Delegation and Loose Commitment

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Abstract

This paper analyzes and compares the performance of different delegation schemes when the central bank has imperfect commitment. A continuum of loose commitment possibilities is considered ranging from full commitment to full discretion. The results show that the performance of inflation targeting improves substantially with higher commitment levels. On the other hand, the performance of other targeting regimes does not necessarily improve with the commitment level of the central bank. While it was previously thought that inflation targeting is inferior to other targeting regimes, the results show that it can be the best performing regime as long as the commitment level is not too low. These results may provide a theoretical explanation for the high popularity of inflation targeting among central banks.

JEL *classification*: E52, E58, E61

Keywords: Targeting Regimes, Imperfect Commitment

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1 Introduction

The optimal design of monetary institutions and objectives has received considerable attention both from academics and policymakers. Rogoff (1985) showed that if optimal monetary policy is time-inconsistent and the central bank operates under full discretion, then the central bank should be delegated objectives which are different than society's. More recent results regarding monetary policy (e.g. Clarida et al. (1999) among many others) have shown that even without an inflation bias it is still desirable to distort the central bank objectives in order to improve the short-run response to shocks (so-called stabilization bias).

The literature that has analyzed delegation and the stabilization bias typically assumed that central banks operate with full discretion. This seems to be, to some extent, unrealistic. Central banks may have some credibility problems, but assuming that central banks have no credibility at all seems to be rather extreme. Indeed, it is not clear that central banks lack commitment. Blinder (1998) stated that commitment problems are dealt with by "norms of behavior" (Blinder, 1998 p. 49)". Obviously if one considers that central banks have full commitment then there is no role for delegation. However, there is a role for delegation in a setting where there is a continuum of loose commitment possibilities ranging from full commitment to full discretion. In such setting, the central bank has partial commitment (or imperfect credibility to maintain promises). These loose commitment settings are modeled as in Roberds (1987), Schaumburg and Tambalotti (2007), and Debortoli and Nunes (2007, 2008a).

In this paper, I assume that the objectives of the central bank cannot be changed, unlike Debortoli and Nunes (2008a). Thus, society can perfectly commit to a delegation scheme.[1] Once central bank's objectives are set, instead of assuming that the central bank behaves with full discretion, I assume an imperfect commitment setting. In this context, the paper examines several delegation schemes and shows how their performance changes with the commitment level of the central bank.

An optimal precommitment policy (the best possible policy under full commitment) imparts inertia to policy even when expectations are purely forward-looking. A central bank operating under full discretion will fail to introduce inertia. Because of this feature, delegation schemes often introduce an endogenous state-variable in the central bank objective function, which imparts inertia into a monetary policy even under full discretion. However, if the central bank has a modest degree of commitment it already imparts inertia into the system. In such a case, delegation schemes which introduce an endogenous state-variable may impart an excessive and detrimental amount of inertia. Due to this reason, the properties of the economy are likely to change substantially with intermediate degrees of commitment relative to the case of full discretion.

The paper is organized as follows. Section 2 introduces the model and different delegation schemes. Section 3 presents the main results. Section 4 examines alternative scenarios. Section 5 concludes.

2 The model

The analysis is based on a simple New Keynesian model. The New Keynesian Phillips curve (NKPC) is a reduced form approximation of the relationship between inflation and output in an economy with monopolistic competition and staggered

[1] For another recent analysis with objective changes see Korinek and Stiglitz (2008).

price setting.[2] Throughout the paper, I assume a perfect information environment.[3] Following Galí and Gertler (1999), I consider the possibility that the Phillips curve may also include a backward-looking term. The hybrid Phillips curve takes the form

$$\pi_t = \kappa x_t + \alpha\beta E_t\pi_{t+1} + (1-\alpha)\beta\pi_{t-1} + u_t \tag{1}$$

where π_t denotes price inflation and $x_t = y_t - y_t^n$ measures the output-gap, i.e. the difference between current output (y_t) and the output level that would prevail under flexible prices (y_t^n). The natural output level (y_t^n) follows an AR(1) process given by

$$y_t^n = \rho_y y_{t-1}^n + \zeta_t^y \qquad 0 \leq \rho_y < 1 \tag{2}$$

where ζ_t^y is a mean-zero innovation with standard deviation σ_y. The cost-push shock u_t follows an AR(1) process given by

$$u_t = \rho_u u_{t-1} + \zeta_t^u \qquad 0 \leq \rho_u < 1 \tag{3}$$

where ζ_t^u is a mean-zero innovation with standard deviation σ_u. As is standard in the optimal monetary policy literature, it is assumed that the central bank controls inflation and the output-gap directly.[4] The welfare loss function of society is assumed to take the form

$$L = E_0 \sum_{t=0}^{\infty} \beta^t \left[-\frac{1}{2}(\pi_t^2 + \omega {x_t}^2) \right] \tag{4}$$

A few remarks about equation (4) are in order. First, the assumption of a zero inflation target is merely a convenient normalization. Second, such a loss function

[2]The theoretical framework underlying such relationship is described for instance in Yun (1996), Woodford (2003a) and Galí (2008).

[3]For two very interesting discussions of optimal monetary policy with imperfect information see Mertens (2007) and Kim and Henderson (2005).

[4]The interest rate i_t required to implement the desired inflation level can be obtained from the demand side of the economy, not modeled here.

can under some circumstances be derived as an approximation to the utility function of a representative consumer in the case of a pure forward-looking NKPC. I will consider both a pure forward-looking and a hybrid NKPC. Most studies on delegation have assumed such a loss function even under inflation persistence. To allow comparability of results, I follow the same approach, and analyze how targeting regimes are affected by the introduction of imperfect commitment. Finally, in line with the related literature, I assume an output-gap target of zero. The potential gains from delegating targeting regimes are only due to an improved stabilization bias in response to shocks. Unlike in Rogoff (1985), the potential gains from delegation do not accrue from correcting the inflation bias. Also, an output-gap target of zero does not introduce an incentive for monetary surprises in steady-state. In this case, the optimal precommitment policy and the non-optimal timeless perspective policy coincide.[5]

2.1 Loose commitment and imperfect credibility

Imperfect credibility or loose commitment is modeled as in Roberds (1987). Schaumburg and Tambalotti (2007) generalized Roberds (1987) results to linear quadratic settings and provided a very interesting application to monetary policy. Debortoli and Nunes (2007) provided proofs and extended the results to general dynamic-programming problems, and showed an application to fiscal policy. The central bank is assumed to be able to make a policy plan regarding future actions. However, in future periods previous promises may either be fulfilled or reneged according to an exogenous stochastic probability. The central bank optimization problem is analogous to the firm problem facing an exogenous Calvo probability

[5]Currie and Levine (1993), Marcet and Marimon (1998) and Woodford (2003b) provide a detailed discussion of this topic.

of being able to change prices.[6] This allows for tractability of the model, and still allows to analyze optimal policy in such settings. Both the private sector, and the central bank itself know that the policy plan is only expected to last for some periods (not known with certainty). When the policy plan breaks, a reoptimization occurs and a new plan is implemented. The parameter defining the expected duration of a plan determines the commitment level of the central bank. At one extreme, the plan is never kept and one is back to the full discretion solution. At the other extreme, the plan is known to be effective forever and one is back to the full commitment setup.

Such a setting characterizes situations when policymakers can guarantee their own promises but cannot influence the behavior of their successors, who are expected to formulate a new policy plan. Such situations are common given governor appointments in central banks and staff turnover. Moreover the same policymakers may, under some exogenous circumstances, reformulate and reoptimize their plans.

