\partial f}{\partial(\pi - \underline{\pi})} > 0$: Thus, for each type the strategy to never signal may no longer remain an equilibrium strategy as $\pi - \underline{\pi}$ increases, whereas it will remain an equilibrium strategy as $\pi - \underline{\pi}$ decreases. Similarly, strategies that involve signalling when the current in‡ation target is low will always remain equilibrium strategies as $\pi - \underline{\pi}$ increases, whereas they may no longer be equilibrium strategies as $\pi - \underline{\pi}$ decreases.

Part (2) follows in a similar way. Neither of the strategies that involve signalling when the current in‡ation target is low are a¤ected by changes in Á. For a central bank with $¼^{CB}_{t¡1} = \underline{¼}$, the strategy to never signal will always remain an equilibrium as Á increases, whereas it may no longer be an equilibrium as Á decreases. This follows from di¤erentiating the relevant restriction on the …xed cost with respect to Á and noting that it satis…es $\frac{@f}{@Á} < 0$. However, for a central bank with $¼^{CB}_{t¡1} = ¼^{¤}$ the opposite holds true since the relevant constraint satis…es $\frac{@f}{@Á} > 0$: ■

The following corollary is useful in understanding the results from Proposition 4.3.

Corollary 4.4. The frequency of signalling is non-decreasing in the magnitude of the central bank's news.

Proof. An increase in $¼^{¤} ¡ \underline{¼}$ represents an increase in the central bank's news for both types of central banks, and thus, by Part (1) of Proposition 4.3, the frequency of signalling is non-decreasing in any news that stems from an increase in $¼^{¤} ¡ \underline{¼}$. Moreover, a decrease in Á for a central bank with $¼^{CB}_{t¡1} = \underline{¼}$ implies that the central bank's news is larger, since whenever the preferences do remain unchanged this would be less expected from the private sector's point of view. On the other hand, a decrease in Á for a central bank with $¼^{CB}_{t¡1} = ¼^{¤}$ implies that the central bank's news instead is smaller, since if the target actually switches this would be less of a surprise to the private sector. Thus, by Part (2) of Proposition 4.3, the frequency of signalling is also non-decreasing in any news that stems from a change in Á. ■

That the frequency of signalling is non-decreasing in the news the central bank has to reveal also relates to the result from Stein [14]. It was earlier argued that the signal itself may be more precise the larger the central bank's news. Moreover, Corollary 4.4 shows that the larger the news the central bank has to reveal, the more frequently we expect to see the announcements. However, that the frequency of signalling is increasing in the central bank's news con…rms the results in Guthrie and Wright [7] and seems more in line with the examples of announcements from Sweden and Canada given in the Introduction.

5 Conclusions

This paper tries to explain why central banks sometimes, but not always, announce their objectives or intentions to the private sector. The paper uses a model that closely resembles the model in Kydland and Prescott [9] and Barro and Gordon [2], but it introduces an uncertainty over the central bank's preferences. This uncertainty is represented by a stochastic in‡ation

target, upon which only the central bank can condition its actions. Thus, announcements can be seen as another example of signalling, but the signalling device is no longer the same as the central bank's policy instrument. However, for signalling to a¤ect the private sector's beliefs it must be perceived as costly for a central bank to use such announcements. This cost is modelled as two distinct parts, a …xed cost and a variable cost. The …xed cost may represent for example the actual cost of holding a press conference, giving public speeches, or incorporating the announcement in an in‡ation report. The variable cost captures two things, a loss of ‡exibility and a reputational e¤ect. The loss of ‡exibility arises because the central bank commits to bringing the actual in‡ation in line with the announcement if the announcement itself does not achieve this. The loss of reputation arises when the central bank announces something that can be proved incorrect ex post, since any future announcement will be disregarded by the private sector.

Within this framework the paper …rst derives how large the variable part of the signalling cost must be to a¤ect the private sector's beliefs. It is shown that the e¤ect of an increase in the uncertainty over the central bank's objectives has ambiguous e¤ects on the size of the signalling cost. It seems natural that a more precise announcement would be perceived as more costly to the central bank and thus, counter to what a cheap-talk equilibria suggests, that the signal may be more precise the larger the central bank's news.

Signalling is assumed to be discretionary, and this paper studies if and when a central bank will make announcements. It is shown that weak central banks will never make announcements whereas tough central banks sometimes, but not always, will resolve the informational asymmetry through an announcement. There are multiple equilibria in this model, some of which involve no signalling and some of which involve signalling from a tough central bank. The paper studies what happens to these equilibria as the central bank's private information increases and shows that the more news the central bank has to reveal the more frequently they will use the announcements. This result goes well in line with the examples of announcements in the introduction to this paper where both the Swedish Riksbank and Bank of Canada announced their targets at the early stage of in‡ation targeting, when the uncertainty over their objectives was large.

The paper assumes that the private sector always believes that the signal is perceived as costly to the central bank because the central bank commits to bringing the in‡ation rate in line with the announcement if the announcement itself does not achieve this. Thus, the mechanism

that prevents a central bank with a high in‡ation target from mimicking a central bank with a low in‡ation target is this commitment, which implies that all announcements are perfectly credible in this model. However, in real life all announcements are not credible, which may stem from the lack of such a commitment. Hence, it would be interesting to analyze the e¤ects of announcements in a model where the central bank itself also can choose whether to bring the in‡ation rate in line with the announcement if the announcement itself does not get the in‡ation rate aligned. This would give a better microfoundation for what a signalling cost represents and would help us understand why some signals a¤ect the private sector's expectations whereas others don't. However, most of the qualitative results from this paper will probably be valid in such a model as well.

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