

# Inflation Targeting: A Framework for Communication\*

Maria Demertzis<sup>†</sup>

De Nederlandsche Bank and University of Amsterdam

Nicola Viegi<sup>‡</sup>

University of Cape Town and ERSA

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## Abstract

We analyze how the provision of an explicit numerical inflation target provides a focal point for agents' expectations, when information is imperfect. Communicating a target and a tolerance band around it provides a clear framework with which to evaluate monetary policy outcomes. We show how inflation targeting exploits the self-reinforcing loop between success and credibility, to help the Central Bank endure large and long-lasting shocks. Last, we derive the optimal band width around the target, that exploits the benefits of providing a focal point, while maximizing the probability of success.

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<sup>†</sup>Corresponding author: m.demertzis@dnb.nl, Research Department, De Nederlandsche Bank, P.O. Box 98, 1000 AB, Amsterdam, the Netherlands, tel: +31 (20) 524 2016, fax: +31 (20) 524 2506, [http://home.hetnet.nl/~m\\_demertzis/index.html](http://home.hetnet.nl/~m_demertzis/index.html).

<sup>‡</sup>nicola.viegi@uct.ac.za, School of Economics, University of Cape Town, Private Bag, Rondebosch, 7700, Cape Town, South Africa, tel: +27 (21) 650 2763, fax: +27 (21) 650 2854.

# 1 Introduction

It is often argued that the two distinct features of inflation targeting (IT) are the provision of an anchor for expectations, and a transparent set of criteria with which to evaluate Central Banks (King 2002). In this paper, we depart from a set-up of full information and concentrate on how inflation targeting operates as a communication framework in a world of imperfect information. Demertzis and Viegli (2008) show that, when information available to agents is imperfect, the provision of a clear signal, even if partial, can potentially provide a focal point at which agents coordinate. In this paper we extend their static set-up into a repeated game and address the second feature mentioned above, namely how inflation targeting provides a clear framework for assessing monetary policy. In doing that we model two important mechanisms. The first is the inter-temporal, self-reinforcing loop between credibility and success, which implies that credible Central Banks (CBs) are more successful, and successful Central Banks are easier credible. The second is modelling the choice of band-width around the announced target, in a way that captures the trade-off between providing a clear signal on the one hand (narrow bands), but wishing to be successful (wide bands), on the other. Allowing for these two mechanisms, we can then discuss the circumstances in which announcing an inflation target can be an effective communication framework.

The key assumption that drives these results is that, in an environment characterized by imperfect information, policy communication is relevant for controlling private sector expectations. In turn, modern monetary policy has emphasized that maintaining a stable monetary environment depends crucially on the ability of the policy regime to control inflation expectations (Blinder et al, 2001, Woodford, 2003). Evidence of that is shown by Paloviita and Virén (2005) for inflation in the euro area and by Orphanides and Williams (2005) in their analysis of US monetary policy history. The latter argue that monetary policy failures are connected with changes in public sentiment about the future state of the economy. In other words, policy mistakes alone are not enough to produce long-term negative effects on monetary stability. Expectations will also have to deviate from long term objectives for these effects to materialize. As a means of preventing such expectations deviations, policy makers develop communication strategies that aim explicitly to align expectations with their own policy objectives. The provision of an explicit numerical inflation target is one such example of a communication strategy, the main advantage of which is arguably its ability to provide a focal point for expectations. Empirical evidence appears to confirm that explicit quantitative targets for inflation succeed in that capacity.<sup>1</sup> Central Bankers themselves emphasize the link between the two in their own evalua-

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<sup>1</sup>As shown by Mishkin and Schmidt-Hebbel (2001, 2007), Johnson (2002) and more recently by Levin *et al* (2004), Fatás et al (2007) and Gürkaynak et al (2006) and Walsh (2008) provides a recent review. See also Leiderman and Svensson (1995) and Bernanke et al (1999) for earlier accounts of experiences with inflation targeting. Also, without looking at expectations, Benati (2008) shows how the communication of an explicit numerical target has reduced inflation persistence in a number of countries.

tions of their respective monetary policies. Mervyn King claimed in 2002, (p.4) that for the UK case, inflation expectations had indeed been anchored to the pre-announced target. Similarly Issing et al (2005) emphasized the importance of announcing a clear inflation objective for helping coordinate expectations.

However, clear and precise communication is not enough for achieving stable and ‘on target’ expectations. We argue that communication of the central bank is always evaluated in the context of credibility. In the absence of sufficient credibility, any announcement can be discarded by the private sector, thus hindering the central bank’s ability to achieve the desired policy objective. A credible central bank is on the other hand, more likely to be successful. However, it is also true that a central bank that has been demonstrably successful, sees its credibility increase. What this implies is that credibility and ‘success’ feed into each other in a self-reinforcing loop. In this paper we look at a repeated game in which, given an initial level of credibility, ‘successful’ monetary policy increases credibility and higher credibility achieves success easier. We argue that the dynamic nature of this loop is what provides an inter-temporal link, crucial to the decisions Central Banks make (as they try to build up reputation), and is an essential component of modelling monetary policy in practice.<sup>2</sup> The advantage of modelling monetary policy as an information game is that it provides an explicit measure for ‘sufficient’ credibility. At the same time, announcing an inflation target and a tolerance band around it provides a very clear measure of success. We will show how communicating a target exploits favorable circumstances better in terms of building up credibility, that will then increase a Central Bank’s ability to withstand shocks when unfavorable conditions arise. This is the main contribution of our paper.

Last, we examine the relevance of the width of the tolerance band, when defining monetary policy ‘success’. Using a Bayesian updating mechanism, the direction in which credibility changes is determined by past inflation performance. As success helps acquire credibility, there is a natural tendency to overestimate the size of the bands in order to increase one’s success record. However, it is also the case that wide bands are discounted as unclear signals that show no confidence in achieving pre-defined objectives. Our methodology will capture this trade-off and thus identify the optimal band-width as a function of the actual economic environment.

The paper is organized as follows. Section 2 briefly describes the static framework from Demertzis and Viegli (2008), where monetary policy is modelled as an information game and shows how the provision of an inflation target may provide a focal point for expectations. Section 3 then introduces the repeated game and links credibility to success inter-temporally. We thus derive how credibility improves or worsens depending on previous period’s inflation performance. Section 4 describes the results of Monte-Carlo simulations to generalize the circumstances in which communicating an inflation target provides the greatest

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<sup>2</sup>See for example Blinder, (2000), Moscarini, (2007), Blackburn and Christensen, (1989) and Bomfim and Rudebusch, (2000).

gains in credibility and inflation performance. Section 5 then explores which band-width is required for the inflation target to be part of an effective communication strategy and how it varies with different assumed parameterizations. Section 6 offers a brief discussion of our results and concludes.

## 2 Monetary Policy as an Information Game

We model monetary policy as an information game and examine how individuals go about interpreting the information that is available to them when forming expectation. For simplicity reasons we assume a standard set-up in which the Central Bank chooses the rate of inflation  $\pi$  to minimize the distance from the inflation objective set  $\pi^T$  and close the output gap  $y$ ,

$$L_{CB}|\xi = \frac{1}{2} \mathbb{E} \left[ (\pi - \pi^T)^2 + y^2 \right], \quad (1)$$

subject to a standard Lucas supply function,  $y = \pi - \pi^e + \xi$  where  $\xi$  is a supply shock with zero mean and constant variance,  $\sigma_\xi^2$ . Note that any Central Bank will have an objective  $\pi^T$  irrespective of whether it communicates it to the public clearly, or even at all. We assume for simplification that the CB's instrument is  $\pi$ . Optimization of (1) implies that

$$\pi|\xi = \frac{\pi^T}{2} + \frac{\pi^e}{2} - \frac{\xi}{2}, \quad (2)$$

where  $\pi$  is now the *ex post* inflation outcome conditional on the shock  $\xi$  and  $\pi^e$  is private sector expectations about the relevant rate of inflation. Representation (2) is of a structural form,<sup>3</sup> in the sense that expectations are not replaced (Leitemo, 2006). Svensson (2003) argues in favour of such a representation in order to indicate that factors like judgement that contribute to the way expectations are formed but cannot always be modelled, are an important contributor to monetary policy. In a typical full information commitment game, where the Central Bank communicates its target  $\pi^T$  and commits to it, expectations formed by all individuals collectively are equal to the CB's objectives,  $\pi^e = \pi^T$ , and the ex post outcome is

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<sup>3</sup>Note that (2) is specific to the underlying Lucas supply function assumed but demonstrates that the outcome is a function of both the policy the Central Bank pursues, as well as what the private sector anticipates. For the standard Neo-Keynesian model based on Clarida Gali and Getler (1999),

$$\begin{aligned} \pi_t &= \beta E_t \pi_{t+1} + k y_t + \varepsilon_t \\ y_t &= E_t y_{t+1} - \gamma (i_t - E_t \pi_{t+1}) + \eta_t \end{aligned}$$

the structural representation of the *ex post* inflation outcome is:

$$\pi_t = \frac{k^2}{1+k^2} \pi^T + \frac{1}{1+k^2} E_t \pi_{t+1} + \frac{\varepsilon_t}{1+k^2}.$$

Our point is to show that the *ex post* outcome is a function of both the CB objective as well as the expectations of the private sector (and naturally the shocks).

$$\pi|\xi = \pi^T - \frac{\xi}{2} \quad (3)$$

$$\mathbb{E}(\pi) = \pi^T. \quad (4)$$

Modeling monetary policy as an information game implies a departure from the assumption of full information and analyses instead how individuals go about interpreting the information that is available to them when forming expectations. Every individual  $i$  will be forming an expectation of inflation  $\pi_i$ , such that the collective outcome (for a continuum of agents) is  $\pi^e = \int_0^1 \pi_j dj$ , which is the expectation that is relevant to *ex post* inflation. The timing of the game assumed has the Central Bank deciding what its objectives are first, shocks occur next, then private agents form expectations based on information available about these shocks and the policy objectives, and finally the CB sets the policy instrument accordingly.