If plans are expected to last for (T) periods with an i.i.d. exogenous probability (q) to be broken at any point in time, then the problem can be formulated as:[7]

$$
\begin{aligned}
V(\pi_{t-1}, u_t) &= \max_{\{\pi_t, x_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} (\beta q)^t \{-\frac{1}{2}\left[\pi_t^2 + \omega x_t^2\right] + \beta(1-q) E_t V(\pi_t, u_{t+1})\} \qquad (5) \\
s.t. \quad \pi_t &= \kappa y_t + (1-\alpha)\beta\pi_{t-1} + \beta\alpha q E_t \pi_{t+1} + \beta\alpha\,(1-q)\, E_t \Psi(\pi_t, u_{t+1}) + u_t \\
u_t &= \rho_u u_{t-1} + \zeta_t^u \qquad \forall t = 0, 1, ...
\end{aligned}
$$

Since agents anticipate that next period promises may be either reneged or kept, forward-looking expectations consist of two components. The term $E_t \pi_{t+1}$ refers to the expected inflation rate if no default occurs. The term $E_t \Psi(\pi_t, u_{t+1})$ refers to the

[6] The central bank problem is more complex because its constraints depend on future actions.

[7] More precisely, $T = \frac{1}{1-q}$.

expected inflation rate if previous plans are not carried out. The inflation rate under default $\Psi(\pi_t, u_{t+1})$ does not depend on any previous plans, and is a function of the state-variables (last-period inflation and the contemporaneous cost-push shock).[8] Under imperfect credibility, the objective function is also slightly changed. The central bank can make a plan for all future variables if default does not occur. But if default does occur, the current central bank anticipates the policies and the value function (V) that is implemented from that node onwards.

The following equilibrium definition is employed:

Definition 1 *A Markov Perfect Equilibrium solution of problem (5) must satisfy the following:*

1. Given V and Ψ, the sequence $\{\pi_t, x_t\}_{t=0}^{\infty}$ maximizes problem (5).

2. The value function V is the maximum of problem (5).

3. Define $\psi(\pi_{t-1}, u_t, \lambda_{t-1})$ to be the optimal policy function of inflation solving problem (5), where $\{\lambda_t\}_{t=0}^{\infty}$ is the sequence of lagrange-multipliers associated with the NKPC constraints. Then $\Psi(\pi_{t-1}, u_t) = \psi(\pi_{t-1}, u_t, 0)$.

We refer to a Markov Perfect Equilibrium, because Ψ only depends on the state variables (π_{t-1}, u_t). The first part of the definition states that, given the anticipated continuation value (V) and private sector beliefs about the default policy (Ψ), the central bank is maximizing. The second part imposes that, when a default occurs, the central bank makes a new plan that is optimal attaining the maximum welfare value (V).[9] The final part requires private sector beliefs about the default policy

[8] If $\alpha = 1$, then the cost-push shock is the only state-variable.

[9] If central bank's objectives before and after defaulting do not coincide, then the second part of the definition should not hold. This corresponds to a case with alternating regimes or with political disagreement, which has been addressed in Debortoli and Nunes (2008a,b).

to be correct and consistent with the optimal policy function implemented in such case. As Marcet and Marimon (1998) discuss, previous promises are summarized by the last-period lagrange-multiplier (λ_{t-1}). In case of default, λ_{t-1} is reset to zero since previous promises are abandoned. Further details on this type of formulation can be found in Debortoli and Nunes (2007).

2.2 Delegation schemes

Delegation schemes are modeled as a set of incentive mechanisms for central banks, which induce a behavior that aims at attaining various policy goals. (e.g. Rogoff (1985), Walsh (1995), Svensson (1997)). These set of incentives are also known as targeting regimes. The targeting regimes considered are understood to be flexible, i.e. the central bank may optimally let variables be off target.

In related work, Debortoli and Nunes (2008a) consider that the imperfect credibility in the economy relates to changing monetary policy objectives. In this work, I consider that there is perfect credibility when implementing the targeting regime, however the central bank itself has imperfect credibility about committing to future policy actions. Hence, it is always assumed that society can fully commit to an institutional setup. This feature is subject to the McCallum (1995) critique of monetary delegation theories, since society itself would like to take control of policy once expectations are set. This paper only discusses targeting regimes where the relevant parameters (weights and targets) are constrained to be constant. As Beetsma and Jensen (1999) argue, a monetary institutional setup with characteristics that do not change with the business cycle is less subject to the McCallum (1995) critique.[10] In addition, as Walsh (2003a) describes, the temptation to renege on a targeting regime

[10]Time-inconsistency issues could be hard to monitor if it was institutionally allowed to change the loss function frequently according to the evolution of the economy.

may be overcome due to the high embarrassment costs of overriding the publicly known targeting regime and the laws that enforce it. In this sense, it may be easy to commit to a targeting regime if it is explicitly and publicly adopted and enforced through a clear mandate.

The optimal benchmark for the delegation schemes is the policy that a central bank with full commitment would implement when minimizing the social welfare function. We denote this best possible scenario as the "optimal precommitment policy". As it is well known, in response to cost-push shocks the optimal precommitment policy implies a promise of a prolonged recession which induces a deflation. The future deflation makes the current inflation to be dampened due to an expectations effect. The optimal policy is also inertial since the recession is less costly if it is small and prolonged rather than drastic and short-lived.

The first targeting regime considered is inflation targeting (IT), which was proposed in different forms, for instance, by Rogoff (1985) and Svensson (1997). The period loss function under IT is:

$$U_{IT} = -\frac{1}{2}(\pi_t^2 + \omega_{IT} x_t^2) \tag{6}$$

It is well know that there are gains from IT even if the output-gap target is zero. These gains accrue due to a more efficient response to cost-push shocks. Previous studies found that delegating an IT regime when the central bank has full discretion produces only limited welfare gains. Assigning $\omega_{IT} \leq \omega$, makes the central bank correct the impulse response function dampening more strongly inflation in the current and future periods. However, an inflation targeting regime fails to produce a deflation or to impart inertia into policy.

Walsh (2003b) has proposed a speed limit targeting regime (SLT). In this case, the period loss function is given by:

$$U_{SLT} = -\frac{1}{2}(\pi_t^2 + \omega_{SLT}(x_t - x_{t-1})^2) \tag{7}$$

Walsh showed that in a full discretion environment a speed limit policy manages to induce persistence in policy. The lagged output-gap term induces history dependence, as in the optimal precommitment policy. In face of a positive cost-push shock, inflation rises and the output-gap becomes negative. After the impact response, the output-gap remains negative, because large changes in the output-gap carry a cost to the central bank. The persistent recession is associated with deflationary pressures. Therefore, even inflation in the initial period is well anchored due to expectations of low future inflation.

Jensen (2002) has proposed nominal income growth targeting (NIGT). The period loss function assigned to the central bank is given by:

$$U_{NIGT} = -\frac{1}{2}(\omega x_t^2 + \omega_{NIGT}(\pi_t + y_t - y_{t-1})^2) \tag{8}$$

This regime also induces inertia and history dependence into the system mimicking quite well the optimal precommitment policy. After the initial rise in inflation and drop in output, the recession is somewhat persistent to keep nominal income at target. Since the central bank would like to bring output back to steady state, output grows sluggishly. In order to attenuate the increase in nominal income the central bank has the incentive to keep future inflation quite low. In summary, the optimal precommitment patterns of future low inflation and a persistent recession are insured.

The optimal precommitment policy leaves the output-gap and inflation unchanged in response to shocks in the natural output level.[11] The NIGT regime

[11] That is to say, output responds one-to-one to natural-output leaving the output-gap unchanged.

features an inefficient response to these type of shocks; the central bank fails to stabilize the output-gap completely as this conflicts with stabilizing nominal income.

Vestin (2006) describes in detail the benefits of a price-level targeting regime (PT).

$$U_{PT} = -\frac{1}{2}(p_t^2 + \omega_{PT} x_t^2) \tag{9}$$

After the initial rise in inflation and the price level, the central bank immediately entails a deflation to bring the price level back to target. In doing so, inflation in the first period is well anchored due to expectations of low future prices.

