The macroeconomic effects of unstable monetary policy objectives*

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Abstract

Monetary policy objectives and targets are not necessarily stable over time. We analyze the optimal response of central banks to such objective instability and the resulting macroeconomic consequences. The possibility to adopt more "liberal" objectives in the future increases current inflation through an accommodation effect. Simultaneously, the central bank tries to anchor inflation by promising to be even more "conservative". The immediate effect is an output contraction, the opposite of what the pressures to adopt more "liberal" objectives may be aiming for. We also analyze the importance of commitment in the presence of unstable objectives and discuss the case where objectives may become more "conservative" in the future, which may be the relevant case for countries considering the adoption of inflation targeting.

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1 Introduction

Monetary policy objectives and targets can change over time due to a variety of reasons. Structural changes in the economy may lead the monetary policy authority to revise its objectives. For instance, the degree of monopolistic power, distortionary taxes, and frictions in the labor market may change over time. Changes in policy objectives may also simply be due to the the appointment of a new central bank chairman or staff, who may have different views from the predecessors. There may be different opinions towards the benefits of output vs inflation stabilization or, for instance, what is the efficient level of output that should be targeted.

Political interference and external pressures are another source of objectives instability. Even though there has been a big effort to build monetary institutions that are independent from political forces and other types of external pressures, independence is never absolute. It has often been the case that central banks are subject to some pressures to change their policy goals. For instance, the European Central Bank has been recently criticized for adopting policies that do not properly take into account output growth. In other cases, as it is currently happening in the United States, the adoption of inflation targeting or other institutional reforms are being discussed. Even if there is not an immediate change in objectives, the central bank and the public may attach some probability that monetary policy may change its objectives in the future.

Abstracting from the specific sources of objectives instability, the aim of the paper is to study its effects on optimal policy and current economic outcomes. It is widely accepted in the modern macroeconomic literature that firms and households, when setting current prices and wages, take into account expectations of future variables. In this context, when policy objectives are expected to change in the future, current prices and wages will be affected. As a consequence, the possibility of a future change in policy objectives affects the economic variables already in the current period.

Since objectives can change, current and future policies interact in several ways. As described before, future policy affects current outcomes and policy through an expectations channel. In addition, the current policymaker can already set the state variables in a strategic way to influence future policy. The current policymaker can also change its promised future policy. In this case, current policymakers bind future actions through promises. To make the interaction among current and future policy more realistic, we consider a model where, as in reality, policy objectives can not always be changed immediately because of institutional features and policy implementation lags.

We first consider the case where current objectives are conservative.[1] However, there is the possibility that future objectives become less conservative. In that case, future policies will imply a higher inflation bias (henceforth, a "liberal policy"). We find that the possibility that liberal policies may be implemented implies an increase in current inflation through an accommodation effect. At the same time, the central bank tries to anchor inflation expectations by promising to be even more conservative in the future. The immediate effect is an output contraction, which is the opposite of what the pressures to implement liberal policies may be aiming for. These effects are stronger the higher is the probability that objectives change. In this respect, adopting inflation targeting may be better than appointing a conservative central banker. In the former case, changing objectives usually requires a costly institutional reform. In the latter, it just requires that the central bank chairman and advisors, at the end of their term of office, are substituted by ones with different policy objectives.

We also analyze the opposite case, where objectives may become more conservative in the future. This is the relevant scenario for countries discussing the adoption of more stringent and explicit inflation objectives, which is, arguably, the case of the United States. In this context, the possibility of more conservative policy in the future creates a positive externality.

When considering that policy objectives are unstable it is also important to make some assumption regarding policymakers' commitment about future policies. In this respect, we consider several alternative scenarios. For instance, when objectives change, it is plausible to assume that the central bank implements the best possible policy to fulfill its new objectives, and the plans made when priorities were different will become irrelevant. In this setting, we assume a limited commitment technology as in Schaumburg and Tambalotti (2007), who have abstracted entirely from unstable objectives. Besides limited commitment, we also examine alternative settings with full-commitment and discretion. Rogoff shows that appointing a conservative central banker, even operating under discretion, can significantly reduce the time-inconsistency problem. As a result, it may be concluded that the commitment abilities of a conservative central bank may be of little importance. However, even if current objectives are conservative, future policy may become less conservative. We find that in the presence of unstable policy objectives, even a Rogoff conservative central banker can benefit from commitment. Besides other considerations, commitment is important to counteract the effects of the possibility of changes

[1] As shown by Rogoff (1985), appointing a central banker with higher aversion towards inflation than the overall society reduces the inefficiencies associated with time-inconsistency.

in policy objectives.

Our paper is related to the literature on political economy and monetary policy, following the seminal contribution of Alesina (1987). Our goal is not to provide a partisan analysis of monetary policy, where one attributes economic cycles to political parties. According to the empirical literature, it seems difficult to match timely and systematically certain parties with effective changes in monetary policy.[2] Since we use a standard New Keynesian framework, the possibility of a future change in policy objectives implies a different level of inflation and output in earlier periods. With respect to the partisan theory of economic fluctuations, our analysis suggests that it is difficult to find a link between economic outcomes and the objectives of certain policymakers. Also, our analysis can provide a rationale for the changes in interest rate rules, as analyzed by Davig and Leeper (2007). But once again, our results caution that it may be hard to interpret whether current policy has changed or is optimally reacting to possible future changes.

The paper is organized as follows. Section 2 briefly reviews some empirical evidence on unstable objectives. Section 3 presents the main model. Section 4 examines an alternative case with objectives instability. Section 5 concludes.

2 Unstable objectives: some empirical evidence

Modern monetary economics attributes a central role to expectations of future variables. Future policy is obviously a key determinant shaping expectations. Therefore, future changes in policy objectives matter for current policy and outcomes. Davig and Leeper (2007) and other recent studies have found that interest rate rules are subject to regime breaks. These regime breaks can be rationalized by policy objectives changes, which may occur due to several reasons. First, structural changes in the economy may change policy objectives. Second, the understanding of monetary policy theory and practice evolves over time. Third, different policymakers may have different priorities regarding policy objectives. As governors and central bank staff are changed the views on the economy may change. Also, as

[2] Alesina et al. (1997) point out several empirical successes of the Alesina (1987) model, while Sheffrin (1989) and Drazen (2000) point out some empirical failures. Chappell et al. (1993) conclude that political influences on the Federal Reserve are not clearly connected with a party tenure, since they occur indirectly through the appointments of FOMC members and thus different ideologies overlap in the committee. Faust and Irons (1999) conclude that partisan effects in US macroeconomic data are fragile, and that there is little evidence that the partisan effects on the economy operate through changes in monetary policy.

Drazen (2000) describes, changes in the fiscal policy may lead a central bank to change its priorities.

Political interference and external pressures are obvious reasons for objectives instability. It is not our claim that any external pressure is credible and consequential, but given the empirical evidence it seems desirable to determine what is the best response of a central bank when facing such pressures. Several empirical studies have confirmed external pressures are present, and that independent central banks are better insulated from these external pressures.[3] In addition, central bank independence is never complete, and central banks often seek political and popular support for their actions.

Governments can affect monetary policy objectives through appointments to central bank boards and councils. Chappell et al. (1993) and Berger and Woitek (2005) find an empirical relationship for the US and the Bundesbank, respectively. Moreover, both in the past and in more recent years, there has been several specific episodes where future monetary objectives were uncertain due to the different economic and political forces. For instance, during the Great Depression, the Thomas's Amendment gave Franklin Roosevelt broad powers to inflate and effectively eliminate the independence of the Federal Reserve.[4] Pierce (1979) documents several episodes involving the Nixon adminstration and Arthur Burns. Writes Business week "Says a Burns confidant, the Chairman 'was getting calls from the White House in December saying "what are you doing with this tight money?'" [3, April 15, 1972, p. 82]. In addition, Grier (1991) finds that the Senate Banking Committee leadership does exert a significant influence on monetary policy. Havrilesky (1995) extensively documents episodes in the US where different economic agents had divergent views and tried to influence monetary policy objectives. Havrilesky also builds an index based on pressures reported in newspapers, and finds that such pressures often succeed in shaping monetary policy choices.

In summary, there is evidence in the literature that monetary policy objectives can change for a variety of reasons. Also, there is a large consensus that the expectations about future policies matter for the current economic outcome. In what follows, abstracting from the particular sources of objective instability, we analyze

[3]Several studies have found that the level of inflation is negatively correlated with central bank independence (e.g. Alesina (1988), Grilli et al. (1991), Cukierman (1992), Cukierman et al. (1992), Berger et al. (2001), Cukierman et al. (2002)). Alesina and Gatti (1995) and Waller and Walsh (1996) made the theoretical point that since external pressures change policy goals they also increase economic variability. Several empirical studies have confirmed these effects (e.g. Alesina and Summers (1993) and Eijfinger and Schaling (1993)).

