

Inflation Range Targets with Hard Edges

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Abstract

A number of inflation targeting central banks operate under provisions that allow for increased flexibility when faced with large supply shocks. These so-called escape clauses, however, are usually hard to interpret and discretionary in nature. This paper argues that a practical and more viable option is to specify a hard edged target range. Within the range, the central bank enjoys complete independence. Should, however, a large supply shock force inflation outside the range, the government may overrule the bank unless it adjusts its policy to address the government's concerns. Such an arrangement has the advantage of being easily understood and non-discretionary. Furthermore, it is shown that the bandwidth of the target range is inversely related to the degree of flexibility of the inflation targeting regime and thus, provides an easy way for the central bank to communicate its preferences to the public. The paper also discusses various determinants of the optimal design of the target range.

Keywords: Monetary Policy; Inflation Range Targeting; Escape Clauses; Discretion

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1 Introduction

By the early 1980s, policymakers realized that sustained expansionary policy to achieve unrealistic employment and output goals would only lead to elevated inflation expectations, higher inflation and no long-run gains in economic activity. As a result, central bankers began to emphasize the importance of price stability. Their disinflation attempts were largely successful, but came with significant losses in output and employment. To avoid future inflationary episodes, price stability was made a centerpiece in modern central banking. The mandate for the European Central Bank, set by the Maastricht treaty, illustrates this clearly as it places price stability as the bank's overriding objective. But perhaps the most palpable manifestation of this worldwide trend towards greater price stability has been the emergence of inflation targeting. Although there is some disagreement about what truly constitutes an inflation targeting regime, there is little disagreement about its emphasis on price stability. Perhaps the most radical case is the Reserve Bank of New Zealand, whose mandate specifies price stability as its only objective.¹ In practice, however, it is apparent that inflation targeting central banks do care about output stabilization as well as price stability. Svensson (1999) has thus more appropriately re-labeled this monetary framework as *flexible* inflation targeting.

1.1 Flexibility and Escape Clauses

But how flexible should inflation targeting central banks be? Indeed, one of the most frequently voiced concerns with respect to inflation targeting is that it places too much weight on inflation stabilization. Such emphasis is argued to constrain the central bank's flexibility to mitigate output shocks, and thus exacerbate output fluctuations (e.g., Friedman and Kuttner, 1996).² This line of argument mirrors Rogoff's (1985) seminal work showing that a weight-conservative central banker, while reducing the inflation bias arising under discretionary policy, also incurs welfare costs in

¹Clause 4(b) of the Policy Targets Agreement (PTA) does state that "in pursuing its price stability objective, the Bank shall implement monetary policy in a sustainable, consistent and transparent manner and shall seek to avoid unnecessary instability in output, interest rates and the exchange rate."

²Some observers (e.g., Mishkin, 2007) argue that the focus on inflation stability, and in particular the announcement of an inflation target, should have a stabilizing effect on output. The reason is that stable inflation expectations make it easier for the central bank to mitigate output shocks since they do not have to worry that inflation expectations would spiral out of control.

terms of increased output volatility.³ The view that inflation targeting places a greater weight on inflation stabilization relative to other monetary frameworks exists amongst practitioners as well. For instance, Meyer (2004), argues that inflation targeting countries, working under a hierarchical mandate, place a greater relative weight on inflation stability than central banks with a dual mandate such as the Federal Reserve. Kohn (2003), discussing whether inflation targeting is right for the U.S., expresses concerns that inflation targeting "would result in less-than-optimal attention being paid to stabilizing the economy."⁴

Despite these concerns, the popularity of inflation targeting as a monetary framework seems to indicate that the public is comfortable with its focus on price stability. Some observers argue, however, that this may partly be due to the relatively favorable global economic environment under which inflation targeting regimes have existed, and that it is therefore hard to know the true stability of the framework. For instance, minor supply shocks are not likely to threaten the framework's emphasis on price stability. Large negative supply shocks, on the other hand, could cause friction between the government and the central bank as elected politicians are less likely to accept a sharp reduction in economic activity in order to maintain price stability. Indeed, some economists (e.g., Lybeck and Morris, 2004) have stressed the importance of an explicit conflict resolution mechanism to reduce potential tension between the bank management and the government. As is evident from a number of central bank legislations, this concern is not just academic.⁵ For example, the Bank of England Act contains the following provision:

"The Treasury, after consultation with the Governor of the Bank, may by order give the bank directions with respect to monetary policy if they are satisfied that the

³A weight-conservative central banker is defined as a central banker that places a higher relative weight on inflation stability than that which is socially optimal.

⁴Whether or not inflation targeting causes greater output volatility is of course an empirical question. Several studies indicate that inflation targeting has led to improvements in overall economic outcomes and that the framework does not cause a deterioration in output variability (e.g., Bernanke et al, 1999, Corbo, Landerretche, and Schmidt-Hebbel, 2002). Cecchetti and Ehrmann (2002), on the other hand, do find that countries adopting inflation targeting increased their aversion towards inflation variability and consequently experienced increases in output variability. They also find that the same is true for non-targeting European Union countries approaching a monetary union. Corbo, Landerretche, and Schmidt-Hebbel (2002) perform the same empirical test with some modifications and do not find a difference between the inflation and non-inflation targeters. One reason for this somewhat conflicting empirical evidence may be the difficulty of separating overall improved monetary efficiency from a movement along the efficiency frontier. For instance, increased accountability, credibility and transparency are likely to reduce both inflation and output variability as they improve monetary efficiency. On the other hand, an increased focus on inflation variability would reflect the trade-off between inflation and output volatility and a movement along the efficiency frontier. It is quite likely that the inflation targeting framework encompasses both of these aspects.

⁵See Petursson (2004).

directions are required in the public interest and by extreme economic circumstances."

(Bank of England Act, 1998, Section 19:1)

Some central bank legislations avoid direct references to conditions under which the central bank can be overruled. Instead, they include provisions facilitating increased flexibility to the central bank under specific economic conditions such as large terms of trade shocks or sudden hikes in world commodity prices.⁶ These so-called escape clauses or caveats are partly designed to reduce potential tension between the central bank and the public.

The probability of invoking an escape clause is likely to depend on at least three factors. First, the less opportunistic and the more committed the government is to low and stable inflation, the less likely it is to overrule or put pressure on the central bank to use an escape clause. Second, the greater the degree of central bank autonomy and the more cumbersome the legal procedures, the more difficult and costly it is for the government to overrule the central bank.⁷ Finally, if the domestic economy is less prone to large exogenous shocks, conflicts between the government and the central bank are less likely to arise in the first place. For these reasons, it is perhaps not surprising that escape clauses are more frequent in central bank legislation of developing and transitional economies (e.g., Philippines, South Africa, Czech Republic, and Poland) and countries more prone to large exogenous supply shocks (e.g., New Zealand).⁸

Although, there is a consensus that inflation targeting central banks have to be flexible enough when faced with large supply shocks, the need for explicit escape clauses is not obvious. Opponents argue that the inflation targeting framework is already flexible enough without these provisions. Furthermore, explicit escape clauses have the potential to create more confusion than the transparency they are intended to provide. Since the degree of flexibility of the regime is hard to quantify and the "extreme economic circumstance" hard to define, it is not clear when exactly they can be invoked. This makes them unclear and discretionary in nature.⁹ Additionally, if they are invoked

⁶ According to Petursson (2004) the countries including such provisions are Canada, Czech Republic, New Zealand, Phillipines, Poland, South Africa and Switzerland.