We thus start by assuming that typically, individuals form expectations based on two information sets, namely what is publicly available and therefore common to everyone, and what is available to them privately. Furthermore, every individual is aware of the fact that the *ex post* outcome of inflation  $\pi$  will be determined by (2), in other words will be affected by the policy the Central Bank pursues to attain its objectives, as well as the average of expectations formed by the public and last the shock that occurs.<sup>4</sup> However, as the individual is interested in predicting the *ex post* level of inflation correctly, Canzoneri (1985), (on which, for example, to base his wage negotiations), he needs to interpret all components of (2) based on the information he has. His objective is captured by a standard expected dis-utility:

$$u_i(\pi) \equiv \frac{1}{2} \mathbb{E}_i(\pi_i - \pi)^2. \quad (5)$$

Note that subscript  $i$  in the expectations operator indicates that the individual will be seeking to minimize his expected dis-utility, given his own perceptions.<sup>5</sup> Variable  $\pi_i$  is individual  $i$ 's expectation of what inflation will be at the relevant

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<sup>4</sup>Note that the assumption that the Bank operates under full information is not critical in our analysis. The shock  $\xi$  can be interpreted as a combination of supply shock and information imperfection affecting bank policy and outcomes.

<sup>5</sup>The individual's objective function (5) only includes that part that is under his direct control, namely his forecast of inflation in relation to the inflation outcome. This is not in contradiction with having social preferences like in (1). It simply indicates that the individual can only try to minimize the distance from the average using the instrument at his disposal, like in Lucas (1972). In Appendix A we discuss the relation between the two. Also, the loss function (5) is a simple way of introducing strategic complementarity in agents' payoff functions, as defined by Cooper and John (1988), and applied to monetary policy by King and Wolman (2004). In our set-up, the strategic complementarity is given by both the fact that the state of the economy is a function of other agents' expectations, as well as the fact that agents have heterogeneous beliefs. Thus, in trying to minimize their forecast error in (5), agents have to forecast others' forecasts as well, as shown in (6).

horizon and  $\pi$  is again the *ex post* inflation outcome. The individual decides his action  $\pi_i$  based on the first-order condition of (5), i.e.:

$$\arg \min_{\pi_i} u_i(\pi) = \mathbb{E}_i(\pi),$$

and from (2),

$$\begin{aligned} \pi_i &= \mathbb{E}_i(\pi) \\ \pi_i &= \mathbb{E}_i\left(\frac{\pi^T}{2} + \frac{\pi^e}{2} - \frac{\xi}{2}\right) \\ \pi_i &= \frac{1}{2}\mathbb{E}_i(\pi^T - \xi) + \frac{1}{2}\mathbb{E}_i(\pi^e). \end{aligned} \quad (6)$$

The optimal action for individual  $i$  in (6) is thus a function of three things: the objectives of the Central Bank and hence the policy it will pursue, the shock that will have occurred and finally the average expectation formed by all individuals. Moreover, in forming expectations  $\pi_i$ , individual  $i$  needs to evaluate these three things, captured here by the expectations operator, subscript  $i$ . It follows that if  $\pi_i = \pi_j \forall j$ , then  $\pi_i = \pi^e$  and individuals' expectations are matched. However, although desirable, coordination between agents at any level of inflation is not sufficient; the optimal outcome occurs when agents coordinate at the objective pursued by the Central Bank,  $\pi^T$ . Coordination at any other expectation rate still leaves agents away from the level of inflation that the CB aims to achieve. We will argue further down that knowledge of the CB objective is necessary but not sufficient for coordination at it. Following Morris and Shin (2002), we argue that information used by the agents is available in the form of a public signal common to all and a private signal, which is specific to each agent in the economy. Individuals therefore, observe  $p$  and  $z_i$  where,

$$\text{Public signal: } p = (\pi^T - \xi) + \eta \quad (7)$$

$$\text{Private signal: } z_i = (\pi^T - \xi) + \varepsilon_i. \quad (8)$$

The noise terms,  $\eta$  and  $\varepsilon_i$ , are assumed to have a zero mean and variance  $\sigma_\eta^2$  and  $\sigma_\varepsilon^2$ , respectively. Furthermore, the two terms are independent of  $\pi$  and of each other, and  $\mathbb{E}(\varepsilon_i \varepsilon_j) = 0$  for  $i \neq j$ . The clarity of public information is not under the full control of the CB but is affected by a combination of the CB's information strategy, the general market information available and noise. Based on these two types of signals, Morris and Shin (2002) show that agent  $i$ 's action (inflation expectation) then is

$$\begin{aligned} \pi_i &= \frac{2\alpha p + \beta z_i}{2\alpha + \beta} \\ &= \pi^T - \xi + \frac{2\alpha\eta + \beta\varepsilon_i}{2\alpha + \beta}, \end{aligned} \quad (9)$$

where  $\alpha = \frac{1}{\sigma_\eta^2}$  and  $\beta = \frac{1}{\sigma_\xi^2}$ , is the level of precision for the two information sets respectively.

**Definition 1:** We call (9) the ‘MS action’.

We assume homogenous agents and calculate expectations across all agents as follows:

$$\pi^e = \int_0^1 \pi_j dj = \pi^T - \xi + \frac{2\alpha\eta}{2\alpha + \beta}. \quad (10)$$

Equation (10) shows that the average expectation across all agents will be distorted by the (lack of) precision of the two signals, and naturally the underlying model assumed.

## 2.1 Inflation Targets as Focal Points

Our interpretation of a central bank announcing its objective  $\pi^T$  is that the individual effectively receives an extra signal in addition to (7) and (8), i.e.:

$$\text{Central Bank signal: } h = \pi^T. \quad (11)$$

Our interpretation of inflation targeting implies that the individual is now effectively faced with an option to either apply (9), in which case information would now relate to the shock  $\xi$ , or form expectations according to the target. In other words, the ‘action’ the individual takes is either  $a_i = \pi_i$  or  $a_i = \pi^T$  and the ‘average’ action is respectively  $\bar{a} = \pi^e$  or  $\bar{a} = \pi^T$ . The very provision of an inflation target therefore increases the number of options available to the individual and thus the number of potential outcomes. We argue that this is an interesting option for the individual because it overcomes the problem of having to guess what information everyone uses when forming expectations.<sup>6</sup> This is very much in accordance with the Morris and Shin (2002) argument, according to which public information receives a greater weight in people’s action than is justified by its quality. However, the gain of bypassing information imperfections comes at the cost of getting only partial information ( $\pi^T$ ) about the relevant set ( $\pi$ ). The real trade-off therefore faced by the individual is *less information for better precision*. If the individual is confident that everybody else will follow the target when forming expectations, then it is to his advantage to do so as well. The information game shows that when shocks are relatively small, it is always better to follow the target. When shocks on the other hand, are not necessarily small, then it is the level of credibility of the target that will provide (or not) the individual with such confidence. We show this next.

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<sup>6</sup>Note that the individual has just two options: either he uses his whole information set efficiently, or he ignores it (under certain conditions to be described) in order to exploit the possibility of coordinating at a ‘focal point’, in full. There is no sense in which the individual would choose to only partially ignore his information, as that would both make sub-optimal use of the information he has, as well as reduce the potential benefits of salience.