[4]See Roosevelt (1933).

what is the best response of a central bank in these situations.

3 The model

We base our analysis on a simple monetary model. Inflation dynamics are described by a New Keynesian Phillips curve (NKPC). As it is well known, the NKPC is a reduced form approximation of the relationship between inflation and output in an economy with monopolistic competition and staggered price setting.[5] We consider a hybrid NKPC described by:

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

where π_t denotes price inflation and y_t measures the output-gap, i.e. the difference between current output and the output level that would prevail under flexible prices. The parameter $0 < \alpha \leq 1$ determines the level of inflation inertia.[6] The reason to assume a hybrid NKPC is twofold. First, because of its empirical plausibility, as shown by Galí and Gertler (1999). Second, because in this case the current inflation level can be used strategically by the central bank to influence future policies. This feature is interesting when analyzing how the central bank should react to the possibility of future changes in policy objectives, as we do in this paper.

As it is standard in the optimal monetary policy literature, we assume that the central bank controls inflation and the output-gap directly.[7] The monetary policy authority aims at minimizing a weighted average of deviations of inflation and output-gap from their respective targets

$$U = \frac{1}{2}\left[\pi_t^2 + w(y_t - \widetilde{y}_t)^2\right]. \tag{2}$$

The parameter w measures the relative importance of output vs. inflation stabilization. The inflation target is normalized to zero, while $\widetilde{y}_t \geq 0$ represents the (exogenously given) output-gap target. The parameter $\widetilde{y}_t \geq 0$ can be interpreted as the difference between the efficient level of output and the output that would

[5]The theoretical framework underlying such relationship is described in Woodford (2003) and Galí (2008). This specification of the NKPC holds in a neighborhood of a zero inflation steady state. Throughout our analysis, we abstract from the changes that may derive from having a different steady state level of inflation.

[6]The pure forward-looking Phillips curve can obtained as a limiting case with $\alpha = 1$.

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

prevail under flexible prices. This difference generates a trade-off between output and inflation stabilization around their respective targets.

It may not be entirely plausible to assume that objectives of the central bank can be changed immediately. In practice, objectives can only be changed with some delay due to institutional features and policy implementation lags. We assume that objectives remain unchanged with certainty for T periods. After T periods, the current objectives can persist (with probability q) or change (with probability $1-q$).

In what follows, we consider that the objectives of the central bank can be either "liberal" (ℓ) or "conservative" (c). For convenience, we use the term "liberal central bank" to refer to a case where the output target and the relative weight to output stabilization are higher than a "conservative central bank", that is $\widetilde{y}^{\ell} > \widetilde{y}^{c}$, $w^{\ell} > w^{c}$, or both. Different output gap targets may reflect, for instance, a disagreement on the output level that would prevail under flexible prices.

We assume that the central bank can only make credible commitments about future policy while objectives remain unchanged. If objectives do change, a new policy will be set, and previous commitments will be disregarded.[8] This assumption can be justified on the grounds that if objectives change, the central bank will adopt the best possible policy to fulfill its new objectives, and thus disregards the plans made when priorities were different.[9]

Setting $\alpha = 1$ to simplify the algebra, the problem of the central bank can be written as:

$$V^i = \max_{\{\pi_t, y_t\}_{t=0}^{\infty}} E_0 \sum_{m=0}^{\infty} \left(\beta^T q\right)^m \left[-\frac{1}{2} \sum_{t=0}^{T-1} \beta^t \left[\pi_{m+t}^2 + w^i (y_{m+t} - \widetilde{y}^i)^2\right] + \beta^T (1-q) V^{ij} \right] \qquad (3)$$

$$\begin{aligned} s.t.\ \ & \pi_{mT+t} = \kappa y_{mT+t} + \beta E_{mT+t}(\pi_{mT+t+1}) & t = 0, 1, ..., T-2 \quad (4) \\ & \pi_{mT+t} = \kappa y_{mT+t} + (1-q)\beta E_{mT+t}(\pi^j_{mT+t+1}) + q\beta E_{mT+t}(\pi^i_{mT+t+1}) & t = T-1 \quad (5) \\ & \forall\ m = 0, ..., \infty \end{aligned}$$

where m indexes the number of tenures, each lasting for T periods.

The sequence of constraints (4) and (5) reflects the institutional setting. Within any tenure m, we can divide the constraints into two groups. In the periods $t = 0, ..., T-2$, inflation expectations internalize that in the next period objectives do

[8]Throughout our analysis, it is immaterial whether the new policy objectives are carried out by the same officers or by newly appointed ones.

[9]In section 3.3, we analyze the case where the central bank can make credible commitments contingent on its policy objectives.

not change. In the last period of the tenure $(T-1)$, agents recognize that with probability $(1-q)$ objectives do change.

The objective function reflects the institutional setting the central bank faces. At the end of any tenure (T periods where objectives can not change), current objectives (i) can remain unaltered with probability q. This history is summarized in the outer summation. Within each tenure, plans are made for T periods, as indicated in the inner summation. Finally, the central bank (i) internalizes that with some probability $(1-q)$, at the end of tenure the objectives will be of type (j). In this case, central bank (i) will get the loss function V^{ij}. More formally, define the sequence $\{\pi_t^i, y_t^i\}_{t=0}^{\infty} \equiv \arg\max V^i \ \forall i = \ell, c$. The value function V^{ij}, $\forall i = \ell, c$ and $j \neq i$ is given by

$$V^{ij} \equiv E_0 \sum_{m=0}^{\infty} \left(\beta^T q\right)^m \left[-\frac{1}{2} \sum_{t=0}^{T-1} \beta^t \left[\left(\pi_{m+t}^j\right)^2 + w^i (y_{m+t}^j - \widetilde{y}^i)^2 \right] + \beta^T (1-q) V^{ji} \right]. \quad (6)$$

We employ the following definition of equilibrium:

Definition 1 *A Markov Perfect Equilibrium with objective changes must satisfy the following condition. For any $i = \ell, c$ and $j \neq i$, given the sequence $\{\pi_t^j, y_t^j\}_{t=0}^{\infty}$:*

1. The value function V^{ij} satisfies equation (6).

2. The sequence $\{\pi_t^i, y_t^i\}_{t=0}^{\infty}$, solves (3) subject to (4) and (5).

In order to solve problem (3), we first write its recursive formulation. To do so we apply the technique of Marcet and Marimon (1998), and we write the problem as a saddle point functional equation that generalizes the usual Bellman equation. The proof of that result requires considering each tenure as one big period, and then applying the results of Debortoli and Nunes (2006a) and Schaumburg and Tambalotti (2007) to address the probabilistic switch at the end of each tenure. [10] Proposition 1 in the appendix proves this result in detail. As stated in Proposition 2 in the appendix, we can then characterize the policy functions solving our problem as tenure invariant functions of the Lagrange multipliers associated with the constraints (4) and (5). We are not claiming that the policy functions are time-invariant. Indeed, the policy functions change in the different periods within a tenure.

In order to solve our problem we have to find, for both central banks $(i = \ell, c)$, the policy functions satisfying the equilibrium conditions stated above. In particular, for

[10] We also use features of Debortoli and Nunes (2006b), considering disagreement among successive policymakers in a fiscal policy framework.

each central bank, we need to find as many policy functions as the number of periods within each tenure (T). As can be seen in (5), the policies of central bank j enter the problem of central bank i (and viceversa). This implies that we have to solve a fixed point problem in such policy functions. In addition, the implied value functions V^{ij} and V^{ji} also enter the problem and need to be solved for endogenously.[11] We also have to take into account the possibility of default on past promises, an event that occurs whenever there is a change in objectives. The presence of default significantly complicates the numerical procedure, since both the levels and the derivatives of the policy functions enter the first order conditions of the problem.

3.1 An example with an analytical solution

In this section, we consider a simple case where analytical solutions can be obtained. We assume that $T = 1$, and therefore the model does not consider that central bank objectives are hard to change immediately. In addition, we assume a purely forward looking Phillips curve ($\alpha = 1$).