I have chosen these four targeting regimes because they have received considerable attention in the literature. For instance, Walsh (2003b) has analyzed the same targeting regimes, but considered only a full discretion setup. Also, for reasons discussed previously, I am focusing on delegation schemes with constant parameters.

3 Main Results

The calibration is set in table 1. The model is interpreted as being quarterly and the discount factor is set at 0.99. With a discount factor close to one the deviation from the strict natural-rate hypothesis is negligible. The elasticity of current inflation with respect to the output gap is set at 0.1. This value is in line with Rotemberg and Woodford (1997) for annualized inflation rates. The specific importance of forward-looking expectations in the NKPC is highly controversial. I consider an intermediate position and set $\alpha = 0.5$. In the sensitivity analysis, other values of α are examined. All the remaining parameters are set in accordance with the baseline calibrations of Jensen (2002) and Walsh (2003b).

The properties and performance of targeting regimes when the central bank has imperfect commitment have not been studied before, and I carry out such analysis in

Table 1: Calibration

β	ω	κ	α	ρ_u	ζ_u	ρ_y	ζ_y
0.99	0.25	0.1	0.5	0	0.015	0.97	0.005

this section. Figure (1) plots the welfare achieved by society when the stabilization of specific objectives is delegated to the central bank.[12] The upper panel plots the relative change in loss with respect to the optimal precommitment policy.[13] The middle panel follows Jensen (2002) and plots the permanent output-gap yielding the same absolute change in loss.[14] Each line corresponds to a different targeting regime. The welfare achieved by society depends on the expected commitment duration (T), which is plotted in the horizontal axis. When ($T = 1$) the usual full discretion results are recovered, and when ($T = \infty$) the central bank has full commitment. The lower panel plots the optimal weights, which depend on the expected commitment duration.

When the central bank acts with full discretion, IT is the worst performing targeting regime with a relative loss of 17%. SLT performs the best, followed by NIGT and PT. However, the results change substantially if one considers that the promises of the central bank are expected to last for some periods. If the central bank has partial commitment, the welfare attained by IT starts to improve drastically. Even if the expected commitment duration is relatively low, the welfare attained by society under IT becomes very close to the welfare obtained with the optimal

[12] Unconditional welfare was computed as in Jensen (2002). The results are robust if one considers welfare conditional on the initial state-vector being on steady-state. A numerical package that solves for optimal policy with loose commitment settings is documented and provided in Debortoli et al. (2008). The appendix describes the numerical algorithm and the first-order-conditions.

[13] That is to say, $(L_{\cdot\cdot} - L_{OPP})/L_{OPP}$, where L_{OPP} is the optimal precommitment policy loss, and $L_{\cdot\cdot}$ is the loss of a specific targeting regime for a given T.

[14] In other words, the middle panel plots c such that $(L_{OPP} - L_{\cdot\cdot}) = \frac{1}{2}\frac{1}{1-\beta}\omega(\frac{c}{100})^2$.

precommitment policy. In the extreme case in which the central bank has full commitment, IT attains the highest possible welfare. In such a case, it is optimal to make the objectives of the central bank and society to coincide, $\omega_{IT} = \omega$.

While the welfare attained by IT increases with the expected commitment duration, other targeting regimes do not display a similar pattern. The reason is the following. If the central bank has an improved commitment technology, then it will use it to achieve its assigned objectives regardless of society's original objectives. If society's and central bank objectives coincide or are similar, an enhanced commitment will improve both central bank's welfare and society's. This is precisely the case of IT. In the other delegation schemes, society's and central bank's objectives do not coincide. Thus, an improved credibility leads the central bank to maximize its delegated objectives, which may not necessarily improve society's welfare. For instance, in figure (1) one can observe that if society wants to delegate a PT regime to its central bank, then society's welfare is actually higher if the expected commitment duration of central bank's promises is 1 rather than 10 quarters.

To the best of my knowledge no central bank is officially pursuing SLT, NIGT or PT.[15] In recent years, several countries have adopted IT. Since several papers had identified targeting regimes that outperform IT, this empirical observation is hard to justify. The present results may provide a rationale for this empirical evidence. If the central bank faces a credibility problem that is not too severe, then IT seems to be the best performing regime. Despite having different weights potentially, IT and society's objectives coincide, and hence a gain in terms of expected commitment duration of the central bank's promises is translated into improved society's welfare.

[15]Some central banks may *de facto* but not *de jure* pursue a targeting regime. However, identifying such cases is difficult and subject to interpretation. The Bank of Canada has been heavily discussing PT, but has not officially adopted it. In the 1930's the Sveriges Bank adopted PT but than abandoned it.

Another observation is that if society delegates objectives which dramatically differ from the original ones, then the central bank should not try to improve its commitment and credibility over time. In case it does so, these "optimal" policy efforts could very well reduce society's welfare. For instance, consider two economies: in economy A the central bank is incompetent and operates under ($T = 1$), in economy B, the central bank due to a better communication strategy or enhanced accountability achieves a higher expected commitment duration, say ($T = 10$).[16] The welfare of society when implementing a SLT, NIGT or PT regime is higher in the economy where the central bank is incompetent. This effect can be rather perversive, leading central banks to justify poor performance.

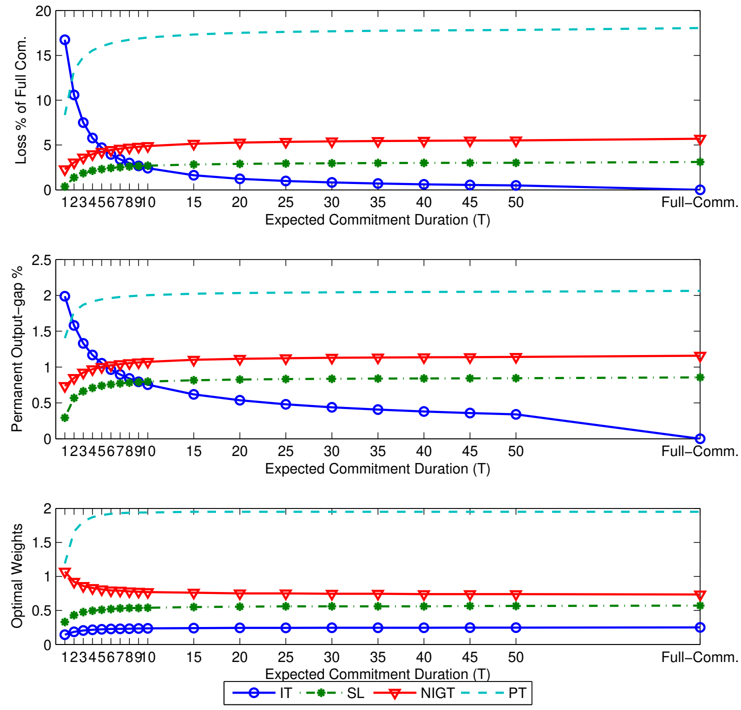
3.1 Inflation Targeting

The first column of figure (2) plots the IT policy if the central bank acts with discretion in every period. In this case, the economy never experiences a recession and a deflation because such promises are not time-consistent. To identify the effects of increasing the expected commitment duration, figure (2) plots the expected path of the impulse response functions (IRF) when $T = 20$. The central bank uses its partial commitment to announce a future recession and a deflation. Such promises will not always be kept. The private sector and the central bank itself anticipate future defaults, and hence central bank credibility is imperfect. The middle column of figure (2) plots the IRF that occurs if, by chance, the central bank would never default, and the effect of a default in period 4. If past promises are not kept, the prolonged recession is abandoned and the output-gap is brought closer to target.