The individual ranks his options by assessing how they impact his utility (5), given the aggregate expectation. This leads to effectively four potential outcomes summarized in Table 1:

Table 1: Individual  $i$ 's dis-utility in Normal Form

$a_i \setminus \bar{a}$	$\pi^e$	$\pi^T$
$\pi_i$	$\frac{\alpha+\beta}{(2\alpha+\beta)^2}$	$\frac{1}{4}\sigma_\xi^2 + \frac{4\alpha+\beta}{(2\alpha+\beta)^2}$
$\pi^T$	$\sigma_\xi^2 + \frac{\alpha}{(2\alpha+\beta)^2}$	$\frac{1}{4}\sigma_\xi^2$

For any given level of information precision, adopting the inflation target  $\pi^T$  becomes a dominant strategy for individual  $i$ , if the variance of the supply shock is below a given threshold,  $\sigma_\xi^2 < \frac{\beta}{(2\alpha+\beta)^2}$ . However, if shocks are relatively large i.e.  $\sigma_\xi^2 \geq \frac{\beta}{(2\alpha+\beta)^2}$ , then individual  $i$ 's optimal response in pure-form strategies requires ‘*matching*’ the average action. In other words,  $a_i = \pi_i$  is the best response to  $\bar{a} = \pi^e$ , and  $a_i = \pi^T$  is the best response to  $\bar{a} = \pi^T$ . It is in this sense that the individual has an incentive to coordinate with the average action. However, to do that, the variable that is going to be pivotal to his decision is the extent to which the Central Bank is credible. This, we believe, is an important component in describing applied monetary policy, as simply announcing an inflation target is neither necessary nor sufficient for tying down expectations. A sufficiently credible, in the eyes of the individual, Central Bank will induce him to opt for  $\pi^T$ . Otherwise, the individual will resort to forming expectations based on all the information that he has,  $\pi_i$ . To choose between the two, the individual asks the following question: “What is the maximum loss that I would incur if I was to ignore all my information,  $p$  and  $z_i$ , and simply followed the salient rate, namely the inflation target?” To answer this question, any information about the shock (variance) is useful to him. If he believes that the central bank is *sufficiently* credible, implying that others would tend to follow the target, he matches it by following the target as well. Otherwise he follows the MS action in which information is used optimally.

But how does this framework determine what *sufficiently* credible mean?

**Definition 2:** Let variable  $v \in [0, 1]$ , denote the degree of the inflation target’s credibility.

This framework relies on Bacharach’s (1993) *Variable Universe Games* contribution on focal points. Appendix B explains in detail how credibility enters the individual’s choice-space in the context of Table 1, and how he would go about deciding between the two actions. The necessary and sufficient condition for credibility, above which agents individually (and collectively, given homogenous agents) would follow the target is:

$$v \geq \frac{(2\alpha + \beta)^2 \sigma_\xi^2 - \beta}{4\alpha + (2\alpha + \beta)^2 \sigma_\xi^2}. \quad (12)$$

Or in other words, (12) shows that the sufficient condition for individual  $i$  to follow the target is when the target's credibility is greater than a minimum level determined by the economic environment. Based on this, individual  $i$  then forms expectations as follows:

$$a_i(\text{and } \bar{a}) = \begin{cases} \pi_i(\text{and } \pi^e) & \text{if } v < \frac{(2\alpha+\beta)^2\sigma_\xi^2-\beta}{4\alpha+(2\alpha+\beta)^2\sigma_\xi^2} \\ \pi^T & \text{if } v \geq \frac{(2\alpha+\beta)^2\sigma_\xi^2-\beta}{4\alpha+(2\alpha+\beta)^2\sigma_\xi^2}. \end{cases}$$

Note that the condition for credibility  $v$  depends on the variability of the shocks, and the precision of the two signals. It does not however depend on the draws of any of the three shocks, - supply, public and private information, at any given period. This is the case because the agent evaluates the Central Bank in knowledge of the distribution properties of the three noise terms, but observes their realizations only imperfectly. The inflation outcome, on the other hand, depends also on the actual supply shock drawn, and if expectations are formed according to the MS action, also on the (public) information shock observed every period.

The information game so far describes the role of credibility in a static framework. Our contribution here is to extend this to a repeated framework by adding two features that mimic, in our view, actual monetary policy. First, we add an endogenous mechanism for updating credibility, such that successful central banks benefit from an increase in credibility, whereas unsuccessful central banks suffer a drop in credibility. At the same time, an increase in credibility implies that (12) is easier satisfied and therefore, with expectations tied to the target, success is also more likely. The opposite effect is achieved by reductions in credibility. Thus we explicitly model the credibility-success loop in a repeated set-up. Second, we show how loose definitions of success come at the cost of clarity in the signal central banks provide. The existence of such a trade-off implies that there exists an optimal band-width, which reaps the benefits of communication, while maximizing the likelihood of being successful in full. We will see how the optimal band-width is affected by economic conditions.

### 3 Evaluating Monetary Policy

We examine next how this target helps the Central Bank gain credibility. The main assumption behind what follows is that credibility is solely determined by a Central Bank's previous performance, or in other words, by how well it has managed to achieve its objectives in the past (Blackburn and Christensen, 1989). However, 'success' itself is in turn affected by two things: the ability to tie down expectations to its target (credibility), but also the size of the supply shocks. Observing then the Central Bank's track record, agents update their beliefs about its abilities and accordingly affect the inflation outcome in the next period. There is therefore an inter-temporal loop between success

and credibility, which is reinforcing in both directions and is essential to the monetary policy outcome.

This approach is very similar, in spirit, to that of Bomfin and Rudebusch (2000) with two important differences. First, expectations in our case are discrete, in that the switch between the two ‘expectations states’ depends on how current credibility compares to the critical condition in (12). Bomfin and Rudebusch (2000) instead have expectations being formed in a continuous manner, depending partially on the target and its credibility (which is also updated given past success) and partially on past performance. The discrete switching applied here is the direct result of the individuals’ incentive to coordinate, which induces them to look for opportunities to converge to focal points. Second, our updating mechanism is also slightly different to that of Bomfin and Rudebusch (2000), in that the individual rewards a successful Central Bank in terms of increasing the level of trust he puts in it, but he also penalizes an unsuccessful Central Bank by reducing credibility. The game is organized in such a way that at a given period, the Central Bank operates with a given ‘stock’ of credibility, very much in the Barro-Gordon (1983) sense. This implies that within that period, the Central Bank can no longer affect its credibility. This is a necessary feature in our view, in order to capture the fact that credibility is intrinsically the result of past performance only. At any given point in time when the Central Bank takes a decision, it reckons with the fact that it has to operate within the confines of its own reputation. However, today’s actions will affect next period’s reputation, the Central Bank’s credibility and ultimately also its ability to be successful thereafter. With the help of numerical simulations we will show, in the next section, how the Central Bank’s success rate increases with the provision of a numerical target and under which conditions. We find the following: it is easier to build up credibility when the economic environment is stable, or put the other way around, it is a lot more difficult to improve reputation when economic circumstances are unfavorable. Within a given set of economic circumstances however, when the CB is credible (i.e. expectations are tied down to the inflation objective), its ability to achieve that objective is enhanced. Irrespective of circumstances, if reputation is linked to performance and performance is linked to exogenous shocks, reputation and credibility can be gained but can also be lost from one period to the next. This emphasizes their ephemeral nature and the importance of capitalizing on favorable circumstances in order to build up credibility that will help withstand unfavorable ones (Goodfriend, 2007). We explain how this updating occurs next.

### 3.1 Credibility Gained, Credibility Lost

We define first the terms ‘success’ and ‘credibility’ in monetary policy.

Let variable  $S \in \{s, \bar{s}\}$  denote whether the Central Bank is successful or unsuccessful and  $\Pr(S = s)$  the probability of a Central Bank being successful. We define  $\rho$  as the radius of tolerance around the target.

**Definition 3:** A successful Central Bank ( $S = s$ ) is one for which  $|\pi_t - \pi^T| \leq \rho$  at a given  $t$ ; by implication an unsuccessful Central Bank ( $S = \bar{s}$ ) is one for which  $|\pi_t - \pi^T| > \rho$ .<sup>7</sup>

Definition 3 above implies that a Central Bank announces an inflation target,  $\pi^T$ , and a band around it,  $(2\rho)$ . It can easily be interpreted as the band-width around an inflation target, as used by most inflation targeting Central Banks in practice. Naturally, as appearing to be successful is of importance to the Central Bank, one could use the band-width strategically to maximize success. However, there is an important trade-off between providing a focal point (narrow band) and being successful (wide band) that leads to the existence of an optimal width. We will discuss this in section 6.

Let variable  $C \in \{c, \bar{c}\}$  denote whether the Central Bank (and therefore its target) is credible or not. From definition 2 above,  $v \equiv \Pr(C = c)$ .

**Definition 4:** A credible Central Bank ( $C = c$ ) is one for which  $\bar{a} = \pi^T$ ; a non-credible Central Bank ( $C = \bar{c}$ ) is one for which  $\bar{a} = \pi^e$ .