⁷ The Reserve Bank Act of Australia does specify a specific procedure for the government to go through if it wants to overrule the decision of the central bank. However, the procedure is seen as so time consuming and unwieldy that it is very unlikely that the government would go down that route.

⁸ So far there have only been a few occasions where an escape clause has been invoked. Perhaps the most notable occasion was when New Zealand invoked its escape clause in 1990-01 and in 1994 due to hikes in commodity prices (see Bernanke, Laubach, Mishkin, and Posen, 1999)

⁹ For example, Section 19.1 of the Bank of England Act does not provide any formal process for invoking the escape clause nor does it specify what is meant by "extreme economic circumstances." Also, Norway and Sweden do not

too frequently, they may erode the credibility of the regime.

1.2 Inflation Range Targeting

Dennis (1997) hints at an interesting alternative to explicit escape clauses. Without providing a theoretical framework, he argues that an inflation point target coupled with escape clauses is very similar to an inflation *range* target. Therefore he continues, "it seems natural for transparency reasons to specify a target range rather than a whole host of escape clauses." Such an interpretation seems to advocate a hard edged target range. That is, whenever inflation ends up outside the range it triggers a discrete change in monetary policy.

Indeed, a number of inflation targeting central banks do specify a target range instead of a point target for inflation. The official motivation for using target ranges, however, is usually that they convey to the public that monetary policy is an imprecise science and thus allows the central bank to miss the point target without losing credibility.¹⁰ Furthermore, central banks predominantly prefer to interpret the edges as soft, and that the policy response, given a target range of say 0-2%, is not significantly different whether inflation is 1.9% or 2.1%.

This paper argues that a target range with hard edges may, contrary to current practice, be attractive for several reasons. A hard edged inflation range is defined as the range within which the central bank is protected against government interference. If a large enough supply shock pushes inflation outside the range, the government has the right to overrule the central bank and will do so unless the central bank adjusts policy to address the government's concerns. The target range is thus a substitute for having to specify a range of escape clauses. The two approaches are equivalent, but the target range has the advantage of being easily understood by the public and unlike escape clauses, does not run the risk of being discretionary in nature. In fact, the central bank would actually never be overruled as it finds it optimal to adjust policy outside the target range rather than losing control over monetary policy. Another attractive, but equally important feature of the derived target range is that it is inversely related to the weight that the central bank places on inflation stabilization vis a vis employment stabilization. Hence, it provides a simple way for the

officially have any escape clauses. However, both central banks try to alleviate concerns about the regime's flexibility by clearly indicating that large supply shocks are legitimate reasons for extended deviations from the inflation target.

¹⁰Another argument is that politicians are more likely to adopt a target range rather than a point target since it appears more flexible.

monetary authorities to communicate to the public the degree of flexibility of the inflation targeting regime.

The theoretical literature on inflation range targeting is not extensive.¹¹ In a related paper, Mishkin and Westelius (2008) examine inflation range targeting as a remedy for the time-inconsistency problem. In their model the central bank is assumed to be subject to political pressure which distorts the bank's objective function. By specifying a target range and making the central bank bear some cost if it misses the range, they show that the time-inconsistency problem can be mitigated. Thus, they do not address the existence of escape clauses. In fact, their analysis shows that inflation range targeting can be modeled as a subset of inflation contracts similar to Walsh (1995). Furthermore, unlike the model presented in this paper, Mishkin and Westelius' model does not present a direct link between the preferences of the central bank and the bandwidth of the target range.

The theoretical literature on escape clauses is also fairly limited. Lohmann (1992), building on the work by Flood and Isard (1988), is by far the most cited work on the topic. Lohmann shows that by specifying escape clauses that allow the government to overrule the central bank when the economy is hit by large supply shocks, overall welfare is improved. The reason is that the increased flexibility of the regime reduces the excess output volatility without a significant deterioration in the average inflation rate. Thus, Lohmann's model neatly captures the motivation behind currently existing escape clauses. However, her analysis does not provide much guidance in terms of how to formulate them in practice.¹²

The rest of the paper is structured as follows. Section 2 presents a simple but attractive framework to analyze the incentives faced by the government when setting monetary policy. Section

¹¹Amano, Black and Kasumovich (1997) examine whether the literature on exchange rate target zones can be applied to inflation band targeting. Erceg (2002) interprets the target range as a confidence interval of inflation derived from the preferences of the policymakers. The optimal bandwidth should then be chosen to reflect the desired point on the trade-off locus between inflation and unemployment volatility. Orphanides and Wieland(2000) recognize that inflation band targeting implies non-linear monetary policy and show that such policy is optimal when preferences are zone-quadratic or the structure of the economy exhibits zone linearity. Athey, Atkeson, and Kehoe (2005) consider the Barro-Gordon set-up when the central bank has private information about the state of the economy. Discretion allows the central bank to react to this information but it also gives rise to a desire to over-stimulate the economy. Thus, the public has to decide the degree of discretion it should give the central bank. The authors show that an inflation cap can implement the optimal solution.

¹²Theoretically, the escape clause is defined in terms of the maximum level of the supply shock for which the government will not overrule the central bank. These supply shock limits depend, in turn, on current inflation expectations and the relative weight that the central bank places on inflation stability. To formulate an escape clause in practice based on these assumptions would be rather challenging.

3 introduces inflation range targeting and discusses various determinants of the optimal design of the target range. Section 4 comments on the inclusion of the New Keynesian Phillips curve, and section 5 concludes.

2 A Simple Framework for Monetary Policy

The economy is modeled by the standard Lucas-type supply curve:

$$u_t = u_t^n - (\pi_t - \pi_t^e) + \varepsilon_t \quad (1)$$

where the unemployment rate, u , fluctuates around its natural rate, u^n , due to unexpected inflation and supply shocks, ε . Inflation expectations, π^e , are determined before the supply shock occurs, while the realized inflation rate, π , is set by the monetary authorities after observing the shock. Thus, monetary policy has the ability to mitigate supply shocks on real activity by creating surprise inflation.

The social welfare level at time t is quadratic in inflation and unemployment and is specified as follows:

$$W_t = -\frac{1}{2}\omega (\pi_t - \pi^*)^2 - \frac{1}{2}(u_t - u^n)^2 \quad (2)$$

The socially optimal inflation level is denoted by π^* and the relative weight on inflation volatility is denoted by ω . The socially optimal rate of unemployment is assumed to be equal to its natural rate.