We focus on the case where current objectives are conservative with a relative weight of output w^c and an output-gap target $\widetilde{y}^c > 0$.[12] At any point in time, objectives may become more liberal. To simplify our analysis, we assume that a change in policy objectives only implies a change in the output target, to a level $\widetilde{y}^\ell > \widetilde{y}^c$, while keeping unchanged the relative weight of output stabilization ($w^\ell = w^c = w$).[13]

In this case, it can be shown that while the current conservative objective function prevails, the output gap and inflation evolve according to

$$\pi_t = \gamma_2^{-t}\pi_0 \tag{7}$$

$$y_t - \widetilde{y}^c = -\frac{\kappa}{w}\frac{1-\gamma_2^{-(t+1)}}{1-\gamma_2^{-1}}\pi_0, \tag{8}$$

where

$$\pi_0 = \frac{1}{\gamma_2\left(1-\gamma_1\right)}\left(\kappa\widetilde{y}^c + \beta\left(1-q\right)\pi_0^\ell\right) \tag{9}$$

[11]Note that V^{ij} and V^{ji} are value functions in the presence of disagreement between successive policymakers, therefore unlike in Debortoli and Nunes (2006a) one can not use an envelope result.

[12]The results for the case where the current objectives are liberal are symmetric to the ones presented here and available upon request.

[13]The case where the relative weight of output changes is discussed in section 4.

and $0 < \gamma_1 < 1 < \gamma_2$ are coefficients satisfying $\gamma_1\gamma_2 = \beta q$ and $\gamma_1 + \gamma_2 = (1 + \beta q + \frac{\kappa^2}{w})$, which are thus independent of the policy objectives.[14] Such coefficients can also be shown to be strictly increasing in q.[15]

Equation (8) implies that the output gap is always below its target and that such difference increases over time. Inflation is always positive, declines over time and converges asymptotically to zero. In the initial period, the central bank can use inflation to expand output towards its efficient level. To do so, it also needs to keep inflation expectations at a low level by promising to reduce inflation in the subsequent periods. As time passes by, inflation is then reduced and output converges to a permanently and inefficiently low level. The policy plan prescribed by (7) and (8) is in general time-inconsistent. Whenever the central bank is allowed to review its policies, it has an incentive to surprise the economy and to implement a higher inflation than expected, thus achieving a higher output.

From these equations we can observe that, at any point in time, the distance between output gap and inflation from their respective targets can be expressed as increasing functions of the initial level of inflation π_0. The latter variable, as described in (9), depends on two factors. First, on the output target of the current policymaker $\widetilde{y}^c$. Second, it depends on the inflation that is implemented if liberal objectives are adopted, π_0^ℓ. This reflects the externality that the possibility of changing the policy objectives generates on the current central bank. In this respect, it is worth noticing the presence of an inflation bias even when $\widetilde{y}^c = 0$, that is in the absence, according to the current objectives, of any trade-off between output and inflation stabilization. Moreover, equations (7)-(9) hold independently of the specific institutional setting (in terms of the central bank credibility, duration of the tenure, etc.) prevailing once the liberal objectives are adopted. The only factor that matters is the initial level of inflation π_0^ℓ implemented in such circumstance. For convenience, we assume that once the change in objectives occurs, the central bank faces a symmetric problem to the one described above.[16]

We can also express inflation in our setting relative to the inflation level that would prevail under full-commitment and stable (conservative) objectives, $\bar{\pi}_t$, as

[14] In the definition of γ_1 and γ_2 (see equations (A-5) and (A-6) in the appendix A), the only parameter related to the policy objectives is the relative weight of output stability w, which is assumed to be constant. This assumption is relaxed in section 4.

[15] See appendix A for the derivation of these results.

[16] The previous assumption can be easily relaxed without affecting qualitatively our results.

follows:

$$\pi_t = \underbrace{\left(\frac{\bar{\gamma}_2}{\gamma_2}\right)^t \frac{\bar{\gamma}_2 - \beta}{\gamma_2 - \beta}}_{\substack{\text{Limited Commitment} \\ >1}} \quad \underbrace{\frac{\widetilde{y}^c + \Phi \widetilde{y}^\ell}{\widetilde{y}^c (1 + \Phi)}}_{\substack{\text{Liberal Objectives} \\ >1}} \quad \bar{\pi}_t, \tag{10}$$

where $\Phi \equiv \frac{\beta(1-q)}{\gamma_2(1-\gamma_1)} = \frac{\beta - \beta q}{\gamma_2 - \beta q} < 1$ and $\frac{\partial \Phi}{\partial q} < 0$. The first fraction on the right-hand side of equation (10) is related to the reduction in credibility. This effect has been identified by Schaumburg and Tambalotti (2007), in a context of limited commitment with stable objectives.

When more liberal objectives may be adopted in the future, another force affects current inflation, independently of whether such changes ultimately occur or not. This effect is represented by the second fraction on the right-hand side. This shows that the possibility of more liberal objectives introduces an inflation bias with respect to the limited commitment case. Such bias can be shown to be increasing in the difference between $\widetilde{y}^c$ and $\widetilde{y}^\ell$ and in the probability of policy changes $(1 - q)$.[17] In other words, the more liberal the alternative objectives are and the more likely the change, the higher is current inflation. Moreover, higher inflation is associated with a reduction in output. Indeed, as can be seen in equation (8), a higher initial inflation (π_0) lowers output in all periods. If objectives are currently liberal and may become conservative in the future the effects are symmetric. Indeed, the second fraction on the left-hand side of (10) would be lower than 1, which implies that the possibility to adopt more conservative objectives reduces the inflation bias and increases output.

Finally, we want to understand whether commitment can be used to counteract the effects of objective instability. To do so, we first compute the policies that would attain if the central bank were not credible at all. In that case, inflation (π^{NC}) and output (y^{NC}) are constant over time and given by

$$\pi^{NC} = \frac{1}{1 + \frac{\kappa^2}{w} - \beta q}[\kappa \widetilde{y}^c + \beta (1 - q) \pi_0^\ell] \tag{11}$$

$$y^{NC} - \widetilde{y}^c = -\frac{\kappa}{w}\pi^{NC} \tag{12}$$

To have an idea of the relative importance of commitment in the presence of unstable objectives, we can now compare (11) with the policies (7) - (9), derived under the limited commitment assumption. In particular, combining (7) and (9),

[17] For the derivation of these results see appendix A.3.

dividing the resulting expression by (11) and considering that the inflation implemented under liberal objectives (π_0^ℓ) would be the same in the two cases, we obtain that

$$\frac{\pi_t}{\pi^{NC}} = \gamma_2^{-t} \frac{1 + \frac{\kappa^2}{w} - \beta q}{\gamma_2 - \beta q} < 1 \tag{13}$$

where the last inequality follows from the fact that $\gamma_2 > 1 + \frac{\kappa^2}{w}$. Moreover, dividing (8) by (12) we have

$$\frac{y_t - \widetilde{y}^c}{y^{NC} - \widetilde{y}^c} = \frac{1 - \gamma_2^{-(t+1)}}{1 - \gamma_2^{-1}} \frac{\pi_t}{\pi^{NC}}, \tag{14}$$

which, at least for $t = 0$, is smaller than 1, implying $y_0 > y^{NC}$.[18]

Our analysis suggests that when policy objectives can change, having credibility is important. It allows to implement a lower inflation and, at least in the short-run, a higher output. This is because a credible central bank can keep inflation expectations relatively low by promising to lower inflation in case liberal objectives are not adopted. In other words, a credible institution can counteract more efficiently, the inflationary pressures arising from the possibility of adopting more liberal objectives.

3.2 The general model: a calibrated example

When we assume a more general version of the model ($T > 1$ and $\alpha < 1$), analytical solutions are not available. We assume a standard calibration with $\beta = .99$, $\kappa = .1$, $w = .048$, and $\alpha = 1$.[19] Schaumburg and Tambalotti (2007) set the output gap target to 0.1, we use this number for the output gap target of the liberal and consider that the conservative has a target of 0.01. We considered that central bank objectives remain unchanged with certainty for four periods ($T = 4$), at that point there is a probability that objectives change equal to $q = 0.5$.[20] In what follows, we report the results both assuming a pure forward-looking NKPC ($\alpha = 1$) and its hybrid counterpart. In the latter case, in accordance with the empirical evidence in Galí and Gertler (1999), we set $\alpha = .7$, while leaving all the rest unchanged.[21]

[18]To obtain this result notice that, from (12), $y^{NC} - \widetilde{y}^c < 0$.

[19]This calibration is used for instance in Woodford (2003) and Schaumburg and Tambalotti (2007).

[20]This calibration implies that objective changes on average every 8 periods.