Agents form views about the Central Bank's credibility  $v$  based on past period's performance. For any period  $t$ , the timing of the game is as follows:

$$v_{t-1} | \pi_{t-1} \rightarrow \xi_t \rightarrow \bar{a}_t = \begin{cases} \pi^e & \text{if } v_{t-1} < \frac{(2\alpha+\beta)^2 \sigma_\xi^2 - \beta}{4\alpha + (2\alpha+\beta)^2 \sigma_\xi^2} \\ \pi^T & \text{if } v_{t-1} \geq \frac{(2\alpha+\beta)^2 \sigma_\xi^2 - \beta}{4\alpha + (2\alpha+\beta)^2 \sigma_\xi^2} \end{cases} \rightarrow \pi |_{\xi_t, \bar{a}_t} \rightarrow \pi_t \rightarrow v_t.$$

The Central Bank begins with a certain level of credibility  $v_{t-1}$ , which is common knowledge. Let  $v'_t \equiv \frac{dv}{dt}$ ; the private sector observes inflation outcome  $\pi_t$  and updates its confidence at the Bank based on Bayes' rule:

$$\text{If } S_t = s \text{ then } v'_t > 0 : \Pr(c|s) = \frac{\Pr(s|c)}{\Pr(s)} \Pr(c)$$

$$\text{If } S_t = \bar{s} \text{ then } v'_t < 0 : \Pr(c|\bar{s}) = \frac{\Pr(\bar{s}|c)}{\Pr(\bar{s})} \Pr(c).$$

**Corollary 1** An implication of this updating is that as success increases credibility  $v$ , it will be easier to satisfy (12) in the next period and therefore tie down expectations. The opposite is also true; if monetary policy is unsuccessful, then it becomes increasingly more difficult to succeed in the period after that.

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<sup>7</sup>'Success' is identified here with meeting one's objectives. Note that as a Central Bank's objectives are chosen based on some societal welfare criteria, a successful central bank is beneficial to society.

Given the new level of credibility  $v_t$ , the sequence of events at period  $t + 1$  is identical to above, i.e.:

$$v_t | \pi_t \rightarrow \xi_{t+1} \rightarrow \bar{a}_{t+1} = \{ \dots \rightarrow \pi |_{\xi_{t+1}, \bar{a}_{t+1}} \rightarrow \pi_{t+1} \rightarrow v_{t+1} \rightarrow \dots,$$

the private sector evaluates the outcome and updates again.<sup>8</sup>

### 3.2 The Inflation Distribution

Based on (2), we derive the first and second moments of inflation, given expectations.

**First Moment:** the expected inflation outcome is always  $\pi^T$ , irrespective of how expectations are formed.

$$\mathbb{E}(\pi_t | \bar{a}) = \begin{cases} \mathbb{E}\left(\frac{\pi^T}{2} + \frac{\pi^T}{2} - \frac{\xi}{2}\right) = \pi^T & \text{for } \bar{a} : \pi^T \\ \mathbb{E}\left(\frac{\pi^T}{2} + \frac{\pi^e}{2} - \frac{\xi}{2}\right) = \pi^T & \text{for } \bar{a} : \pi^e = \pi^T - \xi + \frac{2\alpha\eta}{2\alpha+\beta} \end{cases}$$

**Second Moment:** The variance however is different, depending on how expectations are formed.<sup>9</sup>

$$\sigma^2(\pi_t | \bar{a}) = \begin{cases} \text{var}\left(\frac{\pi^T}{2} + \frac{\pi^T}{2} - \frac{\xi}{2}\right) = \frac{\sigma_\xi^2}{2^2} & \text{for } \bar{a} : \pi^T \\ \text{var}\left(\frac{\pi^T}{2} + \frac{\pi^e}{2} - \frac{\xi}{2}\right) = \frac{\sigma_\xi^2}{2} + \frac{\alpha}{(2\alpha+\beta)^2} & \text{for } \bar{a} : \pi^e = \pi^T - \xi + \frac{2\alpha\eta}{2\alpha+\beta} \end{cases}$$

It is straightforward to see that the variance of inflation is smaller if expectations are tied to the target  $\pi^T$ . We can now calculate the probabilities of success given a certain distribution for the shocks and assuming that inflation is normally distributed, i.e.  $\pi_t \rightarrow N[\pi^T, \sigma^2(\pi_t | \bar{a})]$ . The probability of success when  $\bar{a} = \pi^T$  - i.e.  $\text{Pr}(s|c)$  - is as follows:

$$\text{Pr}(\pi^T - \rho \leq \pi_t | \pi^T \leq \pi^T + \rho) = \text{Pr}\left(\frac{-\rho}{\frac{\sigma_\xi}{2}} \leq z_t \leq \frac{\rho}{\frac{\sigma_\xi}{2}}\right). \quad (13)$$

Naturally the probability of success when  $\bar{a} = \pi^e$  (i.e.  $\text{Pr}(s|\bar{c})$ ) is smaller (as the variance is larger):

<sup>8</sup>The credibility updating mechanism used here implies the (admittedly strong) assumption that the band-width matters because it defines policy success and failure in the eyes of the public. In an inflation targeting regime without any bands, the definition of policy success and failure becomes subjective, as is in any other policy regime. Our intention here is to show how policy communication, and the way it is designed, can affect private sector expectations formation, not how any particular policy communication and design affects it.

<sup>9</sup>Demertzis and Hughes Hallett (2007) observe a very similar result (theoretically as well as empirically), whereby greater degrees of transparency (and in this context inflation targeting is a more transparent regime) do not affect the level of inflation, but do affect its variability.

$$\Pr(\pi^T - \rho \leq \pi_t | \pi^e < \pi^T + \rho) = \Pr\left(\frac{-\rho}{\sqrt{\frac{\sigma_\xi^2}{2} + \frac{\alpha}{(2\alpha+\beta)^2}}} \leq z_t \leq \frac{\rho}{\sqrt{\frac{\sigma_\xi^2}{2} + \frac{\alpha}{(2\alpha+\beta)^2}}}\right). \quad (14)$$

### 3.3 A Numerical Example

Assume the following values for relevant parameters,<sup>10</sup> including initial credibility,  $v_0$ :

$$\pi^T = 2, \quad \rho = 0.5, \quad \sigma_\xi^2 = 2, \quad v_0 = 0.5, \quad \alpha = 4 \quad (\sigma_\eta^2 = 0.25), \quad \beta = 4 \quad (\sigma_\varepsilon^2 = 0.25)$$

Given the current value of  $\rho = 0.5$ , the Central Bank is successful if  $1.5 \leq \pi \leq 2.5$  in each period, with the mid-point being the target announced. Moreover, we assume that the distribution of inflation is  $\pi_t \rightarrow N[2, \sigma^2(\pi_t | \bar{\alpha})]$ , so that we can apply the standard normal tables for updating  $v$ . The Central Bank is assumed to start with credibility equal to 50 percent. The joint probability density function for the two variables  $C$  and  $S$  is shown in table 2:

Table 2: Credibility and Success

$\rho$			
	$s$	$\bar{s}$	$C :$
$c$	$\Pr(c \cap s)$	$\Pr(c \cap \bar{s})$	$\Pr(c) = v$
$\bar{c}$	$\Pr(\bar{c} \cap s)$	$\Pr(\bar{c} \cap \bar{s})$	$\Pr(\bar{c}) = 1 - v$
$S :$	$\Pr(s)$	$\Pr(\bar{s})$	1

From (13), (14) and the standard normal tables we now calculate the following:

$$\Pr(s|c) = \Pr(-0.71 \leq z \leq 0.71) = 0.5205$$

$$\Pr(s|\bar{c}) = \Pr(-0.49 \leq z \leq 0.49) = 0.3781.$$

Accordingly, we fill in the rest of the table:

Table 3: Credibility and Success

$\rho = 0.5$			
	$s$	$\bar{s}$	$C :$
$c$	0.26	0.24	0.5
$\bar{c}$	0.19	0.31	0.5
$S :$	0.45	0.55	1

<sup>10</sup>We will examine further down how alternative parameterizations of the shocks affect our mechanism.

Based now on Bayesian updating, we calculate the level of credibility for the next period, for a successful Central Bank:

$$\begin{aligned} v_1 &= \Pr(c|s) = \frac{\Pr(s|c)}{\Pr(s)} \Pr(c) \\ &= \frac{0.5205}{0.45} 0.5 = 0.58. \end{aligned}$$

We observe therefore, that the private sector will increase the level of confidence that it has about the Bank, from 0.5 to 0.57. If however, the Central Bank is unsuccessful, then it will be penalized in the sense that  $v$  will reduce:

$$\begin{aligned} v_1 &= \Pr(c|\bar{s}) = \frac{\Pr(\bar{s}|c)}{\Pr(\bar{s})} \Pr(c) \\ &= \frac{0.3781}{0.55} 0.5 = 0.44. \end{aligned}$$

Credibility reduces from 0.5 to 0.44.

## 4 Credibility and Success

We can now show how the announcement of an inflation target can help the Central Bank stay within the range of values that constitute successful monetary policy. We will show this first through illustrative numerical simulations for 20 periods and second through Monte Carlo simulations to generalize our results. We assume the following parameterization:

$$\pi^T = 2, \quad \rho = 0.5, \quad \beta = 4 \text{ (or } \sigma_\xi^2 = 0.25\text{)}.$$

Two parameters are now subject to uncertainty, supply shocks  $\xi$  and public information noise  $\eta$ , and they are drawn every period. Both parameters have a zero mean and respective variances,  $\sigma_\xi^2$ ,  $\sigma_\eta^2$  equal to 0.25. Private information precision is fixed in this exercise. In the absence of shocks, if expectations are equal to the target, then the CB achieves its inflation objective and welfare is maximized. If on the other hand, expectations are equal to the MS action, then inflation will not be equal to the target. Irrespective of how expectations are formed however, the presence of supply shocks can seriously hamper the CB's ability to be successful. This inevitably affects the way private agents update credibility. We demonstrate this next.