The government is responsible for setting monetary policy, but does so according to its own objective function, U_t^g , which may or may not coincide with the social welfare function. That is,

$$U_t^g = -\frac{1}{2}\omega^g (\pi_t - \pi^*)^2 - \frac{1}{2}(u_t - u^g)^2 \quad (3)$$

where $\omega^g \leq \omega$ and $u^g \leq u^n$. These two assumptions reflect the tendency for the political process to be biased towards a low and stable unemployment rate. Alternatively, we can write the govern-

ment's objective function as:

$$U_t^g = -\frac{1}{2} \left[\omega^g (\pi_t - \pi^*)^2 + (u_t - u^n)^2 \right] - (u_t - u^n) k^g - \frac{1}{2} (k^g)^2 \quad (4)$$

where $k^g = u^n - u^g$. That is, the government tries to stabilize unemployment around its natural rate but gains some extra utility whenever the unemployment rate is excessively low (i.e., $u_t < u^n$). The last term is a constant and can be disregarded. In this setting it makes sense to think of the parameter k^g as a measure of credibility since it reflects the government's desire to exploit the short-run relationship between inflation and unemployment in order to push unemployment below its natural level.

Optimal policy from the government's perspective can then be derived by solving the following maximization problem:

$$\max_{\pi_t} \sum_{i=0}^{\infty} \beta^i U_{t+i}^g$$

$$s.t. \quad eq(1)$$

Under discretion, the government does not believe that it can credibly manipulate inflation expectations and hence, solves the maximization problem taking the inflation expectations as given. Consequently, it collapses to a period by period maximization exercise. The government's reaction function can then be written as:

$$\pi_t^g = \pi^* + \frac{1}{\omega^g} k^g + \frac{1}{\omega^g} (u_t - u^n) \quad (5)$$

Equation (5) displays the standard "leaning against the wind" policy approach. That is, when unemployment is above its natural rate the central bank engages in expansionary policy and when the unemployment is below its natural rate, the bank contracts the economy.

Under rational expectations it is straightforward to derive the equilibrium levels of inflation and unemployment as:

$$\pi_t = \pi^* + \frac{1}{1 + \omega^g} k^g + \frac{1}{1 + \omega^g} \varepsilon_t \quad (6)$$

$$u = u^n + \frac{\omega^g}{1 + \omega^g} \varepsilon \quad (7)$$

Equation (6) displays the classical inflation bias result first derived by Kydland and Prescott (1977). The lower the credibility (i.e., a high k^g) the greater the inflation bias. Also, if $\omega^g < \omega$ unemployment volatility is lower and inflation volatility higher than what is socially optimal.

The model is an attractive starting point for the purpose of this paper for at least a couple of reasons. First, despite its simplicity, it captures the essence of supply shock management and the resulting trade-off between inflation and unemployment stabilization. The model is also flexible enough to characterize a range of different scenarios. On the one extreme, the government can enjoy perfect credibility (i.e., $k^g = 0$), respond optimally to supply shocks (i.e., $\omega^g = \omega$) and implement optimal policy. On the other extreme, the government can suffer from imperfect credibility (i.e., $k^g > 0$), display a stabilization bias (i.e., $\omega^g < \omega$), and consequently create a too high and volatile inflation rate.

3 Inflation Range Targeting

Suppose now that the government, knowing that it has a tendency to produce suboptimal policy, delegates monetary policy to a central bank with the following objective function:

$$U^{CB} = -\frac{1}{2} \left[(\omega^g + \delta) (\pi_t - \pi^*)^2 + (u_t - u^n)^2 \right] - (u_t - u^n) k^{cb} - \frac{1}{2} (k^{cb})^2 \quad (8)$$

The parameter δ reflects the extra weight that the central bank places on inflation stability. Hence, a central bank with a mandate specifying price stability as the most important objective is characterized by a greater value of δ than a central bank with a mandate setting employment and price stability on an equal footing. Furthermore, I define $k^{cb} = u^n - u^{cb} \geq 0$, where u^{cb} is the bank's unemployment target. Analog to the governments objective function, k^{cb} measures the credibility of the central bank. For instance, a central bank without incentive to exploit the Phillips curve and exhibiting perfect credibility would be denoted by $k^{cb} = 0$.

Following Walsh (2003) I characterize a flexible inflation targeting as a regime where the government delegates monetary policy to a central bank that assigns a greater relative weight to the inflation stabilization goal.¹³ In other words, the parameter δ describes the degree of flexibility of

¹³Note that the model does not exclude the possibility that the central bank's weight on inflation stabilization is equal to the socially optimal weight. If the government has a stabilization bias, then the extra weight assigned to

the regime. As $\delta \rightarrow \infty$ the central bank becomes a *pure* inflation targeter or an "inflation nutter" as King (1997) famously labeled such a regime.

Maximizing (8) subject to the Phillips curve (1), given inflation expectations, the central bank's reaction function can be derived as:

$$\pi_t^{cb} = \pi^* + \frac{1}{\omega^g + \delta} k^{cb} + \frac{1}{\omega^g + \delta} (u_t - u^n) \quad (9)$$

Equation (9) shows that the lower the degree of flexibility the regime exhibits, the less important are potential credibility issues and the lower is the inflation bias. That is, as Rogoff (1985) first pointed out, by delegating monetary policy to a weight-conservative central bank the average inflation level can be reduced. On the other hand, a greater emphasis on inflation stability also leads to an increase in unemployment volatility.¹⁴

Theoretically, it would be optimal to delegate monetary policy to a completely independent central bank with perfect credibility (i.e., $k^{cb} = 0$) and with a degree of flexibility equal to $\delta = \omega - \omega^g$. However, such an arrangement may be politically infeasible since it is unlikely that the government would be willing to permanently forgo all control of monetary policy to a central bank with preferences different than their own. Thus, there may be a limit to the government's commitment to the inflation targeting regime. To incorporate such a limit, I specify the maximum utility loss, C , that the government deems acceptable before negating on its commitment. That is, if $U^g(\pi^g) - U^g(\pi^{cb}) > C$, then the central bank is overruled and the government sets $\pi = \pi^g$.¹⁵ The important point is that as long as supply shocks are relatively small, the loss to the government is small and the regime is stable. Large supply shocks on the other hand may cause a strain between the government and the central bank and create a conflict of interest. This point resonates the concern that inflation targeting central banks have yet to experience large enough supply shocks that could potentially challenge the stability of the framework.¹⁶

inflation stabilization by the central bank may induce optimal supply shock management.

¹⁴Inflation targeting also embraces greater transparency and accountability which may improve monetary efficiency and thereby reducing both inflation and output volatility. However, those elements of inflation targeting are not the focus of this paper.

¹⁵Lohmann (1992) and Obstfeld (1996) take the same approach. Unlike Lohmann, however, I do not treat C as a choice variable.

¹⁶Indeed, the current elevation of commodity prices in the world have raised problems for several inflation targeting central banks. For instance, there have been public demands on the Reserve Bank of South Africa to invoke its version of an escape clause.

To avoid such strains to the framework, it may be optimal to include provisions in the central bank act that facilitates increased flexibility under extreme economic circumstances. Indeed, as argued above, this is exactly what we find amongst some inflation targeting countries.