The last column of figure (2) displays the optimal precommitment policy, and

[16] Mishkin (2008) provides an interesting discussion on central bank commitment and communication.

Figure 1: Welfare - Baseline Calibration



Note: In all panels, the horizontal axis refers to expected commitment duration (T). For each targeting regime with optimally chosen weights, the upper panel plots the society's loss relative to the optimal precommitment policy, i.e. $(L_{\cdot\cdot} - L_{OPP})/L_{OPP}$. The optimal policy precommitment policy loss (L_{OPP}) was found to be -2.9490 ($\times$100). The middle panel follows Jensen (2002) and plots the permanent output-gap yielding an equivalent change in loss, i.e. it plots c such that $(L_{OPP} - L_{\cdot\cdot}) = \frac{1}{2}\frac{1}{1-\beta}\omega(\frac{c}{100})^2$. The lower panel plots the optimal weights.

the optimal delegation regimes if the central bank acts with full discretion or faces an expected commitment duration of 20 periods. If the central bank has more commitment, then the delegated policy tracks more closely the optimal precommitment policy. Consequently, society's welfare improves when the central bank's expected commitment duration increases.

The optimal delegated weight ω_{IT} increases with T, and if $T = \infty$ then $\omega_{IT} = \omega$. As the central bank gains more commitment the positive effects of distorting the central bank objectives diminish.

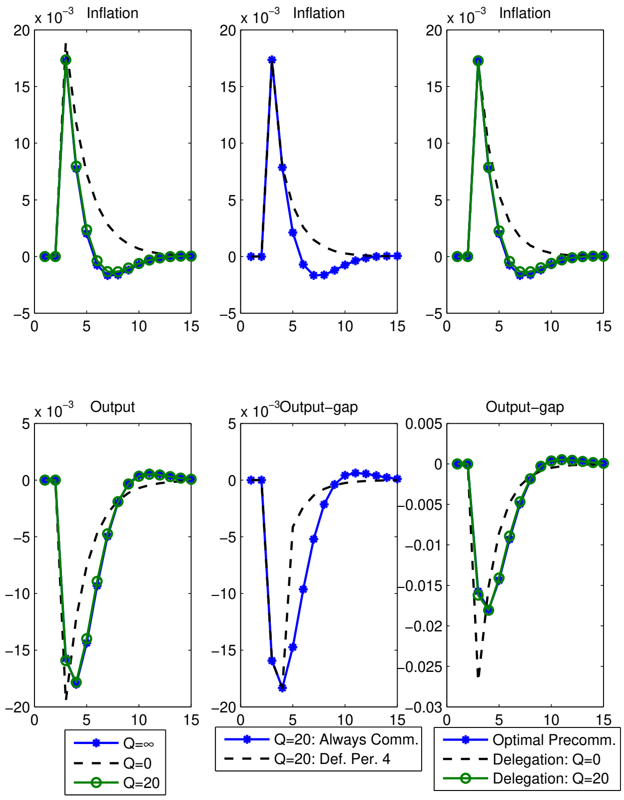
3.2 Speed Limit Targeting

Figure (3) plots the IRF for the SLT case. The first column shows that the ability to make and keep promises induces the central bank to implement a deeper recession. The recession is still persistent in order to avoid costs in terms of output-gap growth, but inflation is reduced at a faster pace. The middle column shows that if the central bank would default, then the recession would be eased.

The optimal delegated speed limit policy when $T = 1$ tracks quite well the optimal precommitment policy. However, if the central bank is more competent, then the optimal delegated speed limit policy does not match as closely what society would desire. As a consequence, society's welfare would be higher if the central bank would be less competent.

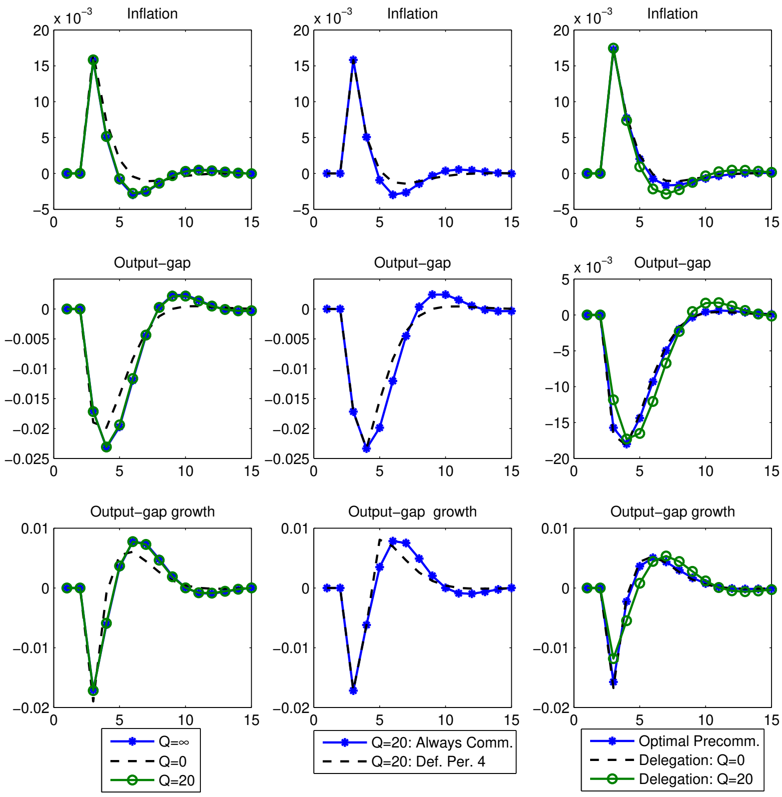
The optimal delegated weight (ω_{SLT}) when $T = 1$ is smaller than when $T > 1$. Since the central bank with more commitment promises more prolonged recessions, society partially offsets this effect by reducing ω_{SLT}.

Figure 2: Inflation Targeting - IRF - Baseline



Note: The first column plots the IRF for a positive one standard deviation cost-push shock under IT and the baseline calibration. The IRFs plotted correspond to three levels of commitment of the central bank, $T \in \{0, 20, \infty\}$ for $w_{IT} = 0.25$. When $T = 20$, the IRF is dependent on the particular realization of "default" or "no default". The expected IRF is computed by averaging 1000 histories. The middle column plots two particular histories. The first IRF corresponds to the history where the central bank always kept past promises. In the second history, the central bank keeps past promises until period 4 and defaults always thereafter. The third column plots the IRF for the optimal precommitment policy, and the IRF for the optimal delegation when $T \in \{0, 20\}$.

Figure 3: Speed Limit Targeting - IRF - Baseline



Note: The first column plots the IRF for a positive one standard deviation cost-push shock under SL and the baseline calibration. The IRFs plotted correspond to three levels of commitment of the central bank, $T \in \{0, 20, \infty\}$ for $w_{SL} = 0.25$. When $T = 20$, the IRF is dependent on the particular realization of "default" or "no default". The expected IRF is computed by averaging 1000 histories. The middle column plots two particular histories. The first IRF corresponds to the history where the central bank always kept past promises. In the second history, the central bank keeps past promises until period 4 and defaults always thereafter. The third column plots the IRF for the optimal precommitment policy, and the IRF for the optimal delegation when $T \in \{0, 20\}$.

3.3 Nominal Income Growth Targeting

Figure (4) plots the IRF for the NIGT case. If the central bank has the ability to keep previous promises, then it realizes that by promising a more prolonged recession it can affect more efficiently current inflation. Nominal income growth is closer to zero, because inflation is lower and income does not grow faster.