[21]We do not change the functional form of the utility function because we want to keep comparability with the pure-forward looking case. Hence, we do not have the goal to characterize policy with indexation, where the functional form of utility may differ from the one considered here. In the presence of a hybrid Phillips curve we have also have to choose the initial condition for the

Figure 1 plots the optimal policy functions with unstable objectives (continuous line). The upper panel plots the policy functions with conservative objectives for inflation and output, the lower panel refers to the liberal policy functions. The conservative central bank implements the policy functions shown in the figure until policy objectives are changed. When such change occurs, the liberal policy is implemented until objectives become conservative again. In this model, the possibility that objectives change is only present every four periods - those periods are signaled in the pictures with continuous vertical lines. Therefore, once it is know that the liberal policies are not implemented, the conservative central bank is insulated from any external pressure for four periods.

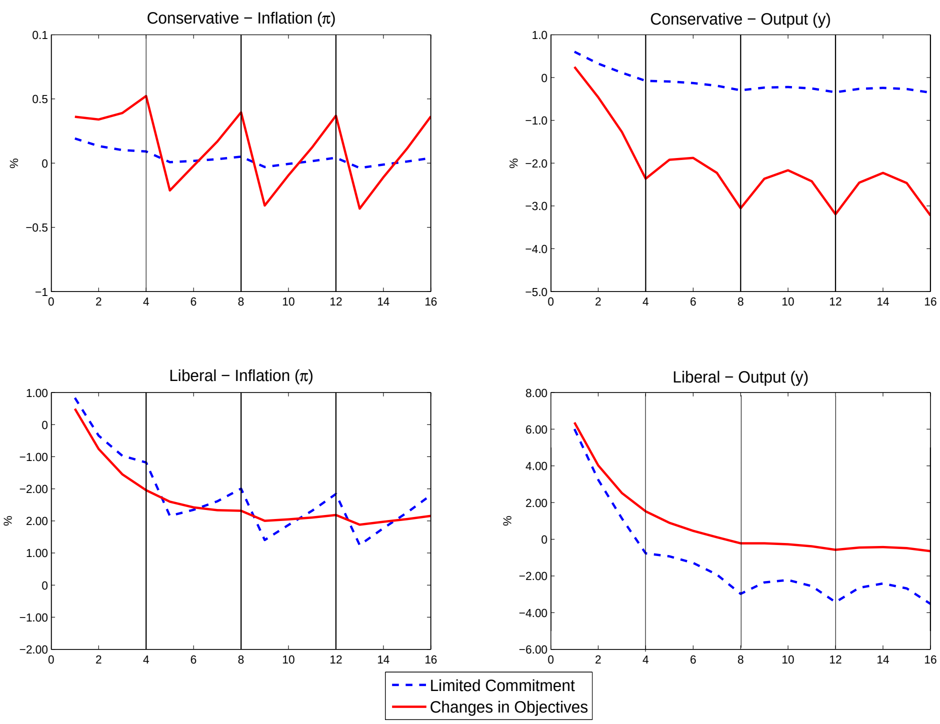
For comparison, in figure 1, we also plot the policy functions that occur in a limited commitment setting (dashed line). Limited commitment refers to the case where the central bank occasionally disregards previous commitments and makes a new plan, but where objectives do not change. In such case, the policy functions with the same objectives are implemented from the beginning until the next reoptimization occurs. The policy functions with limited commitment differ from the policy functions with changes in objectives due to the possibility that objectives change. In both cases, there is a common commitment problem.

The possibility that objectives may become more liberal in the future affects the optimal policy functions of the conservative central bank in several ways, as can be seen in the top panel of figure 1. First, when the conservative central bank starts (periods 1 to 4), inflation is now higher and output is lower (relative to limited commitment where objectives are stable). This is due to an accommodation effect. The possibility that the liberal policies with high inflation are implemented in the future affects current outcomes through inflation expectations. High inflation expectations either imply higher current inflation or lower output. The optimal policy of the conservative implies a combination of higher inflation and lower output.

Second, the conservative central bank implements a low inflation level immediately after knowing that the pressures to adopt liberal policies have dissipated and that objectives will not change in the following four periods (periods 5, 9, 13,...). The rationale of this policy is to anchor inflation expectations, and we denote it as the anchoring effect. When it is known that in the next period a liberal policy may be implemented, inflation expectations increase. In order to keep inflation expectations low, the conservative central bank finds it optimal to promise to reduce inflation if objectives remain unchanged. This promise regarding future policy

initial level of inflation. In our numerical exercises we set $\pi_{-1} = 0$. Considering other values does not affect qualitatively the results.

Figure 1: Model with Occasional Changes in Objectives



Note: This figure refers to the model where objectives can change every 4 periods. The upper two panels plot the policy functions (inflation and output gap) of a conservative central bank, and the lower two panels refer to a liberal central bank. Objectives changes (in the output gap target) can only occur every four periods - marked with continuous vertical lines. The case with objective changes and limited commitment is plotted with a continuous line. The case of no objective changes and limited commitment is plotted with a dashed line. In all panels the horizontal axis refers to the number of periods elapsed after the last change in objectives/reoptimization.

affects beneficially the current period through inflation expectations, thus exemplifying how commitment can be used to balance distortions across time and states of nature. Clearly that promise is extremely time-inconsistent. If there is not a change in objectives, the conservative central bank needs to fulfil its promise of implementing a very low inflation level. In this respect, it is worth noticing that the first period of the conservative central bank (period 1) is fundamentally different from any first period after being confirmed in office (periods 5, 9, 13,...). This is because in period 1, as opposed to periods 5, 9 and 13, previous promises are not binding and thus the anchoring effect is not present. This explains why inflation is relatively high in period 1, when compared, for instance, with period 5.

The combination of the accommodation and anchoring effect explains why the conservative starts with low inflation and then increases it. In the model with one period tenure ($T = 1$), the strength of the anchoring and accommodation effect did not change over time, and therefore we could not separately identify these effects. In that case, we proved analytically that the possibility that liberal objectives could be adopted induced the conservative to implement higher inflation in every period.

Third, the conservative experiences lower output due to the possibility that liberal policies are implemented. This result may come as surprising. If a liberal sector of the economy thinks that current output is too low, and makes pressures for changing the central bank policy, then the outcome is that the economy experiences an even lower output.[22] If the liberal policies are implemented in a later period, then the economy will experience an expansion. However, as long as the objectives do not change, the economy experiences a recession, the opposite outcome of what the pressures for liberal policies may be aiming for. This effect is also quantitatively large. For instance, after period $T = 4$ (i.e. the first period when objectives can actually change) the output-gap would be between -2% and -3% (continous line), while if liberal pressures were not present the output-gap would be roughly zero (dashed line).

Figure 2 reports the results of a model with a hybrid NKPC. The lagged inflation term introduces a state variable in the model. The presence of such state variable is relevant for our analysis, since it allows the central bank to influence strategically future decisions. In particular, with a hybrid NKPC (continous line) the conservative central bank can better counteract the effects of unstable objectives and keep output

[22] In the real world liberal pressures are more likely to materialize during productivity slowdowns or recessions. Given our results, one may be induced to (wrongly) conclude that recessions are inflationary. However, abstracting from the cyclical properties of the variables, our model only suggests that liberal pressures lead to a higher inflation and a lower output than in the absence of such pressures.

and inflation closer to target than with the pure forward looking NKPC (dashed line). Indeed, inflation is closer to zero and the recession is less severe (the output-gap is now about -1% after period 4). This is due to several reasons. First, the conservative central bank, in the last period of its tenure (period 4, 8, 12, ...), sets strategically inflation at a lower level. By doing so, it can reduce inflation expectations. This is because, as can be seen in eq. (1), when liberal objective are adopted, the lower the inherited inflation, the lower will be the level of inflation necessary to achieve the desired (high) level of output. Second, since the weight on expected future inflation is smaller, future policies have a smaller impact on current inflation.[23] This implies that, on the one hand, the necessity to accommodate inflation expectations is not so strong. On the other hand, the benefits of anchoring inflation expectations are smaller. As a result, with respect to the purely forward looking NKPC, with a hybrid NKPC inflation is higher in the first period of the tenure (due to a weaker anchoring effect), and lower at the end of the tenure (due to a weaker accommodation effect and to the strategic use of inflation).