3.1 Specifying a Hard Edged Target Range

Two practical problems arise given the above characterization of inflation targeting. First, how can the central bank communicate the regime's degree of flexibility to the public? Announcing the value of the relative weight assigned to inflation stabilization makes little sense. The public would probably find such information hard to interpret. Additionally, the central bank itself might have a hard time quantifying the parameter. Secondly, if an escape clause is needed, how should it be formulated? Lohmann (1992) defines the escape clause in terms of the range of supply shock values for which $U^g(\pi^g) - U^g(\pi^{cb}) < C$. The problem with such a specification is that it is difficult to implement in practice. For one, how should the central bank quantify the supply shock limits? Also, as shown by Lohmann, the boundaries of the range depend on inflation expectations. To formulate an escape clause conditioned on current inflation expectation would be rather challenging.

Instead, I argue that a time-invariant pre-specified hard edged target range for inflation could potentially solve both these problems. The width of the range would provide information about the regime's degree of flexibility as well as serving as a substitute for escape clauses. Let me first define what I will refer to as a hard edge inflation targeting range:

Definition 1 *A hard edge targeting range for inflation is an interval within which the central bank is protected from government intervention. If, however, an exogenous supply shock forces inflation outside the specified range, the government has the right to overrule the central bank if it perceives current monetary policy too costly.*

An important implication of this definition is that the central bank will not be automatically overruled whenever it misses the target range. As long as the central bank adjusts policy outside the target range to address the government's concerns, the bank continues to be the monetary authority. In fact, as will become clear, the government would never have to overrule the central bank as the bank will always find it optimal to adjust its policy response.

Given the above definition, the hard edged target range can be theoretically derived by extracting the set of inflation rates for which the government's utility loss, $U^g(\pi^g) - U^g(\pi^{cb})$, does not exceed C . That is, inside the target range the central bank sets policy according to (9), i.e., $\pi = \pi^{cb}$. If, however, the central bank would "miss" the target range due to a large enough supply shock, the government may overrule the central bank and set $\pi = \pi^g$. Of course whether the government overrules the central bank depends on whether the central bank can avoid such action by adjusting policy enough to ensure that $U^g(\pi^g) - U(\pi^{cb}) \leq C$.

Proposition 1 *The inflation range for which the utility loss of the government is lower or equal to C can be derived as:*

$$\bar{\pi} = \pi^M + BW, \text{ and } \underline{\pi} = \pi^M - BW \quad (10)$$

where

$$\pi^M = \pi^* - \left[\frac{k^g - k^{cb}}{\delta} \right] \quad (11)$$

$$BW = \frac{\sqrt{2(1 + \omega^g)C}}{\delta} \quad (12)$$

Proof. See appendix ■

There are several interesting results stemming from proposition 1. First, the bandwidth, denoted by BW , is negatively related to the degree of flexibility of the inflation targeting regime, δ . This is an attractive feature since the public can easily get a sense for the flexibility of the regime by observing the width of the target range. Furthermore, the problem of choosing the optimal relative weight on the inflation stability goal has now been transferred from an abstract choice of δ to a tangible choice of a target range for inflation. The two are theoretically equivalent but the latter much more attractive from a practical standpoint. Second, the midpoint of the range, denoted by π^M , is not necessarily equal to the socially optimal level of inflation. In fact, the midpoint of the target range should be set lower than the socially optimal level if monetary policy is delegated to a central bank with greater credibility than the government, i.e., when $k^g - k^{cb} > 0$. Also, the difference between the midpoint and the socially optimal level of inflation is less pronounced the lower the regime's degree of flexibility. To complete the description of monetary policy we need to determine the behavior of inflation outside the target range.

Proposition 2 *Outside the target range, it is optimal for the central bank to adjust the inflation rate such that the utility loss of the government, C , is never exceeded. The resulting inflation rate, π^n , can be derived as:*

$$\pi^n = \rho\pi^g + (1 - \rho)\pi^{cb} \quad (13)$$

where

$$1 - \rho = \begin{cases} \frac{BW}{(\pi^{cb} - \bar{\pi}) + BW} & \text{if } \pi^{cb} > \bar{\pi} \\ \frac{BW}{(\underline{\pi} - \pi^{cb}) + BW} & \text{if } \pi^{cb} < \underline{\pi} \end{cases} \quad (14)$$

Proof. See appendix ■

Proposition 2 makes it clear that if $\pi^{cb} \notin [\underline{\pi}, \bar{\pi}]$, the central bank makes a discrete policy change in order to avoid being overruled by the government. The resulting inflation rate is simply a convex combination of the central bank's and the government's preferred inflation rates. Equation (14) shows that the greater the distance between the boundary of the target range and the central bank's preferred inflation rate, the less bargaining power the central bank has and the more attentive it is to the concerns of the government.

3.2 Equilibrium

According to propositions 1 and 2, the central bank makes sure that it is never overruled by the government and sets the inflation rate according to the following strategy:

$$\pi = \begin{cases} \pi^{cb} & \text{if } \pi^{cb} \in [\underline{\pi}, \bar{\pi}] \\ \pi^n & \text{if } \pi^{cb} \notin [\underline{\pi}, \bar{\pi}] \end{cases} \quad (15)$$

Expected inflation can then be expressed as:

$$E\pi = \phi E[\pi^{cb} | \pi^{cb} \in [\underline{\pi}, \bar{\pi}]] + (1 - \phi) E[\pi^n | \pi^{cb} \notin [\underline{\pi}, \bar{\pi}]] \quad (16)$$

where

$$\phi = \Pr[\pi^{cb} \in [\underline{\pi}, \bar{\pi}]] \quad (17)$$

Assuming rational expectations, it is then possible to find the equilibrium inflation rate by setting $\pi^e = E\pi$.¹⁷ Figure 1 depicts the equilibrium under inflation range targeting and under full discretion (i.e., when the government does not delegate monetary policy to the central bank). The dashed line represents full discretion whereas the solid line represents inflation range targeting. The dotted line depicts the 45 degree line containing all possible equilibrium points. Under full discretion, i.e., when the government sets the inflation rate, the equilibrium inflation rate is 4%, representing an inflation bias of 2%. Under inflation range targeting, the reaction function with respect to inflation expectations is flatter within the target range, intersecting the 45 degree line at a lower point, and thus reducing the inflation bias. Figure 2 shows the policy response to a supply shock under full discretion (dashed line) and inflation range targeting (solid line). The response to the supply shock within the target range is muted relative to the full discretion case. Outside the target range the central bank is more flexible in its response to supply shocks. This discrete change in supply shock management reflects the desire of the central bank to accommodate the government's concern about excessive output fluctuations.