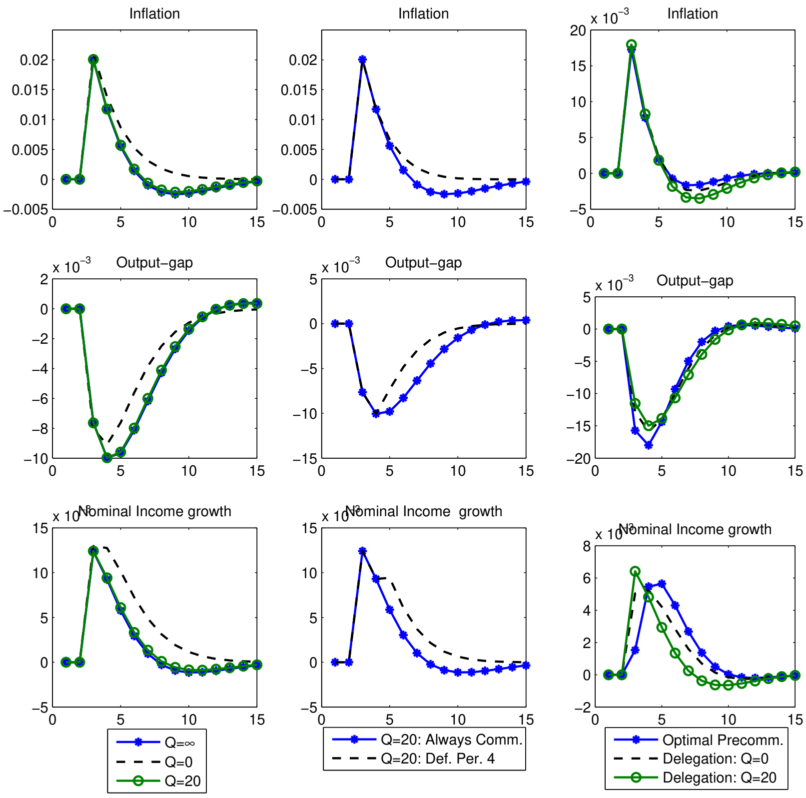
If the central bank would default on its past promises then output would be increased towards target, which would increase inflation. For the central bank, the benefits of increasing output outweighs the costs of higher nominal income. The last column in the figure shows the policy implemented by the central bank when the delegation is chosen optimally with $T = 1$ or $T = 20$. The increased commitment ability of the central bank induces more inertia than what is optimal. As a consequence, in the initial periods output is higher than optimal, and in later periods it is lower than optimal. Since output is too low in later periods, the deflation is too strong.

The optimal delegated weight ω_{NIGT} is lower when T is higher. As society anticipates a stronger response of output when the central bank is more competent, society delegates objectives that give more importance to output (lower ω_{NIGT}).

3.4 Price Level Targeting

The IRF under PT are plotted in Figure (5). The first column shows that, once again, when the central bank has the ability to make a commitment plan, it promises a more prolonged recession. The central bank realizes that the current price level can be further controlled if future inflation is expected to be low. If the central bank would default on its promises then the recession would immediately become milder and the reduction in prices would be slower (displayed in the middle column).

Figure 4: Nominal Income Growth Targeting - IRF - Baseline



Note: The first column plots the IRF for a positive one standard deviation cost-push shock under NIGT and the baseline calibration. The IRFs plotted correspond to three levels of commitment of the central bank, $T \in \{0, 20, \infty\}$ for $w_{NIGT} = 0.25$. When $T = 20$, the IRF is dependent on the particular realization of "default" or "no default". The expected IRF is computed by averaging 1000 histories. The middle column plots two particular histories. The first IRF corresponds to the history where the central bank always kept past promises. In the second history, the central bank keeps past promises until period 4 and defaults always thereafter. The third column plots the IRF for the optimal precommitment policy, and the IRF for the optimal delegation when $T \in \{0, 20\}$.

The final column in figure (5) displays the optimal delegated policies for different commitment levels. The extra inertia induced by commitment is once again not an advantage to society. On impact the negative output-gap response is too moderate, and then due to inertia the recession becomes too strong. As a counterpart, inflation becomes too low after some periods inducing a non-optimal cost of a disinflation. Since extra commitment makes the central bank respond more strongly on output, it is not surprising that, for instance, $\omega_{PT}(T = 20)$ is higher than $\omega_{PT}(T = 1)$.

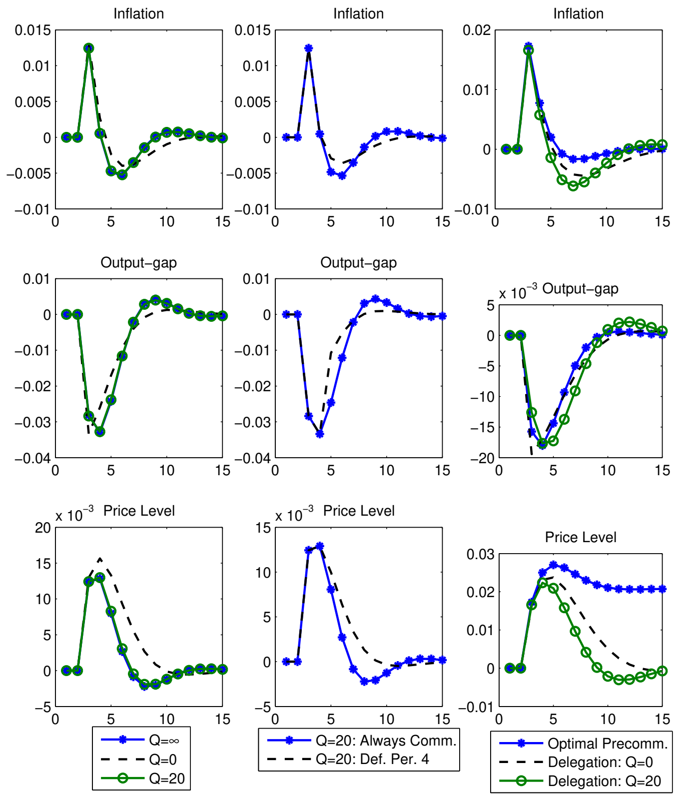
4 Sensitivity Analysis

I examined several alternative scenarios to test the robustness of the results, and the results did not change qualitatively. In one scenario, the persistence of the cost-push shock (ρ_u) was increased to 0.3. Then, the social weight on output-gap stabilization (ω) was set to be the double or half of the baseline value. The most interesting findings relate to the parameter governing the importance of forward-looking behavior (α). Figure (6) presents the welfare results for the pure forward-looking NKPC; the IRFs for each targeting regime are available in the appendix. I found that when the economy is completely forward-looking most of the results remain unchanged. The performance of inflation targeting dramatically improves with the level of commitment, and for reasonable levels of intermediate commitment IT becomes the best performing delegation scheme.