Following the parameterization assumed, the condition for inflation expectations to be equal to the target is 0.62 (from 12). We assume a starting value for  $v = 0.6 (< 0.62)$ , implying that in the first period,  $t = 1$ , expectations will follow the MS rule. Random numbers are drawn for each period for both the supply shock  $\xi$  as well as the shock to public information  $\eta$ , for 20 consecutive periods. Figure 1 demonstrates how successful the CB is under IT ( $\pi_t$  and  $\pi^e$ )

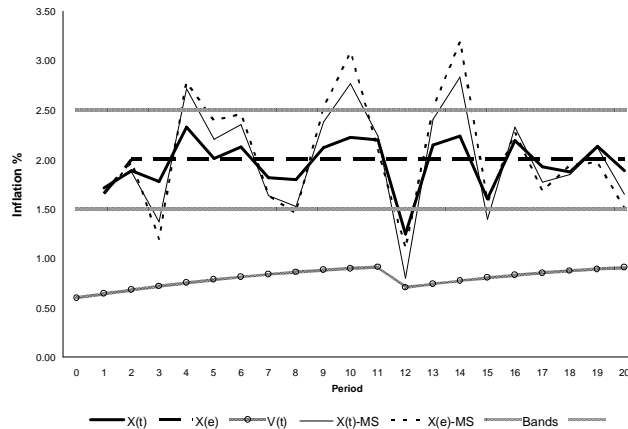


Figure 1: Credibility and Performance

and non-IT ( $\pi_t^{MS}$  and  $\pi^{e,MS}$ ), and how credibility evolves based on the success of IT.

It shows that despite the lack of credibility in the first period, the shocks drawn do not prevent the CB from being successful in maintaining inflation within the specified bands. This success helps reward the CB in the next period by increasing  $v$ , helping it go over the 0.62 mark. For the IT regime this implies that expectations are now tied down to the target. In turn, this helps control inflation in the period after that and given the size of the new shocks that occur, still hold inflation within the bands. The same is true for the MS regime in the first two periods even though expectations do not equal the target. However, after the third period, the shocks occurring are large enough to throw inflation under the MS regime outside the bands. By contrast, the fact that credibility was sufficiently high for expectations to be equal to target implied that the same shock was easier to handle with IT preventing inflation from coming out of the bands. This process reinforces itself in all the periods and while inflation under the MS regime exits the bands on a number of occasions, the fact that expectations are tied to the target under IT allows inflation to remain within the bands. There is only one occasion, at the 12th period, that inflation will fail to remain within the bands and credibility drops as a result. However, this drop does not harm expectations, which remain fixed at the mid-point helping inflation recover after that. Allowing for credibility to affect expectations and the monetary policy outcomes has accounted for the fact that the success rate for IT is 95 percent, whereas that for MS is 70 percent.

However, it is also possible that for the same parameterization, the shocks drawn are unfavorable enough for the coordinating feature of IT to never come into operation. This is shown in figure 2 where the two regimes overlap with each

other.

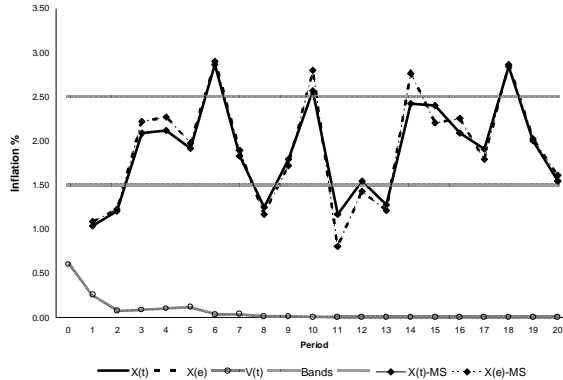


Figure 2: Credibility and Performance

A third possibility (again under the same parameterization) is that illustrated in figure 3. In this example, acquiring credibility through inflation targeting is not a permanent characteristic of the regime: if a series of negative shocks hit the economy, the credibility gained can also be lost. What inflation targeting does however achieve is that it makes the system more robust to unfavorable circumstances. In our example, although credibility starts decaying after the seventh period, the focal point characteristic lasts for an extra period before expectations revert to the MS formation. At period 16 however, the combination of unfavorable shocks and reducing credibility imply that the two regimes become identical.

The question is then how often can IT improve the success rate, and under which conditions are these improvements the greatest? Simulations will demonstrate the general results implied for a variety of shocks, based on 1000 repetitions.

#### 4.1 Simulations

We generalize some of these results by performing Monte-Carlo simulations. Figures 1-3 show a block of 20 consecutive simulations. Given the formula applied for updating credibility, after about twenty periods credibility converges to either one or zero, in which case expectations are either anchored for ever after that (former case), or they follow the MS rule (latter case). For a constant parameterization of the shocks, credibility remains at one of the two extreme levels and therefore policy outcomes are biased accordingly. In evaluating the results from these Monte Carlo simulations, it is important therefore to rely on multiples of 20-period blocks. We will run 1000 (larger numbers of draws do not change the results) of 20-period blocks rather than the alternative of 20000 consecutive simulations. Parameterization will be identical to what is shown

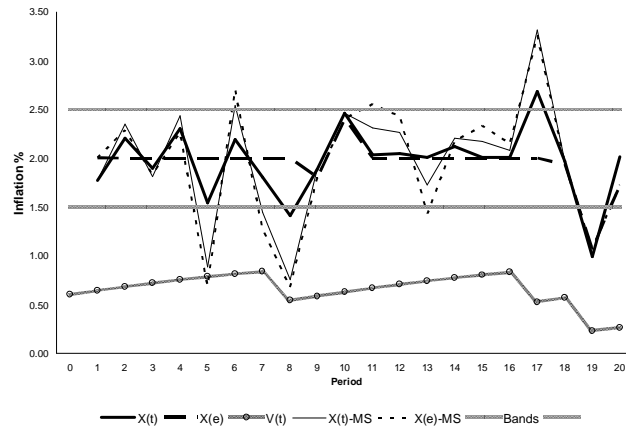


Figure 3: Credibility and Performance

above, unless otherwise stated. We investigate two issues: first, how often the announcement of an IT causes a level of credibility at the end of the 20th period that is higher than that at the first period, i.e. an overall improvement in credibility; and second, what this in turn implies for the success of monetary policy.

#### 4.1.1 Does Announcing a Target Always Improve Credibility?

We first ask whether the announcement of a target always leads to an increase in credibility. In what follows we show the percentage of times for which credibility at the 20th period was higher than the level assumed at the start. This does not account for oscillations in credibility during the 20-period block but provides an indication of what level credibility converges to. We do this for two different levels of initial credibility and for a variety of different assumptions for the two shocks drawn. Table 4 presents the results.

Table 4: Credibility Improvement

$v(0) = 0.5$		%
$\sigma_{\xi}^2 = 0.25,$	$\sigma_{\eta}^2 = 0.25$	20
$\sigma_{\xi}^2 = 0.25,$	$\sigma_{\eta}^2 = 0.5$	49
$\sigma_{\xi}^2 = 0.5,$	$\sigma_{\eta}^2 = 0.25$	0.02
$\sigma_{\xi}^2 = 0.5,$	$\sigma_{\eta}^2 = 0.5$	0.05
<hr/>		
$v(0) = 0.7$		
$\sigma_{\xi}^2 = 0.25,$	$\sigma_{\eta}^2 = 0.25$	74
$\sigma_{\xi}^2 = 0.25,$	$\sigma_{\eta}^2 = 0.5$	83
$\sigma_{\xi}^2 = 0.5,$	$\sigma_{\eta}^2 = 0.25$	0.15
$\sigma_{\xi}^2 = 0.5,$	$\sigma_{\eta}^2 = 0.5$	0.29

Starting with low initial credibility and values for the shocks  $\sigma_{\xi}^2 = 0.25$ ,  $\sigma_{\eta}^2 = 0.25$ , IT will lead 20 percent of the times to an increase in final credibility levels. This improvement occurs 49 percent of the times when public information precision declines. However, the presence of unstable economic conditions (i.e. relatively high supply shocks,  $\sigma_{\xi}^2 = 0.5$ ), irrespective of the quality of public information, prevents IT from improving credibility. A barely 0.02 percent of the times will credibility have increased (and 0.05 percent when public information is more unclear) by the end of the 20 period block.

Alternatively, relatively high levels of initial credibility can make a difference to the extent of improvement brought by the application of IT. In our baseline scenario, inflation targeting will cause an improvement to the initial 0.7 level of credibility, 74 percent of the times. When public information is imprecise, the ‘focal point’ argument is very often (83 percent of the time) helping the Central Bank improve its credibility. But starting from high credibility does not necessarily guarantee further improvements, if the economy is subjected to significant supply shocks. Again, it is the size of the shocks that will determine accumulation versus decumulation of credibility. Inflation targets work as good coordinating mechanisms only when supply shocks are relatively low.