3.3 The Optimal Target Range

This section looks at four relevant determinants of the optimal bandwidth of the target range: (i) the initial inflation bias, (ii) the degree of credibility of the central bank relative to the government, $k^g - k^{cb}$, (iii) the stabilization bias, $\omega - \omega^g$, and (iv) supply shock volatility, σ_ε . The benchmark case for the simulations is consistent with the specification used by most papers in the time-inconsistency literature (e.g., Barro and Gordon, 1983, Rogoff, 1985, Lohmann, 1992, and Walsh, 1995). That is, under full discretion, there is no stabilization bias (i.e., $\omega^g = \omega$) and only an inflation bias which is the same for the central bank and the government (i.e., $k^g = k^{cb} > 0$). Thus, the government responds optimally to supply shocks but aims for a too low unemployment rate.¹⁸

Figure 3 shows the impact of inflation range targeting, given various bandwidths, on welfare, inflation, inflation volatility and unemployment volatility. Note that since $k^g = k^{cb}$ (i.e., the central bank inherits the credibility level of the government), the midpoint of the target range coincides

¹⁷The closed form solution depends on the distribution function of the supply shock. Since I assume that the supply shock is normally distributed, no closed form solution exists and I resort to simulations instead.

¹⁸Unlike Lohmann (1992), the parameter C is not treated as a choice variable, but as an institutional parameter reflecting the government's commitment to the regime.

with the optimal level of inflation. The dashed horizontal lines in each sub-figure represent the levels of each measure for which welfare is maximized. The figure shows how reduced flexibility (i.e., a tighter bandwidth) mitigates the inflation bias but raises unemployment volatility and lowers inflation volatility. The optimal bandwidth is determined at the point where the marginal benefit from a lower average inflation rate equals the marginal cost of higher unemployment variability and lower inflation volatility.

Table 1 shows the optimal bandwidth for various initial inflation levels. Optimal policy represents the case where the monetary authorities can commit to an optimal rule and do not fall into the time-inconsistency trap.¹⁹ Full discretion represents the case where the government is responsible for monetary policy (i.e., no delegation of monetary policy to the central bank). As the inflation bias increases, the optimal bandwidth decreases. This reflects the fact that the benefits of a stricter regime are greater when the credibility level is low and the initial inflation bias is high. This is consistent with the idea that countries with low initial credibility should introduce a less flexible inflation targeting regime and progressively increase the regime’s flexibility as credibility is improved (e.g., Svensson, 2008).

Result 1: *The lower the credibility of the government (and the central bank), the lower the optimal degree of flexibility, and consequently, the narrower the optimal target range.*

The previous result assumes that the central bank inherits the credibility problems of the government. Table 2 shows the optimal bandwidth and midpoint when monetary policy is delegated to a central bank enjoying a higher degree of credibility than the government. The initial inflation bias is assumed to be the same across simulations (i.e., k^g is held constant). The relative degree of credibility is measured by $k^g - k^{cb}$. As the credibility of the central bank increases, the optimal target range widens while the midpoint decreases. The latter result stems from proposition 1, and simply indicates that the entire target range must be adjusted downward due to the increased difference in credibility between the government and the central bank. The widening of the optimal target range, however, reflects the improved credibility of the central bank and thus the reduced need to deal with the inflation bias within the target range. The increased flexibility, in turn, lowers

¹⁹The optimal rule is $\pi_t = \pi^* + \frac{1}{1+\omega}\varepsilon_t$.

unemployment volatility, raises inflation volatility, and increases overall welfare.

Result 2: *The greater the credibility of the central bank relative to the government, the higher the optimal degree of flexibility, and consequently the wider the optimal target range (and the lower the midpoint).*

So far we have not allowed the government's relative weight on inflation stabilization to differ from the socially optimal weight. It is conceivable, however, that the government prefers a more stable unemployment rate (i.e., $\omega > \omega^g$) than what is socially optimal. Table 3 shows how the optimal target range is affected by the degree of the government's stabilization bias. To focus on the stabilization bias, the simulations assume that $k^g = k^{cb} = 0$. There are two factors affecting the optimal bandwidth. First, given δ , as ω^g decreases, the difference between the preferences of the central bank and the government increases, and as seen from (12) the bandwidth must thus decrease. Secondly, to compensate for the rise in the stabilization bias, and the resulting increase in inflation volatility, the central bank would have to become less flexible in its response to supply shocks within the target range.

Result 3: *The greater the stabilization bias of the government, the lower the optimal degree of flexibility, and consequently, the narrower the optimal target range.*

Another important determinant of the optimal target range is supply shock volatility. Table 4 shows the optimal target range for various levels of σ_ε . A higher level of supply shock variation, given the bandwidth, increases the likelihood of missing the target range and raises inflation expectations. By widening the target range and making the regime more flexible, the probability of missing the target range is reduced. The cost of increased flexibility, however, is a greater inflation bias within the target range. The optimal bandwidth is determined at the point where the marginal benefit from a lower probability of missing the target range equals the marginal cost of a higher average inflation rate.

Result 4: *The greater the supply shock volatility, the higher the optimal degree of flexibility, and consequently, the wider the optimal target range.*

Overall, tables 1-4 show that a hard edge target range does fairly well in increasing welfare relative to the full discretion case. In tables 1, 2 and 4 the initial excess inflation of 2% is reduced to 0.3 or less. Also, the excess inflation volatility due to the stabilization bias in table 4 is almost eliminated.²⁰ The welfare improvements could be further enhanced by allowing for the government's maximum welfare loss, C , to be a choice variable. For instance, C could be interpreted as the degree of legal protection and oversight that the central bank is subject to. However, I abstract from this scenario since it would be practically difficult to translate such a measure into a numerical value.

4 The New Keynesian Phillips Curve

The model presented in section 3 is built around a Lucas-type supply curve. Today, however, most theoretical work on monetary policy makes use of the so-called New Keynesian Phillips curve which emphasizes overlapping price/wage contracts which forces agents in the economy to be forward-looking. That is, instead of equation (1) the supply curve relationship is formulated as:

$$\pi_t = \pi_{t+1|t}^e + \lambda x_t + \varepsilon_t \quad (18)$$

where x_t denotes the output gap (i.e., the difference between potential output and the realized output level). The main difference between the Phillips curves is that expectations of future inflation matter in (18) while expectations about the current inflation rate matter in (1).²¹ Such a difference is important in terms of supply shock management as Clarida et al (1999) show. For the purposes of this paper, however, this difference is of little importance. Assuming that inflation expectations are set before the realization of the cost push shock, ε , and that policy is discretionary, proposition 1 and 2 are still valid since the target range is not dependent on inflation expectations. Thus, the target range and the reaction function of the central bank remain the same.

However, in terms of finding the equilibrium on the model, we need to pin down the expectations for the future inflation rate. An attractive way of doing this is presented by Jensen (2002) who

²⁰Mishkin and Westelius (2008) also find that the optimal target range is negatively related to the inflation and stabilization bias, and positively related to supply shock volatility.

²¹Also, in the New Keynesian framework the monetary authorities are assumed to control the output gap through an IS-curve relationship.

makes use of a two-period new Keynesian model, i.e.,

$$\pi_1 = \pi_{2|1}^e + \lambda x_1 + \varepsilon \tag{19}$$

$$\pi_2 = \pi_{3|2}^e + \lambda x_2 \tag{20}$$

where the second period is interpreted as the "long-run." In such a setting, it makes sense to set $\pi_{3|2}^e$ equal to the unconditional expected inflation rate consistent with equation (16) and for the output gap to be zero, i.e., $x_2 = 0$. It then follows that $\pi_{2|1}^e = \pi_{3|2}^e$, which ensures that the equilibrium inflation level is the same as in section 3.