One difference that occurs is that welfare with SLT and NIGT can also be increasing with the level of commitment. The intuition of this result is the following. As Jensen (2002) and Walsh (2003b) point out, both of these delegation schemes do not impart enough inertia into policy.[17] Even with optimally chosen weights,

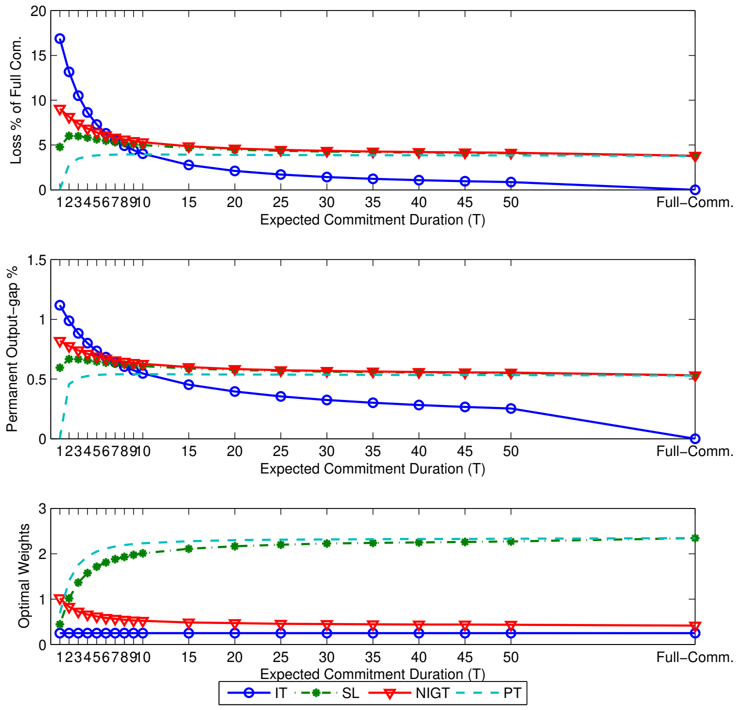
[17]Walsh (2003b) discusses this issue in detail. These patterns can also be observed in the last

Figure 5: Price Level Targeting - IRF - Baseline



Note: The first column plots the IRF for a positive one standard deviation cost-push shock under PT and the baseline calibration. The IRFs plotted correspond to three levels of commitment of the central bank, $T \in \{0, 20, \infty\}$ for $w_{PT} = 0.25$. When $T = 20$, the IRF is dependent on the particular realization of "default" or "no default". The expected IRF is computed by averaging 1000 histories. The middle column plots two particular histories. The first IRF corresponds to the history where the central bank always kept past promises. In the second history, the central bank keeps past promises until period 4 and defaults always thereafter. The third column plots the IRF for the optimal precommitment policy, and the IRF for the optimal delegation when $T \in \{0, 20\}$.

Figure 6: Welfare - Pure Forward-Looking Case



Note: In all panels, the horizontal axis refers to expected commitment duration (T). For each targeting regime with optimally chosen weights, the upper panel plots the society's loss relative to the optimal precommitment policy, i.e. $(L_{..} - L_{OPP})/L_{OPP}$. The optimal policy precommitment policy loss (L_{OPP}) was found to be -0.926 ($\times$100). The middle panel follows Jensen (2002) and plots the permanent output-gap yielding an equivalent change in loss, i.e. it plots c such that $(L_{OPP} - L_{..}) = \frac{1}{2}\frac{1}{1-\beta}\omega(\frac{c}{100})^2$. The lower panel plots the optimal weights.

the response of output is initially too strong and fades out too quickly. But when the central bank has more commitment, then it imparts more inertia into policy. Obviously, the central bank is doing this in order to maximize its assigned objectives instead of society's. But society finds it very useful that the central bank reacts in that way because it imparts more inertia into policy and allows society to achieve a higher welfare. These results contradict the ones for the benchmark calibration, in which the economy already has a high degree of backward-looking behavior. In the benchmark case, having more commitment increases the level of policy inertia even further into levels that make it hard to mimic the optimal precommitment policy.

The behavior of price level targeting is slightly different. Vestin (2006) showed that for the pure forward-looking NKPC price level targeting can actually mimic the optimal precommitment policy. In that case, the amount of inertia in the central bank policy under full discretion is already optimal. Increasing inertia due to commitment worsens welfare.

5 Conclusions

Previous analysis of monetary policy delegation and institutional design had assumed that the central bank operates under full discretion (e.g. Clarida et al. (1999), Jensen (2002), Walsh (2003b), Vestin (2006)). Such an assumption is rather restrictive. In practice, central bank's credibility or commitment may be imperfect but not necessarily inexistent.

Insofar as the central bank is partially credible, society can still be better-off by delegating objectives to the central bank. However, the performance of a delegation scheme will depend on whether the central bank operates with intermediate

column of the IRF figures displayed in the appendix.

commitment or full discretion. This paper examined how delegation schemes mitigate the stabilization bias for a continuum of commitment levels that range from full discretion to full commitment. The imperfect credibility or loose commitment settings were modeled as in Roberds (1987), Schaumburg and Tambalotti (2007), and Debortoli and Nunes (2007).

The results showed that while the performance of inflation targeting improved with the level of commitment, the same pattern did not always occur for the other delegation schemes considered. The intuition is that in a standard optimization problem, more commitment increases the level of welfare. The central bank's welfare function under inflation targeting is similar and possibly coincides with the social welfare function. Hence, an improved level of commitment is translated into higher levels of welfare to society. In contrast, other delegation schemes considered endow the central bank with objectives which are very different from society's. Regardless of society's objectives, the central bank would use its enhanced commitment to pursue the objectives that it was assigned to accomplish. Therefore, when society's and central bank objectives differ, the enhanced commitment policies of the central bank are not necessarily beneficial to society.

These results suggest that delegating objectives to the central bank that differ substantially from the society's objectives may be less beneficial than previously thought. In addition, doing so could potentially deter the central bank from behaving competently and trying to improve its credibility. In fact, for the baseline calibration and all delegation schemes except inflation targeting, an economy with an incompetent central bank can be better off than an economy with a competent one. It was also found that, for plausible levels of commitment, inflation targeting can become the best performing regime. If the commitment of the central bank is expected to last more than 10 quarters, then society's welfare under inflation targeting is the highest. In that sense, this paper may provide a rationale for why central banks have increasingly adopted inflation targeting. In previous research, the theoretical evidence of inflation targeting as a relatively inefficient targeting regime could not account for the widespread practice and high popularity of inflation targeting among central banks.

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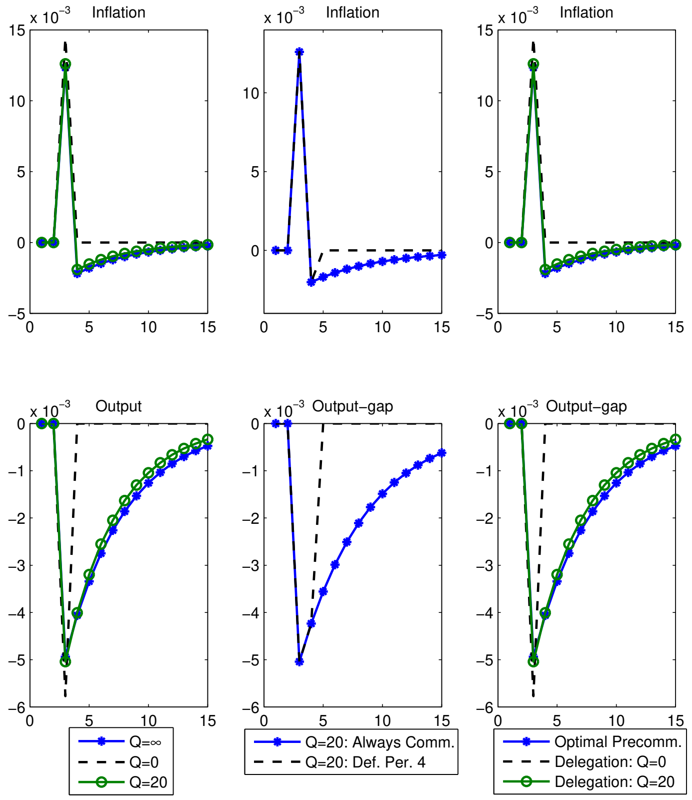
A Appendix