#### 4.1.2 Monetary Policy Regime and Monetary Policy Success

We now evaluate the effectiveness of the two regimes in terms of the rates of success for a variety of model parameterizations. Table 5 presents the success rates for the two regimes, IT and MS, or in other words the number of times that, following the two shocks and the CB’s reaction, inflation ends up being between 1.5 and 2.5 percent. We show this under different parameterizations for the shocks and the initial level of credibility assumed.

Table 5: IT and Successful Monetary Policy

		Success IT %	Success MS %
Baseline:	$\sigma_\xi^2 = 0.25, \sigma_\eta^2 = 0.25$		
	$v_0 = 0.7$	88	66
	$v_0 = 0.5$	71	66
Large Supply Shock:	$\sigma_\xi^2 = 0.5, \sigma_\eta^2 = 0.25$		
	$v_0 = 0.7$	57	50
	$v_0 = 0.5$	51	50
Small Supply Shock:	$\sigma_\xi^2 = 0.1, \sigma_\eta^2 = 0.25$		
	$v_0 = 0.7$	99	84
	$v_0 = 0.5$	99	84
Large Information Shock:	$\sigma_\xi^2 = 0.25, \sigma_\eta^2 = 0.5$		
	$v_0 = 0.7$	91	65
	$v_0 = 0.5$	80	65
Small Information Shock:	$\sigma_\xi^2 = 0.25, \sigma_\eta^2 = 0.1$		
	$v_0 = 0.7$	75	66
	$v_0 = 0.5$	67	66

Our first observation from Table 5 is that initial levels of credibility matter both in terms of the success of IT itself, but also in terms of bringing big improvements by comparison to MS. With reference to (relatively) large supply shocks, the two regimes are almost identical and IT will not be able to help coordinate expectations (except in very extreme cases). When shocks are small on the other hand, although IT helps in that respect, MS is also capable of providing successful results (difference of 15 percent independently of initial credibility assumed<sup>11</sup>). It is when shocks are average in size ('Baseline') that IT can be beneficial, especially when credibility is relatively high to start with (difference of 22 percent for  $v_0 = 0.7$ ). When it comes to the precision of public information, IT is not generally advantageous if information is generally good (small information shocks). However, when all other public information is relatively poor, then the provision of a clear monetary objective can improve the success rate by up to 26 percent. Here the level of initial credibility matters, such that the greater the credibility to begin with, the bigger the increase in IT monetary policy success by comparison to MS. This contributes to our original suggestion that the benefits of communicating and inflation target come in the form of tackling information inefficiencies.

<sup>11</sup>This is because with this parameterization the credibility threshold for the target to become focal point is very low (0.34), i.e. even if the target is not credible there is no implied cost in focusing on it, as the shocks are very low on average.

## 5 Optimal Inflation Targeting Bands

We discuss next how the choice of band-width affects the trade-off between precision and success.<sup>12</sup> On the one hand, while a relative wide band increases the probability of success, at the same time the mid-point target is less effective in terms of acting as a focal point. So the inflation target loses its meaning as the bands widen. On the other hand, while a target and its known range help solve the coordination motive in the agents' objective function, it is also true that the sheer provision of a clear criterion also exposes failure. We illustrate this point through an example in which we calculate the relevant conditional probabilities. For the parameterization assumed in section 3.3, where  $\rho = 0.5$ , the following hold:

$$\begin{aligned} \Pr(c/s) &= 0.58 & \Pr(c/\bar{s}) &= 0.44 \\ \Pr(\bar{c}/s) &= 0.42 & \Pr(\bar{c}/\bar{s}) &= 0.56 \end{aligned}$$

In other words, if success is observed, it is 58 percent likely that this was due to credible policies. If failure is observed, on the other hand, then the probability that this is due to lack of credibility is 56 percent. Now let's see how these probabilities change as the band-width increases. We assume now that  $\rho = 2$ . The joint probability distribution is shown in Table 6:

Table 6: Credibility and Success

$\rho = 2$			
	$s$	$\bar{s}$	$C :$
$c$	0.49	0.01	0.50
$\bar{c}$	0.48	0.02	0.50
$S :$	0.97	0.03	1

The first observation is that the probability of success is 97 percent, which is natural as the bands are now relatively wide.

$$\begin{aligned} \Pr(c/s) &= 0.51 & \Pr(c/\bar{s}) &= 0.09 \\ \Pr(\bar{c}/s) &= 0.49 & \Pr(\bar{c}/\bar{s}) &= 0.91 \end{aligned}$$

However, while it is very difficult to assign the cause of success when it is observed, (51 percent vs 49 percent), once failure is observed (and it will be observed only 3 percent of the time), then it is almost certain (91 percent) that

<sup>12</sup>See Mishkin and Westelius (2008) for an attempt to examine how the band-width deals with time-inconsistency problems. In their attempt, the authors introduce an explicit cost in the CB's utility function for landing outside the bands. In our case this is already incorporated in the mechanism for updating credibility, as we show next. Their approach has the attractive feature that costs from deviating from the target are a function of the distance from the bands. However, it is not obvious that in terms of pinning down expectations, this has made much of a difference in practice.

this failure is the result of lack of credibility. This is intuitive, as failing to keep inflation within a relatively wide band is more likely to be the fault of the Central Bank rather than the outcome of bad luck. So, in this respect, the announcement of the target has worked against the Central Bank, as it provided a very obvious criteria by which to identify its failure. The width of the bands works also in the opposite direction. We assume next very narrow bands, i.e.:  $\rho = 0.1$ .

Table 7: Credibility and Success

$\rho = 0.1$			
	$s$	$\bar{s}$	$C :$
$c$	0.06	0.44	0.5
$\bar{c}$	0.04	0.46	0.5
$S :$	0.10	0.90	1

Success is now rather unlikely (10 percent of the times in Table 7), but once you observe it, it is more likely to be the result of CB credibility (59 percent). By contrast, failure is a lot more likely (90 percent), but the source of this failure is a lot more difficult to discern (49 versus 51 percent).

$$\begin{aligned} \Pr(c/s) &= 0.59 & \Pr(c/\bar{s}) &= 0.49 \\ \Pr(\bar{c}/s) &= 0.41 & \Pr(\bar{c}/\bar{s}) &= 0.51 \end{aligned}$$

But this then points to the fact that there is an optimal band-width for the Central Bank, which encapsulates the trade-off between enhancing the probability of success, and the provision of a clear and precise signal. We apply numerical methods to identify next what the optimal band-width is for a number of different parameterizations.

## 5.1 Grid-Search for the Optimal Band-Width

We plot the radar graphs for the social loss contours based on different values for credibility, supply shocks and information shocks. For every radius  $\rho$  around the target - depicted along the circumference of the radar graphs - we report the average losses (based on equation 1) of 1000 (20-period block) simulations. Losses are minimized at the centre of the circle and are therefore increasing as the ray of each contour lengthens. We start by addressing how the optimal band-width is affected by the initial level of credibility.

Figure 4 displays losses for four different values of initial credibility. We see that as the level of initial credibility increases, losses become smaller. However, for any given level of credibility, losses are minimized at a certain band-width. This is shown by the shortest ray from the centre to the respective contour, depicted in the graph. For example, for  $v_0 = 0.5$  the optimal band width is equal to 0.45. As the level of initial credibility increases the optimal band-width also increases (0.7 and 1 for  $v_0 = 0.6$  and  $v_0 = 0.7$  respectively). This points to the fact

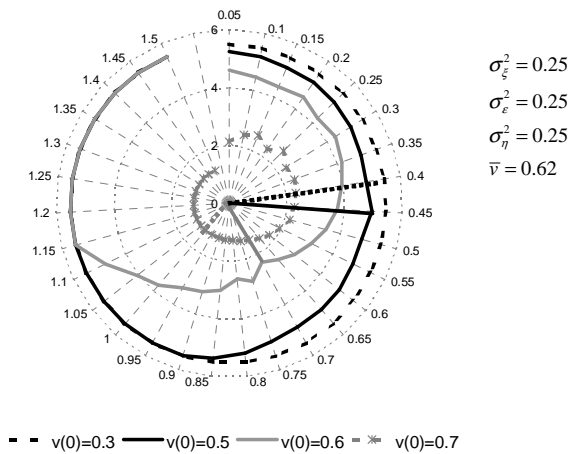


Figure 4: The Relevance of Band-Width: Different levels of Initial Credibility

that Central Banks that are not credible need to be tighter in formulating their ambitions. At the same time we see that when credibility is either very high or very low, losses are fairly invariant (although not exactly) to the different band-widths. In other words, the choice of band-width is not of interest to banks that have "established" credibility at either end of the spectrum. As credibility becomes more critical on the other hand, (0.7 and especially 0.6), identifying the correct band-width can make a substantial difference and therefore become an effective way of increasing welfare.

Figure 5 shows next how the band-width is affected by the size of supply shocks. For small supply shocks, losses are also very small. As the size of the shocks increases from 0.2 to 0.3, then the Central Bank can afford to increase the band-width a little from 0.5 to 0.6. However, as figure 5 shows the losses are fairly constant across the width of the band.