5 Conclusion

This paper analyzes the attractiveness of a hard edged target range in reducing welfare distortions due to the time-inconsistency problem. A hard edged target range is defined as the set of inflation rates for which the central bank enjoys complete independence from the government. Outside the range, however, the government has the power to overrule the central bank if it finds it necessary. It is shown, however, that it is always optimal for the central bank to adjust policy outside the target range in order to retain control of monetary policy. Such an arrangement is attractive for several reasons. First, it functions as a substitute for having to specify a range of escape clauses that may be difficult to interpret and discretionary in nature. Second, since the bandwidth of the target range is inversely related to the degree of flexibility of the regime, it becomes easier for the public to get a sense for the regime's flexibility simply by observing the width of the target range. Furthermore, the problem of choosing the optimal relative weight on the inflation stabilization goal is effectively transferred from an abstract choice to a tangible choice of a target range for inflation.

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A Appendix

A.1 Proof of Proposition 1

Denote the upper and lower boundaries of the target range by $\bar{\pi}$ and $\underline{\pi}$ respectively. Given the central bank's reaction function under inflation targeting (9), inflation is inside the range if the supply shock, ε lies in the interval $(\bar{\varepsilon}, \underline{\varepsilon})$ where

$$\bar{\varepsilon}(\bar{\pi}) = (1 + \omega^g + \delta)(\bar{\pi} - \pi^*) + (\pi^* - \pi^e) - k^{cb} \quad (\text{A.1})$$

$$\underline{\varepsilon}(\underline{\pi}) = (1 + \omega^g + \delta)(\underline{\pi} - \pi^*) + (\pi^* - \pi^e) - k^{cb} \quad (\text{A.2})$$

Using (5) and (9) and the government's utility function (and after some algebraic manipulation), we can derive the government's perceived welfare cost of inflation targeting as:

$$U^G(\pi^g) - U^G(\pi^{cb}) = -\frac{1}{2} \left[\begin{array}{c} \frac{\omega^g}{(1+\omega^g)} [k^g - (\pi^* - \pi^e) + \varepsilon]^2 \\ -\omega^g \left(\frac{1}{(\omega^g + \delta)} [k^{cb} - (\pi^* - \pi^e) + \varepsilon] \right)^2 \\ - \left((k^g - k^{cb}) + \frac{\delta}{(\omega^g + \delta)} [k^{cb} - (\pi^* - \pi^e) + \varepsilon] \right)^2 \end{array} \right] \quad (\text{A.3})$$

Substituting (A.1) and (A.2) into (A.3), and simplifying the expression we have:

$$U^G(\pi^G) - U^G(\pi^{CB}) = \frac{1}{2(1 + \omega^g)} \left[(k^g - k^{cb}) + \delta(\bar{\pi} - \pi^*) \right]^2 \quad (\text{A.4})$$

$$U^G(\pi^G) - U^G(\pi^{CB}) = \frac{1}{2(1 + \omega^g)} \left[(k^g - k^{cb}) + \delta(\underline{\pi} - \pi^*) \right]^2 \quad (\text{A.5})$$

The government will not overrule the central bank as long as $U^G(\pi^G) - U^G(\pi^{CB}) \leq C$. Thus we have that the upper and lower boundaries of the target range must be defined as:

$$C = \frac{1}{2(1 + \omega^g)} \left[(k^g - k^{cb}) + \delta(\bar{\pi} - \pi^*) \right]^2 \quad (\text{A.6})$$

$$C = \frac{1}{2(1 + \omega^g)} \left[(k^g - k^{cb}) + \delta(\underline{\pi} - \pi^*) \right]^2 \quad (\text{A.7})$$

or equivalently,

$$\bar{\pi} - \pi^* = \frac{-(k^g - k^{cb}) + \sqrt{2(1 + \delta^g)C}}{\delta} \quad (\text{A.8})$$

$$\bar{\pi} - \pi^* = \frac{-(k^g - k^{cb}) - \sqrt{2(1 + \delta^g)C}}{\delta} \quad (\text{A.9})$$

Denoting $BW = \frac{\sqrt{2(1 + \omega^g)C}}{\delta}$ and $\pi^M = \pi^* - \frac{(k^g - k^{cb})}{\delta}$, we have the result in proposition 1.

A.2 Proof of Proposition 2

Outside the target range the central bank can no longer set inflation equal to π^{cb} since it will be overruled. However, since π^{cb} maximizes U^{cb} , and the utility function is concave in π , it must true that:

$$U^{cb}(\pi^{cb}) \geq U^{cb}(\rho\pi^g + (1 - \rho)\pi^c) \geq U^{cb}(\pi^g) \quad (\text{A.10})$$

where $0 \leq \rho \leq 1$. The inflation rate that maximizes the central bank's utility without exceeding the maximum government welfare loss can thus be written as:

$$\pi^n = \rho\pi^g + (1 - \rho)\pi^{cb} \quad (\text{A.11})$$

where ρ solves the following equation:

$$U^g(\pi^{cb}) - U^g(\rho\pi^g + (1 - \rho)\pi^c) = C \quad (\text{A.12})$$

After some algebraic manipulation, it is possible to write (A.12) as:

$$\frac{1}{2}(1 - \rho)^2(1 + \omega^g) \left[(\pi^{cb} - \pi^*) - (\pi^g - \pi^*) \right]^2 = C \quad (\text{A.13})$$

Solving for ρ we have:

$$1 - \rho = \sqrt{\frac{2C}{(1 + \omega^g)}} \left[\frac{1}{(\pi^{cb} - \pi^*) - (\pi^g - \pi^*)} \right] \quad (\text{A.14})$$

Finally, using the results from proposition 1, and the fact that

$$(1 + \omega^g)(\pi^g - \pi^*) = (1 + \delta) \left(\pi^{cb} - \pi^* \right) - \left(k^{cb} - k^g \right) \quad (\text{A.15})$$

expression (A.14) can be rewritten as:

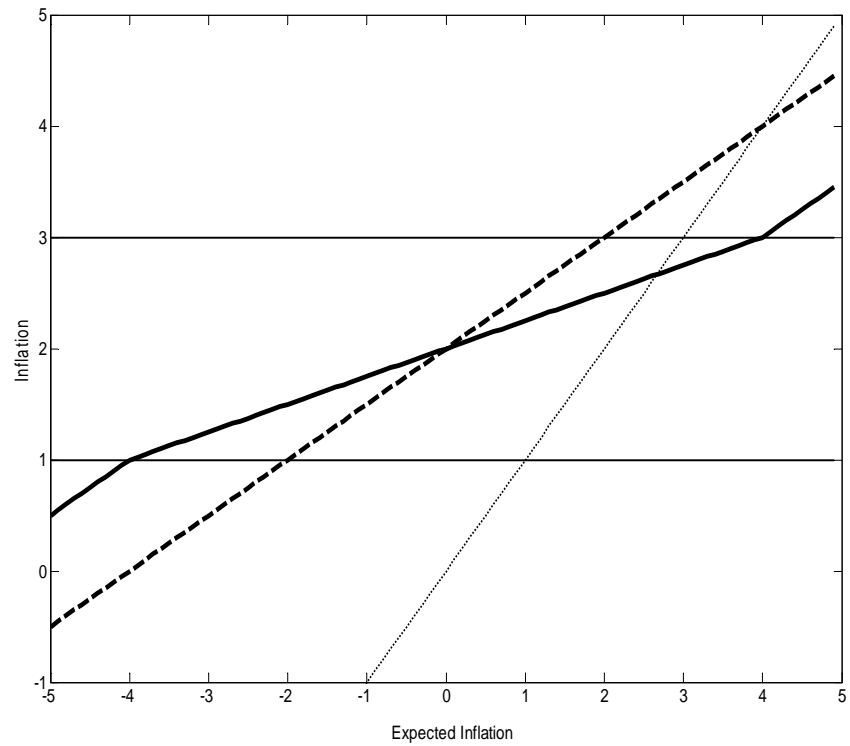
$$1 - \rho = \frac{BW}{(\pi^{cb} - \bar{\pi}) + BW} \quad (\text{A.16})$$

when $\pi^{cb} > \bar{\pi}$ and

$$1 - \rho = \frac{BW}{(\bar{\pi} - \pi^{cb}) + BW} \quad (\text{A.17})$$

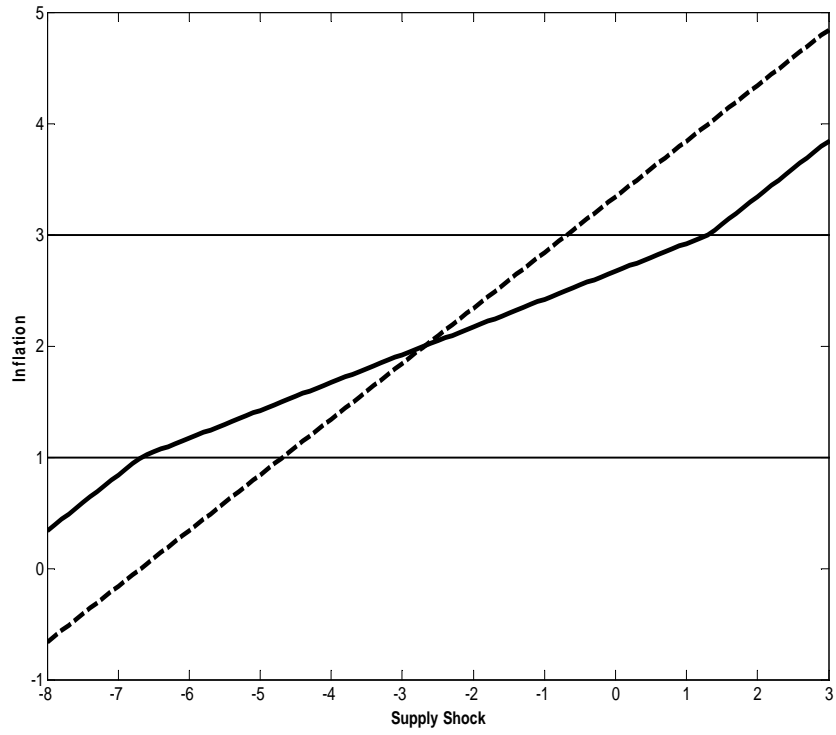
when $\pi^{cb} < \bar{\pi}$.

Figure 1: Equilibrium Inflation



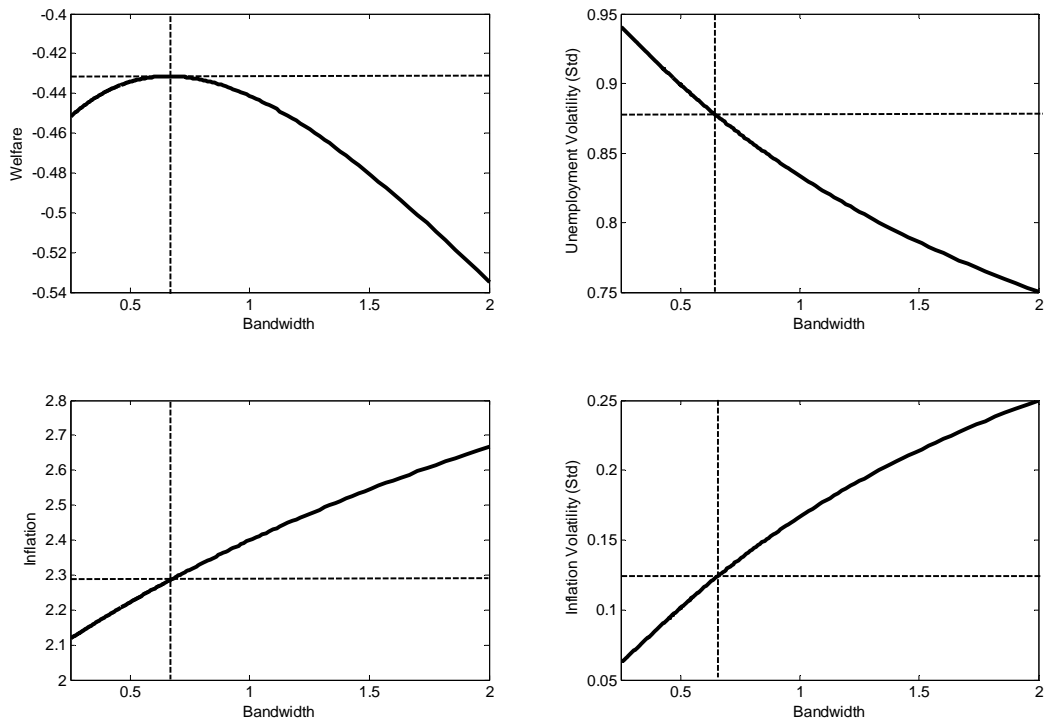
The dashed line represents the government's reaction function without delegation and the solid line represents the reaction function under inflation range targeting. The dotted line is the 45 degree line representing all possible equilibria. The parameterization used to generate the figure was as follows:
 $\delta = 2, \omega^g = 1, k^g = 2, k^{CB} = 2, \pi^* = 2, C = 1$

Figure 2: Supply Shock Management



The dashed line represents the government's reaction function without delegation and the solid line represents the reaction function under inflation range targeting. The dotted line is the 45 degree line representing all possible equilibria. The parameterization used to generate the figure was as follows:
 $\delta = 2, \omega^g = 1, k^g = 2, k^{c^g} = 2, \pi^* = 2, \zeta = 1, \sigma_\varepsilon = 1$

Figure 3: Optimal Bandwidth (BW)



The dashed lines indicate the optimal bandwidth with the respective value for welfare, Inflation, inflation volatility, and unemployment volatility. The parameterization used to generate the figure was as follows: $\omega = 1$, $\omega^g = 1$, $k^g = 2$, $k^{c^g} = 2$, $\pi^* = 2$, $C = 4$, $\sigma_z = 1$. Under optimal policy, the welfare = -0.25, inflation= 2%, inflation volatility = 0.5 (std), and unemployment volatility = 0.5 (std)