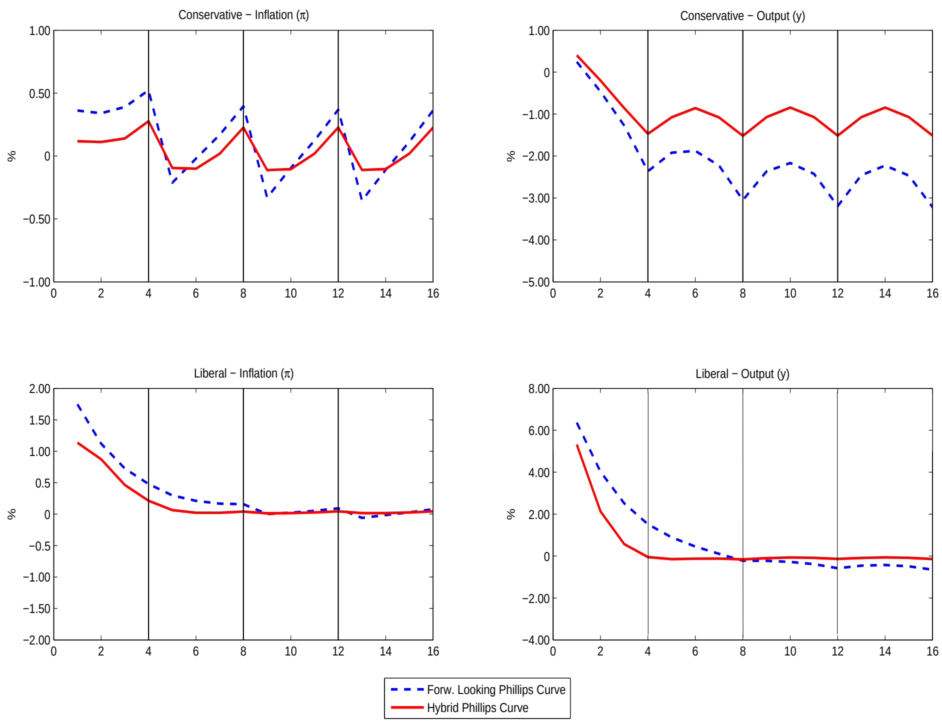
Tables 1 and 2 report, respectively, the average allocations and welfare. The average inflation that the conservative implements (column 1) is higher relative to the limited commitment case where the objectives are stable (column 4). As expected, the overall output average when conservative and liberal objectives coexist (column 3) is higher than the case where the conservative objectives are unchallenged. But, as we cautioned before, the conservative central bank experiences a lower output due to the pressures of liberal policies. Hence, as long as the central bank's objectives do not change, there is a negative effect on output. In terms of welfare, pressures to adopt liberal objectives create a negative externality on the conservative. Even though overall output is slightly higher, inflation is further away from target than under stable objectives.

In a simpler model ($T = 1$ and $\alpha = 1$), Schaumburg and Tambalotti (2007) analyzed the effects of moving from full-commitment to limited commitment. Our work analyzes another dimension of monetary policy which is absent in their work, the effects of moving from stable objectives to unstable objectives. In that regard, we are analyzing the interactions and the externalities that one type of objectives implies to the other type. As shown by the authors, when the economy moves from full to limited commitment, the (unconditional) average output-gap implemented by the central bank always increases.[24] On the contrary, in our case the possibility of

[23]In the limiting case where the Phillips curve is only backward looking ($\alpha = 0$), future objective changes would not produce any effect on current economic outcomes.

[24]For instance, Table 1 shows that the average output-gap under limited commitment is higher than zero, which is the average output-gap under full commitment. This is a general pattern under

Figure 2: Hybrid Phillips Curve



Note: This figure refers to the model where objectives can change every 4 periods and the Phillips curve also has a backward-looking component. The upper two panels plot the policy functions (inflation and output gap) of a conservative central bank, and the lower two panels refer to a liberal central bank. Objectives changes (in the output gap target) can only occur every four periods - marked with continuous vertical lines. The economy with a hybrid Phillips curve is plotted with a continuous line. The economy with a purely forward Phillips curve is plotted with a dashed line. In all panels the horizontal axis refers to the number of periods elapsed after the last change in objectives/reoptimization.

Table 1: Inflation and Output in a Model with Occasional Changes in Objectives

Pure Forward-Looking NKPC ($\alpha = 1$)					
	Changes in Objectives			Limited Commitment	
	Average with c	Average with ℓ	Overall	c	ℓ
π	0.225	0.570	0.397	0.072	0.723
y	-1.689	1.782	0.038	0.008	0.083

Hybrid NKPC ($\alpha = .7$)					
	Changes in Objectives			Limited Commitment	
	Average with c	Average with ℓ	Overall	c	ℓ
π	0.088	0.357	0.222	0.040	0.404
y	-0.850	0.900	0.021	0.004	0.045

Note: The table reports the average allocations across different simulations of the model. The values reported are in percentage points. In the limited commitment case objectives do not change.

more liberal objectives reduces the average output-gap implemented by the conservative central bank. In fact, in our calibration this effect is large, the conservative central bank implements an output-gap average of -1.68% vs 0.008% under limited commitment.

We mentioned that liberal pressures make the conservative central bank increase inflation and reduce output on average. This effect is similar the response to a positive cost-push shock. In this regard, our model can be seen as one way to endogenously incorporate shocks that create a wedge between inflation and output-gap. Since the micro-foundations of cost-push shocks are not well understood, we regard this result as a contribution in itself.[25] However, there are some important differences from the effects we identify and the traditional cost-push shocks. First, the reduction in output and increase in inflation occurs in response to the anticipation of future changes in objectives, and not due to a current change in objectives or a current shock. When objectives change and become liberal, both inflation and output expand. Therefore, it is the anticipation and not the realization of the shock that resembles the traditional (positive) cost-push shock.[26] Second, the anticipation

limited commitment as can be seen in figure 4 of Schaumburg and Tambalotti (2007).

[25] Cost-push shocks have been modeled, for example, as exogenous variations in price and wage markups (see Woodford (2003) and Galí (2008)).

[26] In this respect, our argument is similar to the important distinction between current shocks

Table 2: Welfare Comparisons

	Changes in objectives		Limited Commitment	
	c	ℓ	c	ℓ
Pure-forward looking	-0.0036	-0.0272	-0.0003	-0.0302
Hybrid	-0.0017	-0.0253	-0.0002	-0.0264

Note: The table reports welfare values according to conservative and liberal objectives. In the limited commitment case objectives do not change.

of objective changes creates permanent effects instead of transitory ones. Third, the magnitude of the shock is endogenous and can be influenced by the monetary authority. Indeed, as long as the Phillips curve is not purely forward looking, the current central bank can set inflation and strategically influence future decisions and distortions.

In a seminal partisan theory of output and inflation, Alesina (1987) considered a classical Phillips curve where current inflation surprises affect current outcomes.[27] In that context, the possibility of a future change in policy does not affect current outcomes. For instance, the possibility that a liberal policy is implemented in period 4, 8, 12 would have no consequences on the economy and the optimal policy functions in any other periods. Here, we consider instead a (standard) New Keynesian Phillips curve, where future conditions also influence current outcomes. Therefore, our work has very different mechanisms from the analysis considered in Alesina (1987), where for instance the accommodation effect is simply absent. In addition, in those models it is assumed that the central bank acts with discretion in every period. Given the developments in central bank commitment, we are instead assuming that there is commitment to policies aimed at maximizing the same objectives. Since the anchoring effect found in our model is based on a commitment, that effect is also not present in Alesina's model.

We have solved our model where both the liberal and conservative policies are set optimally. We have mainly described the effects that the possibility of adopting liberal objectives have on a conservative central bank. This may seem the most reasonable case in the OECD economies, where politicians occasionally exert some influence for more expansionary policies.[28] Nevertheless, our model yields impli-

and news about future shocks (see e.g. Beaudry and Portier (2006)).

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

[28]For instance, the index built by Havrilesky (1995) has 396 pressures for ease and 186 for

cations for the opposite case, when a central bank expects that more conservative objectives may be adopted in the future. This may be the relevant case for economies where the adoption of more stringent inflation objectives, like a specific low inflation target, is being discussed.