This is not the case when considering different shocks to public information, for which losses benefit from the identification of the optimal band-width. Figure 6 plots losses for three different information shocks. When looking at just the optimal band-width we see that in the presence of relative imprecise public information ( $\sigma_\eta^2 = 0.7$ ), the optimal band-width is relatively large (0.65). This points to the fact that when information is very poor, any signal is better than no signal. By contrast, when information is by itself very precise ( $\sigma_\eta^2 = 0.3$ ), then for a signal to be helpful it has to be very precise (narrow band, 0.4) before it induces agents to switch forming expectations from MS to IT. We observe that in figure 6 losses are always smaller when information quality is relatively poor by comparison to when it is relatively good. This is in line with

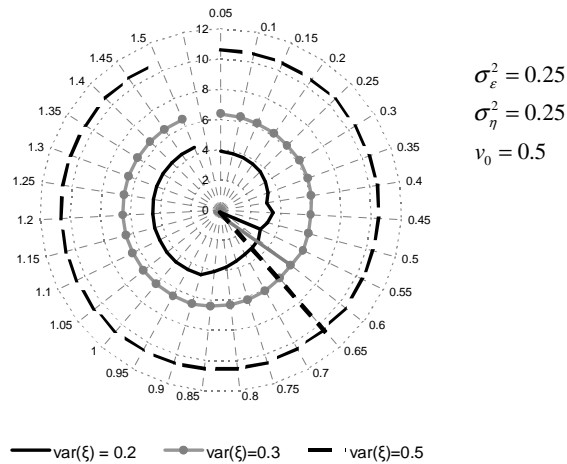


Figure 5: The Relevance of Band-Width: Diffent Supply Shock Variances

results presented at Table 5, where we saw that providing an inflation target is very beneficial to the level of success when information is very poor. By contrast when public information is very precise, then both regimes achieve fairly similar results. Again this points to the substitutability between public information, which is complete but imprecise and the inflation target, which is incomplete but very precise.

Between the three cases (Figures 4-6), we see that identifying the right band-width is particularly important for different levels of initial credibility. The same holds for differences in the quality of public information available, although to a lesser extent. Differences in the shocks on the other hand, are not particularly affected by the width of the bands.

## 6 Conclusions

Critics often argue that inflation targeting as a monetary policy regime puts far too high a weight on inflation to the detriment of output and growth. Friedman, (2003) argues that “...the language in which that debate takes place exerts a powerful influence on the substance of what the participants say, and eventually even over what they think”. He then goes on to say that “...a powerful motivation for adopting this framework, at least in some quarters, is the hope that if the explicit discussion of the central bank’s policy is carried out entirely in terms of an optimal inflation trajectory, concerns for real outcomes may somehow atrophy or even disappear from consideration altogether”. Mervyn King (1997) has objected to this argument by arguing that being an inflation targeter is not synonymous to being an ‘inflation nutter’. To this, our analysis adds that the

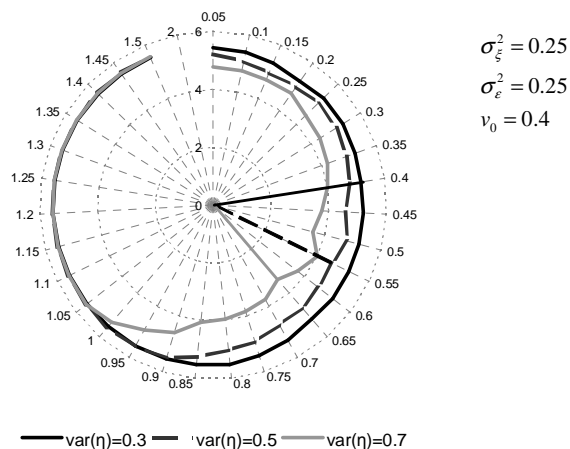


Figure 6: The Relevance of Band-Width: Different Public Information Variances

strength of the ‘use and meaning of words’ argument notwithstanding, the potential benefits of inflation targeting arise from its ability to tackle information imperfections and not necessarily from the monetary policy choices it implies. We argue that the emphasis is on the communication of certain choices, not the choices themselves. The underlying monetary policy strategy (preferences and objectives) is then not necessarily uniquely identified. Indeed, countries have implemented and also experienced inflation targeting in very different ways.<sup>13</sup>

Our analysis also shows under which conditions inflation targeting can make a difference, but by consequence also when it cannot. It is important therefore to note that no regime seals the Central Bank from external shocks totally. There will be occasions when economic circumstances will just prevent good outcomes from occurring. What good and effective communication can achieve however, is help build up the Central Bank’s ability to withstand unfavorable shocks when they arise. Our analysis indicates that the provision of a clear signal will be of the greatest value-added when all other information available is unclear, because it then provides a focal point for expectations. Countries for which information is abundant and clear, and for which Central Banks are either credible already or are faced with small shocks, will see no discernible benefits from dedicating resources to improving their communication.

In fact one needs to examine whether providing a clear signal may even be

<sup>13</sup>Goodfriend (2007) mentions that ITers may differ in four respects: "...1) the announcement of an explicit numerical inflation target by the central bank, 2) patience in reversing an inflationary shock to minimize adverse effects on employment, 3) transparency of central bank concerns and intentions about the economy and interest rate policy, and 4) formal governance mechanisms designed to hold a central bank accountable for inflation outcomes".

harmful. One of the implications of very precise communication is that both success as well as failure are clearly defined for the public to see. The private sector observes where current inflation is vis-à-vis the objective announced and therefore rewards or penalizes the Central Bank. In our analysis, the default monetary policy regime (MS) does not allow for credibility and success to reinforce each other. In every period, the Central Bank and private agents decide on their action to the best of their abilities, without reviewing performance and credibility. The expectations formation process is therefore independent of past performance and by comparison, inflation targeting, that does exploit the performance-credibility loop, can only improve success. However, one could conceivably compare inflation targeting to other regimes that do allow for this credibility-success loop, but then defined less tightly. We could then compare how these alternative regimes affect a Central Bank's credibility in periods of adverse shocks. Our discussion on how the width of the band affects success supports the argument that other less clear definitions might prove less harmful (although also less effective in providing a focal point).

We examine the merits of inflation targeting in communicating monetary policy choices. The clear criteria for evaluating outcomes that it entails, as well as the ability to provide focal points, maximize the way the credibility-performance loop is exploited. Coupled with sound policies, our analysis shows that a clear communication strategy can improve monetary policy performance.

## APPENDICES

### A Social vs. Individual losses

Table A. 1 below summarizes the losses for both society as well as the individual, based on (1) and (5), for the two alternative inflation expectations mechanisms:

	$\pi^e$	$\pi^T$
Social Losses: $L_{CB}$	$\sigma_\xi^2 + \frac{\alpha+\beta}{(2\alpha+\beta)^2}$	$\frac{1}{4}\sigma_\xi^2$
Individual Losses: $u_i$	$\frac{\alpha+\beta}{(2\alpha+\beta)^2}$	$\frac{1}{4}\sigma_\xi^2$

We observe that when expectations follow the MS rule, then individual losses will differ to those faced by society. The difference will relate to the distance between  $\frac{\beta}{(2\alpha+\beta)^2}$  and  $\sigma_\xi^2$ , or in other words, the extent by which relative private information is very different from the variance of supply shocks.<sup>14</sup> And it is such, that  $L_{CB} < u_i$ , if  $\sigma_\xi^2 < \frac{\beta}{(2\alpha+\beta)^2}$  and the individual will do worse than society on average. This is also consistent with our comment below table 1 in the main text, that when shocks are relatively small, the individual has a dominant strategy of following the target. When expectations are on target, then  $L_{CB} = u_i = \frac{1}{4}\sigma_\xi^2$ .

If we assume the standard full-information discretionary set-up, then we need to substitute (3) and (4) into (1) and the Lucas supply function. Society losses are equal to the losses attained under the fully credible inflation targeting regime,  $\frac{1}{4}\sigma_\xi^2$ . So, the standard discretionary set-up under full information is equivalent to the fully credible IT regime with imperfect information.

### B Variable Universe Games

When expectations formation becomes a matching game, individual  $i$  is unable to differentiate between the two Nash equilibria in pure form,  $E_2 \equiv (\pi^T, \pi^T)$  and  $E_3 \equiv (\pi_i, \pi^e)$ . To decide on an action therefore, he needs to compare the *expected* (rather than *actual*) dis-utility that each of them delivers; in other words  $\mathbb{E}[u_i(a_i, \bar{a})]$ , where  $a_i \in \{\pi_i, \pi^T\}$  and  $\bar{a} \in \{\pi^e, \pi^T\}$ . This in turn depends on the probability with which the average action takes one of its own two respective values.

**Definition A1:** Define:  $q \equiv \Pr(\bar{a} = \pi^T)$  and  $(1 - q) \equiv \Pr(\bar{a} = \pi^e)$ ,  $q \in [0, 1]$ .