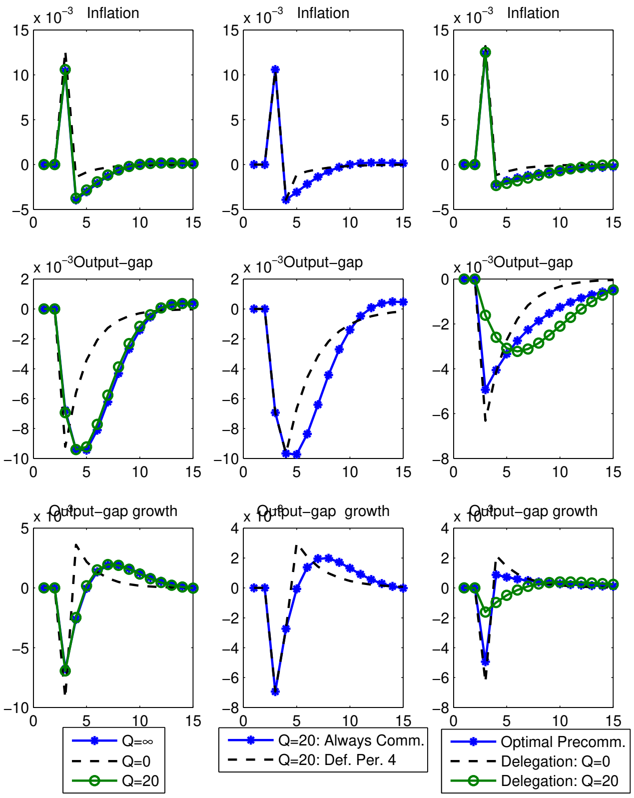
A.1 IRFs - pure forward-looking NKPC

Figure 7: Inflation Targeting - IRF - $\alpha = 1$



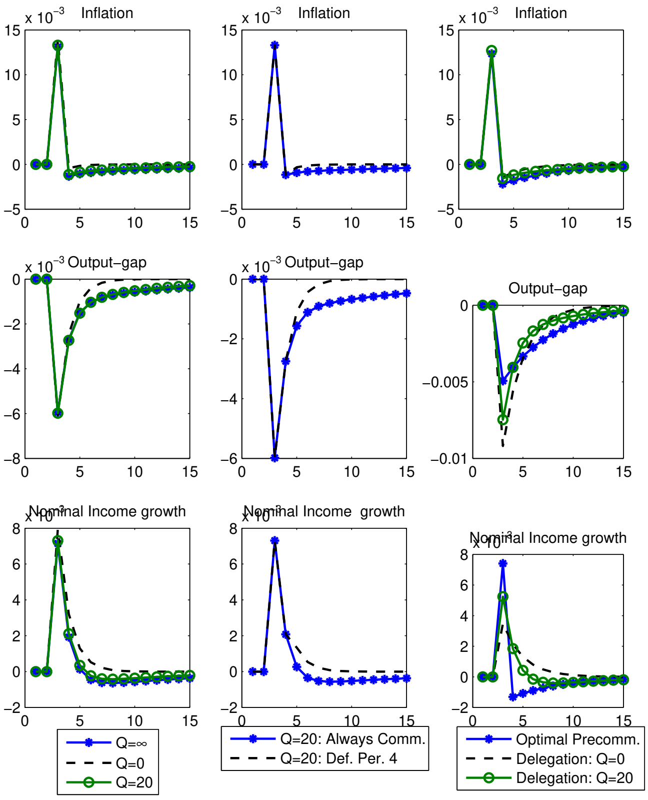
Note: The first column plots the IRF for a positive one standard deviation cost-push shock under IT and the baseline calibration except that $\alpha = 1$. The IRFs plotted correspond to three levels of commitment of the central bank, $T \in \{0, 20, \infty\}$ for $w_{IT} = 0.25$. When $T = 20$, the IRF is dependent on the particular realization of "default" or "no default". The expected IRF is computed by averaging 1000 histories. The middle column plots two particular histories. The first IRF corresponds to the history where the central bank always kept past promises. In the second history, the central bank keeps past promises until period 4 and defaults always thereafter. The third column plots the IRF for the optimal precommitment policy, and the IRF for the optimal delegation when $T \in \{0, 20\}$.

Figure 8: Speed Limit Targeting - IRF - $\alpha = 1$



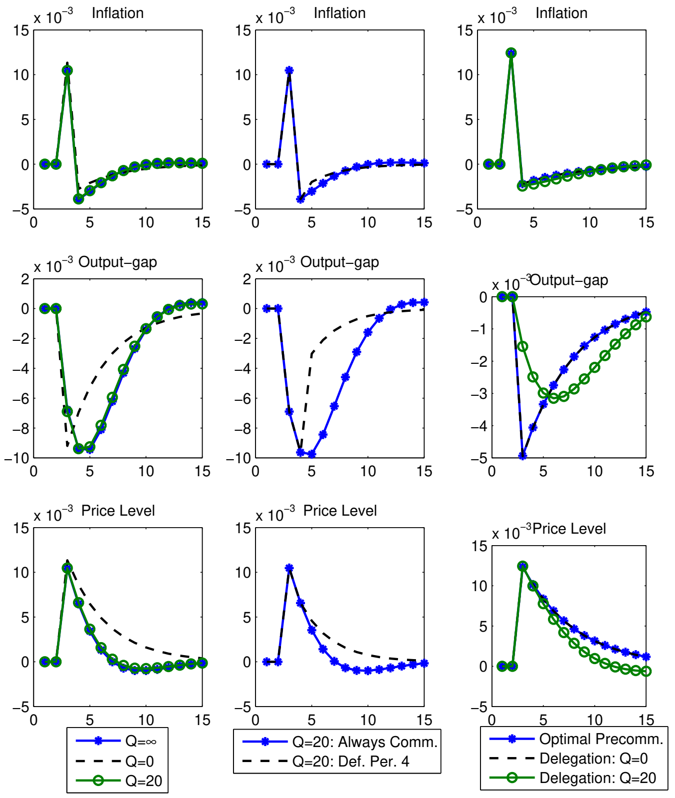
Note: The first column plots the IRF for a positive one standard deviation cost-push shock under SL and the baseline calibration except that $\alpha = 1$. The IRFs plotted correspond to three levels of commitment of the central bank, $T \in \{0, 20, \infty\}$ for $w_{SL} = 0.25$. When $T = 20$, the IRF is dependent on the particular realization of "default" or "no default". The expected IRF is computed by averaging 1000 histories. The middle column plots two particular histories. The first IRF corresponds to the history where the central bank always kept past promises. In the second history, the central bank keeps past promises until period 4 and defaults always thereafter. The third column plots the IRF for the optimal precommitment policy, and the IRF for the optimal delegation when $T \in \{0, 20\}$.

Figure 9: Nominal Income Growth Targeting - IRF - $\alpha = 1$



Note: The first column plots the IRF for a positive one standard deviation cost-push shock under NIGT and the baseline calibration except that $\alpha = 1$. The IRFs plotted correspond to three levels of commitment of the central bank, $T \in \{0, 20, \infty\}$ for $w_{NIGT} = 0.25$. When $T = 20$, the IRF is dependent on the particular realization of "default" or "no default". The expected IRF is computed by averaging 1000 histories. The middle column plots two particular histories. The first IRF corresponds to the history where the central bank always kept past promises. In the second history, the central bank keeps past promises until period 4 and defaults always thereafter. The third column plots the IRF for the optimal precommitment policy, and the IRF for the optimal delegation when $T \in \{0, 20\}$.

Figure 10: Price Level Targeting - IRF - $\alpha = 1$



Note: The first column plots the IRF for a positive one standard deviation cost-push shock under PT and the baseline calibration except that $\alpha = 1$. The IRFs plotted correspond to three levels of commitment of the central bank, $T \in \{0, 20, \infty\}$ for $w_{PT} = 0.25$. When $T = 20$, the IRF is dependent on the particular realization of "default" or "no default". The expected IRF is computed by averaging 1000 histories. The middle column plots two particular histories. The first IRF corresponds to the history where the central bank always kept past promises. In the second history, the central bank keeps past promises until period 4 and defaults always thereafter. The third column plots the IRF for the optimal precommitment policy, and the IRF for the optimal delegation when $T \in \{0, 20\}$.