In the baseline case, as can be seen comparing columns 2 and 5 of Table 1, the possible adoption of more conservative objectives makes the liberal to implement a lower inflation rate. In addition, inflation expectations become lower, which allows the liberal central bank to achieve higher output. Both these effects make the liberal to achieve a better welfare outcome. In this sense, the possibility that more conservative objectives are adopted constitutes a positive externality for a liberal central bank. All these conclusions are mainly robust to the other scenarios considered.[29]

3.3 Unstable objectives with full commitment

For the sake of realism, we assumed an intermediate level of commitment where the central bank could make binding promises as long as objectives do not change. This feature reflects the inherent disagreement on different policy objectives. In this section, we analyze a setting where the central bank has full commitment, even though the policy objectives may change over time. One interpretation of this framework is that the structural parameters of the economy, like the degree of nominal rigidities and the degree of firms' monopolistic power, evolve stochastically, thus changing the magnitude of the distortion the central bank aims to correct and the effectiveness of its policy.[30] Another interpretation of this setting is that the central bank itself is subject to preferences shocks. The setting in this section models the central bank has being extremely forward-looking, since it already makes a plan and commits to certain policy actions even if future objectives differ from the current ones. Another essential assumption for the present setting is that there is no disagreement about policy objectives, in which case considering limited commitment

tightness.

[29]The only exception is the model with full commitment and no disagreement, as the one considered in section 3.3. There, liberal policies implement an even higher inflation level, and then reduce it over time achieving a specially high output. This policy is only possible because the conservative policies are cooperative, and anchor inflation expectations very firmly by promising a very low inflation level. The main feature that an expansion is obtained still holds in that case.

[30]This interpretation of the model is partly related to the literature on robust control of Hansen and Sargent (2007), and to the literature about optimal monetary policy in the presence of noisy indicators as in Aoki (2003). In our analysis, however, we focus on the effects of evolving objectives, and assume the structural relationships describing the economy and the exogenous shocks are known and common knowledge.

would be necessary. In fact, since there is no disagreement, we can think that there is a unique policymaker taking decisions.

We consider the same calibration as in section 3.2. The problem of the central bank can be written as:

$$
\begin{aligned}
V\left(\widetilde{y}_0\right) &= -\frac{1}{2}E_0\sum_{t=0}^{\infty}\beta^t\left[\pi_t^2 + w(y_t - \widetilde{y}_t)^2\right] \\
s.t. \quad \pi_t &= \kappa y_t + \beta E_t \pi_{t+1}
\end{aligned}
$$

where expectations are taken with respect to the variable $\widetilde{y}_t$.

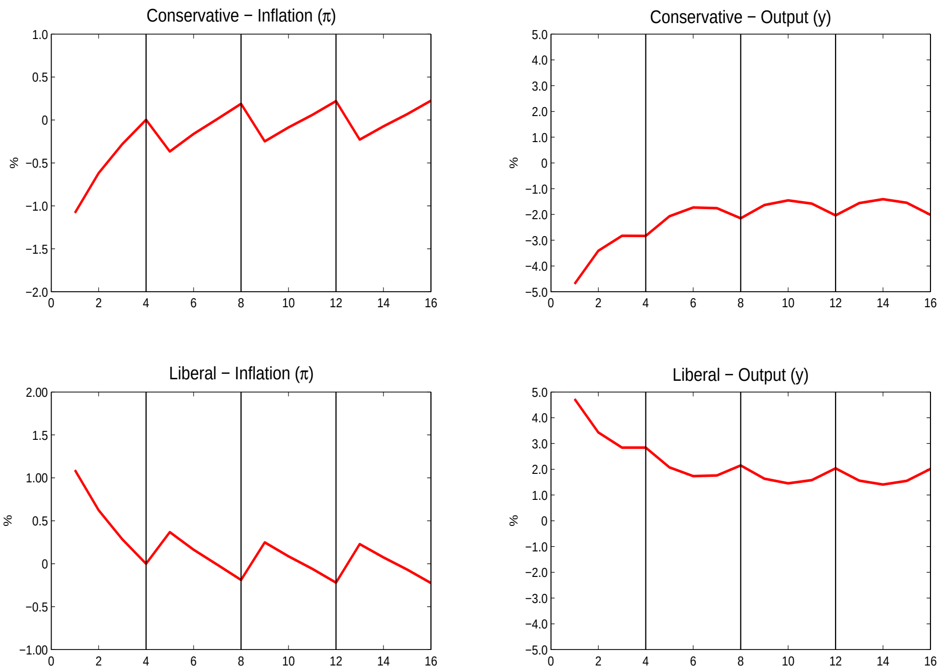
Figure 3 plots the policy functions for both types of objectives.[31] The main difference in the conservative policy between this model and the baseline case of section 3.2 resides in the initial period. In the present model, inflation in the first period is lower. This is mainly because in this setting past plans are always fulfilled. Therefore, the anchoring effect is also present in the initial period. The other interesting feature is that this anchoring effect is much stronger when objectives becomes conservative (period 1 in the graph) rather than when such objectives are reconfirmed (periods 5, 9, 13). In this setup, there is cooperation between the two regimes. In this respect, promising to reduce inflation if objectives become conservative allows the central bank with liberal objectives to achieve a higher level of output for any given level of current inflation. This policy is optimal since when objectives are liberal, achieving high output is relatively more important.

Table 3 shows the average allocations in the economy and confirms our findings in previous sections. The possibility that future policy objectives may become more liberal affects considerably the current optimal policy with conservative objectives. We still observe an accommodation and an anchoring effect. The latter is stronger and is present more frequently in this economy.[32] In fact, when policy objectives may

[31] In the model of section 3.2, when policy objectives are changed the lagrange multiplier is reset to zero. Afterwards, the policy functions depend on the evolution of the lagrange multiplier. There, we plotted the policy functions depending on the time spent in office, because there is a unique mapping between the evolution of the lagrange multiplier and the time spent in office. In the setup of this section, the lagrange multiplier is never set to zero. Therefore, even when objectives change, policy functions depend on the entire history that occurred previously. Nevertheless, we found that the qualitative features of the policy functions are not affected by the previous history of events.

[32] In the baseline model of section 3, the anchoring effect is not present in the initial 4 periods. Note that the policies of the conservative from period 1 to 4 are more likely to be implemented than the policies from period 5 to 8, which in turn are more likely to be implemented than subsequent policies.

Figure 3: Full Commitment and Objective Changes



Note: This figure refers to the model where objectives can change every 4 periods and the central bank commits to future policy, even if objectives do change. The upper two panels plot the policy functions (inflation and output gap) of a conservative central bank, and the lower two panels refer to a liberal central bank. Objectives changes (in the output gap target) can only occur every four periods - marked with continuous vertical lines. The case with objective changes and full commitment is plotted with a continuous line. The case of no objective changes and full commitment would correspond to zero inflation and zero output gap. In all panels the horizontal axis refers to the number of periods elapsed after the last change in objectives.

Table 3: Inflation and Output - Full commitment case.

	Changes in Objectives			No changes in objectives	
	Average with c	Average with ℓ	Overall	c	ℓ
π	-0.243	0.251	0.003	0	0
y	-2.518	2.547	0.002	0	0

Note: The table reports the average allocations across different simulations of the model. The values reported are in percentage points.

become more liberal, a conservative regime implements a lower average inflation, which comes at the expense of a deeper recession.[33] The effects on the output-gap are quite large. The conservative policy implements an average output-gap reduction of 2.5% whereas with stable objectives the output-gap would be 0%. If we analyze the symmetric case, the possibility of a conservative policy makes the output-gap to expand to 2.5% under the liberal policy.

4 Unstable objectives and the role of commitment

The optimal monetary policy literature has proposed many ways to limit the time-inconsistency problem, which is present in our framework. In a remarkable contribution, Rogoff (1985) suggested to appoint a conservative central bank that is more averse than society towards inflation.[34] Rogoff shows that appointing a conservative central banker, i.e. a central banker that is more inflation averse than society, even operating under discretion, can significantly reduce the time-inconsistency problem, and in some cases can implement the same policy of a benevolent planner with full-commitment (the best possible policy). As a result, it may be concluded that the credibility of a central bank may be of little importance, as long as its degree of inflation aversion is high enough.

In order to relate our framework to this literature, we now consider the case where both conservative and liberal objectives agree on the output target level,

[33]We do not compare welfare between this case and the full-commitment with stable objectives benchmark, because the utility functions are different making such comparison meaningless.

[34]Walsh (1995) and Svensson (1997) also suggested alternative ways to solve the time-inconsistency problem.

but disagree on the importance of inflation stabilization. In particular, we assume $\widetilde{y}^c = \widetilde{y}^\ell = \widetilde{y}$ and $w^c < w^\ell$.[35] In this context, the conservative central bank can be interpreted as one with higher inflation aversion than society, in the spirit of Rogoff (1985). As a consequence, the possibility that objectives become more liberal can be thought as being intrinsic to the preferences of the society.