TABLE 1
Inflation Bias and the Optimal Target Range

	Inflation Bias (k^g)				
	1.25	1.50	1.75	2.00	2.25
Optimal Target Range (BW)	1.31	1.03	0.82	0.66	0.53
Midpoint (π^M)	2.00	2.00	2.00	2.00	2.00
Inflation					
Optimal Policy	2.00	2.00	2.00	2.00	2.00
Full Discretion	3.25	3.50	3.75	4.00	4.25
Inflation Range Targeting	2.31	2.31	2.30	2.28	2.27
Inflation Volatility (std)					
Optimal Policy	0.50	0.50	0.50	0.50	0.50
Full Discretion	0.50	0.50	0.50	0.50	0.50
Inflation Range Targeting	0.20	0.17	0.15	0.12	0.11
Unemployment Volatility (std)					
Optimal Policy	0.50	0.50	0.50	0.50	0.50
Full Discretion	0.50	0.50	0.50	0.50	0.50
Inflation Range Targeting	0.80	0.83	0.86	0.88	0.89
Welfare Level					
Optimal Policy	-0.25	-0.25	-0.25	-0.25	-0.25
Full Discretion	-0.78	-1.13	-1.53	-2.00	-2.53
Inflation Range Targeting	-0.39	-0.41	-0.42	-0.43	-0.44

The simulations assume that the central bank inherits the government's credibility level (i.e., $k^g = k^{cb}$). The parameterization used to generate the table was as follows: $\omega = 1$, $\omega^g = 1$, $\pi^* = 2$, $C = 4$, $\sigma_\varepsilon = 1$. Optimal policy represents the case where the government commits to a 2% inflation level and responds to supply shocks optimally (i.e., with the social optimal weight). Full discretion represents the case where monetary policy is set by the government (i.e., no delegation).

TABLE 2
Central Bank Credibility and the Optimal Target Range

	Credibility ($k^g - k^{cb}$)				
	0	0.25	0.5	0.75	1
Optimal Target Range (BW)	0.66	0.81	1.02	1.32	1.79
Midpoint (π^M)	2.00	1.95	1.87	1.75	1.55
Inflation					
Optimal Policy	2.00	2.00	2.00	2.00	2.00
Full Discretion	4.00	4.00	4.00	4.00	4.00
Inflation Range Targeting	2.28	2.30	2.30	2.31	2.31
Inflation Volatility (std)					
Optimal Policy	0.50	0.50	0.50	0.50	0.50
Full Discretion	0.50	0.50	0.50	0.50	0.50
Inflation Range Targeting	0.12	0.14	0.17	0.20	0.24
Unemployment Volatility (std)					
Optimal Policy	0.50	0.50	0.50	0.50	0.50
Full Discretion	0.50	0.50	0.50	0.50	0.50
Inflation Range Targeting	0.88	0.86	0.83	0.80	0.76
Welfare Level					
Optimal Policy	-0.25	-0.25	-0.25	-0.25	-0.25
Full Discretion	-1.88	-1.88	-1.88	-1.88	-1.88
Inflation Range Targeting	-0.43	-0.42	-0.41	-0.39	-0.37

The simulations assume that the government's credibility level is 2 (i.e., $k^g = 2$). The parameterization used to generate the table was as follows: $\omega = 1$, $\omega^g = 1$, $\pi^* = 2$, $C = 4$, $\sigma_\varepsilon = 1$. Optimal policy represents the case where the government commits to a 2% inflation level and responds to supply shocks optimally (i.e., with the social optimal weight). Full discretion represents the case where monetary policy is set by the government (i.e., no delegation).

TABLE 3
Stabilization Bias and the Optimal Target Range

	Stabilization Bias ($\omega - \omega^g$)				
	0.40	0.50	0.60	0.70	0.80
Optimal Target Range (BW)	1.35	1.10	0.85	0.73	0.60
Midpoint (π^M)	2.00	2.00	2.00	2.00	2.00
Inflation					
Optimal Policy	2.00	2.00	2.00	2.00	2.00
Full Discretion	2.00	2.00	2.00	2.00	2.00
Inflation Range Targeting	2.00	2.00	2.00	2.00	2.00
Inflation Volatility (std)					
Optimal Policy	0.50	0.50	0.50	0.50	0.50
Full Discretion	0.63	0.67	0.71	0.77	0.83
Inflation Range Targeting	0.50	0.51	0.51	0.54	0.58
Unemployment Volatility (std)					
Optimal Policy	0.50	0.50	0.50	0.50	0.50
Full Discretion	0.38	0.33	0.29	0.23	0.17
Inflation Range Targeting	0.50	0.49	0.49	0.46	0.43
Welfare Level					
Optimal Policy	-0.25	-0.25	-0.25	-0.25	-0.25
Full Discretion	-0.27	-0.28	-0.30	-0.32	-0.36
Inflation Range Targeting	-0.25	-0.25	-0.25	-0.25	-0.26

The simulations assume that ω^g varies between 0.2 and 0.6. The parameterization used to generate the table was as follows: $\omega = 1, \pi^* = 2, C = 0.1, \sigma_\varepsilon = 1$. Optimal policy represents the case where the government commits to a 2% inflation level and responds to supply shocks optimally (i.e., with the social optimal weight). Full discretion represents the case where monetary policy is set by the government (i.e., no delegation).

TABLE 4
Supply Shock Volatility and the Optimal Target Range

	Supply Shock Volatility (σ_ε)				
	0.50	0.75	1.00	1.25	1.50
Optimal Target Range (BW)	0.22	0.43	0.66	0.91	1.16
Midpoint (π^M)	2.00	2.00	2.00	2.00	2.00
Inflation					
Optimal Policy	2.00	2.00	2.00	2.00	2.00
Full Discretion	4.00	4.00	4.00	4.00	4.00
Inflation Range Targeting	2.10	2.19	2.28	2.37	2.45
Inflation Volatility (std)					
Optimal Policy	0.25	0.38	0.50	0.63	0.75
Full Discretion	0.25	0.38	0.50	0.63	0.75
Inflation Range Targeting	0.02	0.07	0.12	0.20	0.28
Unemployment Volatility (std)					
Optimal Policy	0.25	0.38	0.50	0.63	0.75
Full Discretion	0.25	0.38	0.50	0.63	0.75
Inflation Range Targeting	0.48	0.68	0.88	1.05	1.22
Welfare Level					
Optimal Policy	-0.06	-0.14	-0.25	-0.39	-0.56
Full Discretion	-2.00	-2.14	-2.25	-2.39	-2.56
Inflation Range Targeting	-0.12	-0.26	-0.43	-0.64	-0.89

The parameterization used to generate the table was as follows: $k^g = k^{cb}=2$, $\omega = 1$, $\omega^g = 1$, $\pi^* = 2$, $C = 4$. Optimal policy represents the case where the government commits to a 2% inflation level and responds to supply shocks optimally (i.e., with the social optimal weight). Full discretion represents the case where monetary policy is set by the government (i.e., no delegation).