A.2 Numerical algorithm solving loose commitment problems

The policy functions of certain variables, in case of default, appear in the constraints of the problem. In addition, the future value functions also appear explicitly in the problem. Following Debortoli and Nunes (2007), I used envelope results for the derivative of the value function. The policy functions must be guessed before solving the problem. The computations in the paper used the following iterative procedure:

1. Guess $\Gamma_t^D = Cs_t$, where Γ_t^D is the vector of policy functions under default that appear in the problem, C is the guess matrix, and s_t is the vector of state variables. Since the problem is linear quadratic, the policy functions are linear.

2. Given the guess, solve the problem with a rational expectations solution algorithm. I used the Uhlig (1999) toolkit.

3. Update the guess. From the results of Debortoli and Nunes (2007) the policy functions under commitment and default coincide, but the last-period lagrange multiplier associated with forward-looking constraints are set to zero.

4. If the solution and guess coincide stop, otherwise go back to step 1.[18]

I first solved the full commitment problem, and then used an homothopy to solve the loose commitment problems until full discretion. This procedure guarantees that

[18]Debortoli and Nunes (2007) proposed a global solution method with one fix point problem. The problem in this paper is simpler since it is linear quadratic, and can be efficiently solved relying on two fix points (one fix point in the default policies guess, and a second fix point in the rational expectations solution). An iterative procedure for the full discretion case is available in Dennis (2007).

the initial guess is always accurate. Following the discussion in Blake and Kirsanova (2008), I have not found evidence of multiple solutions. An implementation of this algorithm is available in Debortoli et al. (2008).

A.3 First Order Conditions

The FOCs of each targeting regime are obtained by solving a problem similar to (5), with the period loss function given by the delegated objectives. One can find the maximum social welfare with the corresponding optimal ω_M by evaluating each targeting regime in a grid of points ω_M.

In the following FOCs, $I_{q\neq 0}$ denotes the indicator function with $I_{q\neq 0} = 1$ if $q \neq 0$, and $I_{q\neq 0} = 0$ if $q = 0$. Variables with a superscript D, denote variables evaluated under default. Variables with a superscript DC denote variables where in one period **D**efault occurs and in two periods **C**ommitments are kept. An analogous convention applies for variables with a superscript DD or CD. For convenience, superscripts C and CC are omitted. The derivative of f at $t+1$ w.r.t. g is written as $f_{t+1,g}$. The paper only considers bounded solutions, which necessarily satisfy the transversality conditions.

A.3.1 Inflation Targeting

$$E_t\{-\pi_t + \beta^2(1-q)\lambda^D_{t+1}(1-\alpha) - \lambda_t + \beta^2 q(1-\alpha)\lambda_{t+1} + \alpha\lambda_{t-1}I_{q\neq 0} + \lambda_t\beta\alpha\,(1-q)\,\pi^D_{t+1,\pi}\} = 0 \tag{A-1}$$

$$-\omega_{IT}x_t + \lambda_t\kappa = 0 \tag{A-2}$$

$$-\pi_t + \kappa x_t + \beta(1-\alpha)\pi_{t-1} + \beta\alpha q E_t\pi_{t+1} + \beta\alpha\,(1-q)\,E_t\pi^D_{t+1} + u_t = 0 \tag{A-3}$$

A.3.2 Speed Limit Policies

$$
\begin{aligned}
E_t\{-\pi_t + \beta^2(1-q)\lambda^D_{t+1}(1-\alpha) - \lambda_t + \beta^2 q(1-\alpha)\lambda_{t+1} \\
+\alpha\lambda_{t-1}I_{q\neq 0} + \lambda_t\beta\alpha\,(1-q)\,\pi^D_{t+1,\pi}\} = 0 \qquad \text{(A-4)}
\end{aligned}
$$

$$
\begin{aligned}
E_t\{-\omega_{SLT}(x_t - x_{t-1}) + \beta q\omega_{SLT}(x_{t+1} - x_t) + \beta(1-q)\omega_{SLT}(x^D_{t+1} - x_t) \\
+\lambda_t\kappa + \lambda_t\beta\alpha\,(1-q)\,\pi^D_{t+1,x}\} = 0 \qquad \text{(A-5)}
\end{aligned}
$$

$$
-\pi_t + \kappa x_t + \beta(1-\alpha)\pi_{t-1} + \beta\alpha q E_t\pi_{t+1} + \beta\alpha\,(1-q)\,E_t\pi^D_{t+1} + u_t = 0 \qquad \text{(A-6)}
$$

A.3.3 Nominal Income Growth Targeting

$$
\begin{aligned}
E_t\{-\omega_{NIGT}(\pi_t + y_t - y_{t-1}) + \beta^2(1-q)\lambda^D_{t+1}(1-\alpha) - \lambda_t \\
+\beta^2 q(1-\alpha)\lambda_{t+1} + \alpha\lambda_{t-1}I_{q\neq 0} + \lambda_t\beta\alpha\,(1-q)\,\pi^D_{t+1,\pi}\} = 0 \qquad \text{(A-7)}
\end{aligned}
$$

$$
\begin{aligned}
E_t\{-\omega x_t - \omega_{NIGT}(\pi_t + y_t - y_{t-1}) + \beta q\omega_{NIGT}(\pi_{t+1} + y_{t+1} - y_t) \\
+\beta(1-q)\omega_{NIGT}(\pi^D_{t+1} + y^D_{t+1} - y_t) + \lambda_t\kappa + \lambda_t\beta\alpha\,(1-q)\,\pi^D_{t+1,y}\} = 0 \qquad \text{(A-8)}
\end{aligned}
$$

$$
-\pi_t + \kappa x_t + \beta(1-\alpha)\pi_{t-1} + \beta\alpha q E_t\pi_{t+1} + \beta\alpha\,(1-q)\,\pi^D_{t+1} + u_t = 0 \qquad \text{(A-9)}
$$

A.3.4 Price Level Targeting

$$
\begin{aligned}
E_t\{-p_t + \beta\,(1-q)\,V^{t+1}_{p_t} + \beta^2 q\,(1-q)\,(-\lambda^{CD}_{t+2}\beta\,(1-\alpha)) \\
-\lambda_t[1 + \beta q\alpha - \beta\alpha\,(1-q)\,(p^D_{t+1,p_t} - 1)] + \alpha\lambda_{t-1}I_{q\neq 0} \\
-\lambda_{t+1}\beta q[-1 - \beta\,(1-\alpha) - \beta\alpha\,(1-q)\,p^{CD}_{t+2,p_t}] - \lambda_{t+2}\,(\beta q)^2\,\beta\,(1-\alpha)\} = 0 \qquad \text{(A-10)}
\end{aligned}
$$

$$
-\omega_{PT}x_t + \lambda_t\kappa = 0 \qquad \text{(A-11)}
$$

$$
\begin{aligned}
-p_t + p_{t-1} + kx_t + \beta\,(1-\alpha)\,(p_{t-1} - p_{t-2}) \\
+\beta q\alpha E_t\,(p_{t+1} - p_t) + \beta\alpha\,(1-q)\,(E_t p^D_{t+1} - p_t) + u_t = 0 \qquad \text{(A-12)}
\end{aligned}
$$

$$
\begin{aligned}
E_t\{-V^{t+1}_{p_t} + \beta\,(1-q)\,(-\lambda^{DD}_{t+2}\beta\,(1-\alpha)) \\
-\lambda^D_{t+1}[-1 - \beta\,(1-\alpha) - \beta\alpha\,(1-q)\,p^{DD}_{t+2,p_t}] - \lambda^{DC}_{t+2}\beta^2 q\,(1-\alpha)\} = 0 \qquad \text{(A-13)}
\end{aligned}
$$