In this framework, when policy objectives can change in every period ($T = 1$) with probability $1 - q$, we can show that inflation evolves according to

$$\pi_t \;=\; \underbrace{\frac{(1+\Phi^\ell)(1-\Phi^c)}{1-\Phi^c\Phi^\ell}}_{\substack{\text{Liberal Objectives} \\ >1}} \; \underbrace{\left(\frac{\bar{\gamma}_2}{\gamma_2}\right)^t \frac{\bar{\gamma}_2-\beta}{\gamma_2-\beta}}_{\substack{\text{Limited Commitment} \\ >1}} \; \bar{\pi}_t, \qquad (15)$$

where $\Phi^c \equiv \frac{\beta(1-q)}{\gamma_2^c\left(1-\gamma_1^c\right)} = \frac{\beta-\beta q}{\gamma_2^c-\beta q} < \Phi^\ell \equiv \frac{\beta(1-q)}{\gamma_2^\ell\left(1-\gamma_1^\ell\right)} = \frac{\beta-\beta q}{\gamma_2^\ell-\beta q} < 1$.

Consistently with our analysis in the previous analysis, we can conclude the possibility of increasing the relative weight of output stabilization generates an inflation bias. This bias increases with the probability of a policy change $(1-q)$. The appendix displays the results for the general model with $T = 4$.

As we have shown in section 3.1, when objectives are unstable, if the conservative central bank does have some commitment, it can achieve more favorable allocations. Even independent and conservative central banks, may be subject to some external pressures to adopt more liberal policies. As a consequence, our work shows that even a Rogoff conservative central banker can benefit from commitment. Commitment is indeed important to counteract the effects of the possibility of changes in policy objectives.

Our analysis also contributes to the debate on adopting inflation targeting vs. appointing a conservative central banker. A conservative central banker is more inflation averse than society and can therefore be equivalent to an inflation targeting regime.[36] However, we have shown that the probability that objectives change in the future matters. If an inflation targeting regime has been implemented, changing policy objectives is likely to be harder. It requires institutional reforms that are

[35] In a model where cost-push shocks are the only source of trade-off between inflation and output, the possibility of liberal preferences would induce more inflation volatility for the conservative central bank.

[36] Both the Rogoff conservative central banker and an inflation targeting regime are typically formalized as a central bank with a high relative weight on inflation stabilization (see Rogoff (1985) and Walsh (2003)). As a special limiting case, strict inflation targeting is obtained when inflation stabilization is the only objective ($w = 0$).

usually costly and lengthy. On the contrary, when a conservative central bank is in office, without a clearly specified target, changing policy objectives is easier. It is enough that the next chairman is not as conservative as the current one. Therefore, implementing an inflation targeting regime or appointing a conservative central bank is not equivalent. The two cases imply different probabilities that objectives change in the future, which immediately affect current outcomes.

5 Conclusions

This paper analyzes the macroeconomic effects induced by the possibility that central bank objectives may change. Objectives may be unstable due to a variety of factors. Structural changes in the economy, advances in economic theory, central bank staff turnover or political interference are some possibilities. We analyze optimal policy in such situation and its economic implications.

The paper is not aimed at providing a theoretical basis for partisan economic fluctuations, as for instance in Alesina (1987) and Drazen (2000). In practice, it may be hard to match directly political parties and elections with systematic and successful changes in central bank policy. In this respect, the novelty of our analysis is to show how the possibility of future changes in policy already produces effects in earlier periods. Following the recent literature on monetary policy, we model inflation dynamics with a New Keynesian Phillips curve, where expectations about future economic conditions affect current outcomes. Our analysis thus clarifies the theoretical difficulties to find a clear relationship between economic outcomes and policymakers' objectives. We indeed show that if liberal objectives can be adopted in the future, high inflation may be the optimal response of a conservative central bank. We can thus observe a high level of inflation no matter whether liberal objectives are eventually adopted or not.

Overall, we find that the possibility that policy objectives may become more liberal generates a negative externality for the conservative central bank. More interestingly, we also find that they lead to a contraction in current output, which is precisely the opposite of what the adoption of more liberal objectives may be aiming for. The more likely is the adoption of liberal objectives, the stronger are these effects. Along this dimension, the adoption of an inflation targeting regime seems to be preferable to a conservative central bank *à la* Rogoff, namely one with higher aversion towards inflation than society. An inflation targeting regime may imply more stable policy objectives. Changing policy objectives indeed requires an institutional reform, rather than simply appointing a chairman or advisors with different views.

We have also discussed to which extent credibility matters, in a context where policy objectives can be changed. In particular, we show how credible institutions are able to partially counteract the bad externalities generated by the possibility that policy objectives may become more liberal. This result is interesting since it clarifies that having a central bank with sufficient aversion towards inflation, as suggested by Rogoff (1985) does not eliminate the scope for having credible institutions.

Finally, our paper draws conclusions about the reverse case, where the current central bank may perceive that policy objectives may become more conservative in the future. In this case, the possibility of more conservative policy in the future creates a positive externality for the liberal central bank. Also, inflation expectations become lower, which is translated into lower current inflation and higher current output. This case may be relevant for countries that are discussing the adoption of inflation targeting regimes, which is, arguably, the case of the United States.

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Appendix

A Optimal monetary policy with changes in policy objectives

We derive the solution to the optimal policy problem with $T = 1$ and $\alpha = 1$.

$$\pi_t : \quad -\pi_t - \lambda_t + \lambda_{t-1} = 0 \tag{A-1}$$

$$y_t : \quad -w^i(y_t - \widetilde{y}^c) + \lambda_t \kappa = 0 \tag{A-2}$$

$$\lambda_t : \quad \pi_t = \kappa y_t + \beta q \pi_{t+1} + \beta (1-q) \pi_0^\ell \tag{A-3}$$

where λ_t is the Lagrange multiplier associated with the NKPC and $\lambda_{-1} = 0$. Rearranging equations (A-1)-(A-3) we obtain the second-order difference equation

$$\left[\beta q L^{-2} - \left(1 + \beta q + \frac{\kappa^2}{w^c} + 1\right) L^{-1} + 1\right] \lambda_{t-1} = \kappa \widetilde{y}^c + \beta (1-q) \pi_0^\ell$$

whose solution is given by

$$\left(1 - \gamma_1^c L^{-1}\right)\left(1 - \gamma_2^c L^{-1}\right) \lambda_{t-1} = \kappa \widetilde{y}^c + \beta (1-q) \pi_0^j \tag{A-4}$$

where,

$$\gamma_1 = \frac{\left(1 + \beta q + \frac{\kappa^2}{w^i}\right) - \sqrt{\left(1 + \beta q + \frac{\kappa^2}{w^i}\right)^2 - 4\beta q}}{2} \tag{A-5}$$

$$\gamma_2 = \frac{(1 + \beta q + \frac{\kappa^2}{w^i}) + \sqrt{(1 + \beta q + \frac{\kappa^2}{w^i})^2 - 4\beta q}}{2}. \tag{A-6}$$

It is convenient to emphasize that $\gamma_1 \gamma_2 = \beta q$ and $\gamma_1 + \gamma_2 = \left(1 + \beta q + \frac{\kappa^2}{w}\right)$ and $0 < \gamma_1 < 1 < \gamma_2$. Moreover,

$$\frac{\partial \gamma_2}{\partial q} = \frac{\beta}{2}\left(1 + \frac{(\gamma_1 + \gamma_2) - 2}{\gamma_2 - \gamma_1}\right) = \beta\left(\frac{\gamma_2 - 1}{\gamma_2 - \gamma_1}\right) > 0.$$

The unique stable solution to (A-4) is given by the expression

$$\lambda_t = \frac{1}{\gamma_2^c} \lambda_{t-1} - \frac{1}{\gamma_2^c (1 - \gamma_1^c)} \left(\kappa \widetilde{y}^c + \beta (1-q) \pi_0^\ell\right).$$

Solving backward and imposing the initial condition $\lambda_{-1} = 0$, we obtain

$$\lambda_t = \frac{1 - (\gamma_2^c)^{-(t+1)}}{(1 - \gamma_1^c)(1 - \gamma_2^c)} \left[\kappa \widetilde{y}^c + \beta (1 - q) \pi_0^\ell\right].$$

Using (A-1) we obtain the following expression for the evolution of inflation and output

$$\pi_0 = -\lambda_0 = \frac{1}{\gamma_2^c (1 - \gamma_1^c)} \left[\kappa \widetilde{y}^c + \beta (1 - q) \pi_0^\ell\right]$$

and

$$\begin{aligned} \pi_t &= (\gamma_2^c)^{-t} \pi_0 \\ y_t - \widetilde{y}^c &= -\frac{\kappa}{w^c} \frac{1 - (\gamma_2^c)^{-(t+1)}}{1 - (\gamma_2^c)^{-1}} \pi_0 \end{aligned}$$

which corresponds to equations (7)-(9).