Expected dis-utility for individual  $i$  for each of his two actions is then:

$$\mathbb{E}\{u_i[\pi_i, (\pi^e \text{ or } \pi^T)]\} = (1 - q)u_i(\pi_i, \pi^e) + qu_i(\pi_i, \pi^T) \quad (15)$$

$$\mathbb{E}\{u_i[\pi^T, (\pi^e \text{ or } \pi^T)]\} = (1 - q)u_i(\pi^T, \pi^e) + qu_i(\pi^T, \pi^T). \quad (16)$$

<sup>14</sup>By construction, private information is not relevant at the aggregate level.

The difficulty with this however, is that probability  $q$  is unknown to individual  $i$  and he is thus unable to evaluate which action to take based on (15) and (16). He needs therefore, to identify an alternative framework that provides him with sufficient information that he can then base his choice on. We will argue that rather than evaluate  $q$ , it will suffice for individual  $i$  to simply know how the target is perceived (and not necessarily applied) on average. Otherwise put, it will suffice for the individual to know the proportion of people that consider the target credible. We believe that in the context of monetary policy this information is publicly available and easier for the individual to deduce. Based on that, we will show that he can then identify under which conditions following the target provided by the Central Bank is to his advantage.

As  $q$  is not known to the individual, we need to identify an other prior that captures information that is more readily available to the individual. The regime of inflation targeting implies the following:<sup>15</sup>

1. First, the option of following the target is available to everyone. We believe this to be an adequate representation of the fact that inflation targets are widely announced and are therefore, seen and understood by everyone. In that respect, it is reasonable to assume that any random individual would understand that the options shown in Table 1 under IT are now available to them.
2. Second, not necessarily everyone believes that the target is credible. In other words, not everyone believes that the CB can actually achieve the target, or even that the notion of ‘price stability’ and the value  $\pi^T$  announced are necessarily equivalent. This is in our view an important reflection of the fact that revealing a quantitative objective is not automatically sufficient for attaining it.
3. Finally, while credibility is by no means certain, there is nevertheless a common perception as to how credible such a target might be. In other words, everyone knows and understands how the target is perceived by others. More specifically, one could interpret this likelihood as the proportion of people, say  $v$ , who consider the target credible. We assume that  $v$  is common knowledge and sufficient for the individual to base her choice on.

Based on Bacharach’s (1993) paper, we can rely on this likelihood  $v$  to evaluate individual  $i$ ’s expected dis-utility  $\mathbb{E}[u_i(a_i, \bar{a})]$  of following action  $a_i$  for a given collective action  $\bar{a}$ . This has the advantage that the priors used are now known to him. However, as  $v$  is not the actual probability with which the collective

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<sup>15</sup>Note that our description of what the provision of an explicit quantitative target implies draws heavily from the common notion that IT constitutes "...a simple yardstick by which to judge policy. Given lexicographic preferences over inflation and other goals, an inflation target range, and a fixed horizon, inflation targeting becomes very easy to monitor", Faust and Henderson (2004), p127.

action is equal to the target ( $v \neq q$ ), we need to proceed in three steps in order to provide a comprehensive framework that accounts for all possible outcomes.

**Case 1:** First, we consider the case when the collective choice is always the default MS action. The target is therefore never applied, irrespective of whether it is deemed credible. This may happen either because the average perception is that the CB's target is not credible, or because the average individual does not believe that about others. The default MS action is then applied on average and inflation expectations equal  $\pi^e$ . Are there then circumstances in which individual  $i$  is still better-off following the target? Her expected dis-utility of following either of his two options is then:

$$\begin{aligned}\mathbb{E}[u_i(\pi_i, \pi^e)] &= (1-v)u_i(\pi_i, \pi^e) + vu_i(\pi_i, \pi^e) \\ &= u_i(\pi_i, \pi^e) \\ \mathbb{E}[u_i(\pi^T, \pi^e)] &= (1-v)u_i(\pi^T, \pi^e) + vu_i(\pi^T, \pi^e) \\ &= u_i(\pi^T, \pi^e).\end{aligned}$$

From Table 1, these equal respectively

$$\begin{aligned}\mathbb{E}[u_i(\pi_i, \pi^e)] &= \frac{\alpha + \beta}{(2\alpha + \beta)^2} \\ \mathbb{E}[u_i(\pi^T, \pi^e)] &= \sigma_\xi^2 + \frac{\alpha}{(2\alpha + \beta)^2}.\end{aligned}$$

It follows that

$$\begin{aligned}\mathbb{E}[u_i(\pi^T, \pi^e)] &< \mathbb{E}[u_i(\pi_i, \pi^e)] \quad \text{iff} \\ \sigma_\xi^2 &< \frac{\beta}{(2\alpha + \beta)^2}.\end{aligned}\tag{17}$$

Expression (17) illustrates the condition for which individual  $i$  would effectively ignore the fact that everyone else applies the MS default action, and still follow the target, even though he is aware he would be the only one. But this is only rational if following the target constitutes his dominant strategy. It is therefore, no surprise that (17) is identical to the condition shown in the main text under dominance.

**Case 2:** Second, we then relax the stringency of the first assumption and assume now that the proportion of people who believe that the target is credible, actually apply it. When should then individual  $i$  choose the target? This is a somewhat less restrictive case than the one above and expected dis-utility for player  $i$  of pursuing either of his two options is now,

$$\begin{aligned}\mathbb{E}\{u_i[\pi_i, (\pi^e \text{ or } \pi^T)]\} &= (1-v)u_i(\pi_i, \pi^e) + vu_i(\pi_i, \pi^T), \\ \mathbb{E}\{u_i[\pi^T, (\pi^e \text{ or } \pi^T)]\} &= (1-v)u_i(\pi^T, \pi^e) + vu_i(\pi^T, \pi^T)\end{aligned}$$

and from Table 1,

$$\begin{aligned}\mathbb{E}\{u_i[\pi_i, (\pi^e \text{ or } \pi^T)]\} &= (1-v)\frac{\alpha+\beta}{(2\alpha+\beta)^2} + v\left[\frac{1}{4}\sigma_\xi^2 + \frac{4\alpha+\beta}{(2\alpha+\beta)^2}\right], \\ \mathbb{E}\{u_i[\pi^T, (\pi^e \text{ or } \pi^T)]\} &= (1-v)\left[\sigma_\xi^2 + \frac{\alpha}{(2\alpha+\beta)^2}\right] + v * \frac{1}{4}\sigma_\xi^2.\end{aligned}$$

It follows that,

$$\begin{aligned}\mathbb{E}\{u_i[\pi^T, (\pi^e \text{ or } \pi^T)]\} &< \mathbb{E}\{u_i[\pi_i, (\pi^e \text{ or } \pi^T)]\}, \text{ iff} \\ \sigma_\xi^2 &\leq \frac{\beta + v4\alpha}{(1-v)(2\alpha+\beta)^2}.\end{aligned}\tag{18}$$

Again, the size of the shock needs to be below a given ratio before the individual applies the target. However, as the condition is less restrictive than before, (since  $\frac{\beta}{(2\alpha+\beta)^2} < \frac{\beta+v4\alpha}{(1-v)(2\alpha+\beta)^2}$ ), it is also the sufficient condition for individual  $i$  to follow that target. Interestingly, we can re-write this condition in terms of  $v$

$$v \geq \frac{(2\alpha+\beta)^2\sigma_\xi^2 - \beta}{4\alpha + (2\alpha+\beta)^2\sigma_\xi^2}.\tag{19}$$

This now shows that the sufficient condition for individual  $i$  to follow the target is when a suitably large proportion of the public believe the target to be credible.

**Case 3:** The average action is now assumed to always be the target. One could envisage a situation (admittedly unlikely) in which everyone thinks for themselves that the target is not credible but choose nevertheless to follow it, because they believe they are alone in thinking that. It is trivial then to show that following the target is individual  $i$ 's preferred strategy.

$$\begin{aligned}E\{u_i[\pi_i, \pi^T]\} &= \frac{1}{4}\sigma_\xi^2 + \frac{4\alpha+\beta}{(2\alpha+\beta)^2} \\ E\{u_i[\pi^T, \pi^T]\} &= \frac{1}{4}\sigma_\xi^2 \\ E\{u_i[\pi^T, \pi^T]\} &< E\{u_i[\pi_i, \pi^T]\}.\end{aligned}$$

Based on these three cases, figure 7 summarizes how the individual decides on his strategy, based on the value of the variance of the supply shock.

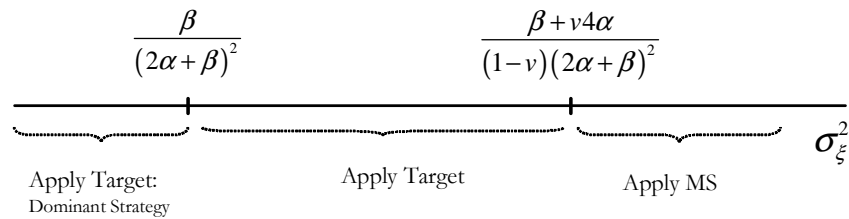


Figure 7: Individual  $i$ 's options.

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