For later convenience, we notice that since the liberal central bank is facing a problem that is symmetric with the one described above, using a symmetric expression to (9) we have

$$\pi_0^\ell = \frac{1}{\gamma_2^\ell \left(1 - \gamma_1^\ell\right)} \left[\kappa \widetilde{y}^\ell + \beta (1 - q) \pi_0^c\right] \tag{A-7}$$

A.1 The case of full-commitment and constant policy objectives

The standard case of full-commitment and no uncertainty about policy objectives is a special case of the problem described above where $\widetilde{y}^c = \widetilde{y}^\ell \equiv \widetilde{y}$, $w^c = w^\ell \equiv w$ and $q = 1$. In this case, we have that $\pi_0^\ell = \pi_0^c \equiv \bar{\pi}_0$. Defining $\bar{\gamma}_2$ as the value taken by (A-6) when $q = 1$ we have

$$\bar{\pi}_0 = \frac{1}{\bar{\gamma}_2 - \beta} \kappa \widetilde{y}^c \tag{A-8}$$

Moreover, from (7) and (8)

$$\bar{\pi}_t = \frac{\bar{\gamma}_2^{-t}}{\bar{\gamma}_2 - \beta} \kappa \widetilde{y}^c \tag{A-9}$$

$$\bar{y}_t - \widetilde{y}^c = -\frac{\kappa}{w} \frac{1 - \bar{\gamma}_2^{-(t+1)}}{1 - \bar{\gamma}_2^{-1}} \frac{1}{\bar{\gamma}_2 - \beta} \kappa \widetilde{y}^c \tag{A-10}$$

A.2 The case of limited commitment

The case of limited commitment is one where policy objectives do not change. However, the monetary authority is not fully credible because at any point in time there is a probability $(1-q)$ that its previous promises are disregarded and that a reoptimization occurs. This case corresponds to one where $\widetilde{y}^c = \widetilde{y}^\ell \equiv \widetilde{y}$, $w^c = w^\ell \equiv w$ and $0 < q < 1$. As in the full-commitment case, we have that $\pi_0^\ell = \pi_0^c \equiv \bar{\pi}_0$. The resulting allocations are given by similar expressions to (A-8)-(A-10), substituting the value of γ_2 as given by (A-6), instead of $\bar{\gamma}_2$. As a consequence, we have that inflation and output are given by

$$\begin{aligned} \pi_t^{LC} &= \frac{\gamma_2^{-t}}{\gamma_2 - \beta}\kappa\widetilde{y}^c \\ y_t^{LC} - \widetilde{y}^c &= -\frac{\kappa}{w}\frac{1-\gamma_2^{-(t+1)}}{1-\gamma_2^{-1}}\frac{1}{\gamma_2-\beta}\kappa\widetilde{y}^c. \end{aligned}$$

Since $\frac{\partial \gamma_2}{\partial q} > 0$ we have that the higher is the probability of commitment, the lower are inflation and output. Finally, dividing the above expression by (A-9) one obtains:

$$\pi_t^{LC} = \left(\frac{\bar{\gamma}_2}{\gamma_2}\right)^t \frac{\bar{\gamma}_2 - \beta}{\gamma_2 - \beta}\bar{\pi}_t, \tag{A-11}$$

where $\bar{\pi}_t$ is the level of inflation prevailing under the assumption of full commitment and no uncertainty about policy objectives.

A.3 The case of changes in the output target

We now analyze the case where there is uncertainty about the output target, i.e. where the current conservative target can be replaced by $\widetilde{y}^\ell > \widetilde{y}^c$, but keeping unchanged the weight on output stabilization, $w^c = w^\ell = w$. Substituting this into (9), and using the fact that in this case, being the output target the only difference among the two types of policymakers, $\gamma_1^c = \gamma_1^\ell \equiv \gamma_1$ and $\gamma_2^c = \gamma_2^\ell \equiv \gamma_2$ we obtain

$$\pi_0^c \left(1 - \frac{\beta^2 (1-q)^2}{\left[\gamma_2 (1-\gamma_1)\right]^2}\right) = \frac{1}{\gamma_2 (1-\gamma_1)}\left[\kappa\widetilde{y}^c + \frac{\beta(1-q)}{\gamma_2(1-\gamma_1)}\kappa\widetilde{y}^\ell\right].$$

For convenience, we define $\Phi \equiv \frac{\beta(1-q)}{\gamma_2(1-\gamma_1)} = \frac{\beta - \beta q}{\gamma_2 - \beta q} < 1$ and notice that $\frac{\partial \Phi}{\partial q} < 0$.

We thus have

$$\pi_0 = \frac{\Phi}{(1-\Phi)} \frac{\kappa}{\beta(1-q)} \frac{\widetilde{y}^c + \Phi \widetilde{y}^\ell}{(1+\Phi)}$$

Using this expression to substitute for π_0 in (7) and then dividing everything by (A-9) one obtains

$$\pi_t = \underbrace{\frac{\widetilde{y}^c + \Phi \widetilde{y}^\ell}{\widetilde{y}^c (1+\Phi)}}_{\substack{\text{Liberal Objectives} \\ > 1}} \underbrace{\left(\frac{\bar{\gamma}_2}{\gamma_2}\right)^t \frac{\bar{\gamma}_2 - \beta}{\gamma_2 - \beta}}_{\substack{\text{Limited Commitment} \\ > 1}} \bar{\pi}_t,$$

which is the same as (10).

Finally, it easy to see that π_t is increasing in the difference between $\widetilde{y}^\ell$ and $\widetilde{y}^c$. We can also show that it is strictly decreasing in q, indeed

$$\frac{\partial \pi_t}{\partial q} = \frac{\widetilde{y}^c + \Phi \widetilde{y}^\ell}{\widetilde{y}^c (1+\Phi)} \frac{\partial \pi_t^{LC}}{\partial q} + \frac{\partial \frac{\widetilde{y}^c + \Phi \widetilde{y}^\ell}{\widetilde{y}^c (1+\Phi)}}{\partial q} \pi_t^{LC} < 0,$$

since both terms of the sum are negative. The first term is negative because of our result in the previous section, while the second term can be written as

$$\frac{\partial \frac{\widetilde{y}^c + \Phi \widetilde{y}^\ell}{\widetilde{y}^c (1+\Phi)}}{\partial q} \pi_t^{LC} = \frac{\partial \frac{\widetilde{y}^c + \Phi \widetilde{y}^\ell}{\widetilde{y}^c (1+\Phi)}}{\partial \Phi} \frac{\partial \Phi}{\partial q} \pi_t^{LC} = \underbrace{\frac{\widetilde{y}^\ell - \widetilde{y}^c}{\widetilde{y}^c (1+\Phi)^2}}_{>0} \underbrace{\frac{\partial \Phi}{\partial q}}_{<0} < 0.$$

A.4 The case of changes in the relative weight of output w

When there is uncertainty about the output weight, we have that the current conservative weight can be replaced by $w^\ell > w^c$, while keeping unchanged the output target $\widetilde{y}^c = \widetilde{y}^\ell = \widetilde{y}$. Substituting (A-7) into (7) one obtains

$$\pi_t = \frac{(\gamma_2^c)^{-t}}{\gamma_2^c (1-\gamma_1^c)} \frac{\left(1+\Phi^\ell\right)}{\left(1-\Phi^c \Phi^\ell\right)} \kappa \widetilde{y}$$

which divided by (A-9) delivers equation (15).

B Results with changes in the relative weight of output w

We provide a quantitative example, for the case where the tenure of the central bank lasts for $T = 4$ periods. More specifically, we consider that $\widetilde{y}^c = \widetilde{y}^\ell = 0.03$, $w^c = 0.048$ and $w^\ell = 0.48$. This case is also plausible since it has been argued that the full-commitment microfounded calibration of w is much lower than what policy makers often implement in practice. Figure 4 presents the policy functions and Table 4 presents the average allocations in the economy.

Table 4: Inflation and Output - Changes in w

	Changes in Objectives			Limited Commitment	
	Average with c	Average with ℓ	Overall	c	ℓ
π	0.336	1.1208	0.7265	0.2168	2.0627
y	-1.3006	1.4567	0.0713	0.0249	0.2137
welfare	-0.007	-0.0329	.	-0.0027	-0.0483

Note: The table reports the average allocations across different simulations of the model.

C Recursive formulation of the problem of section 3

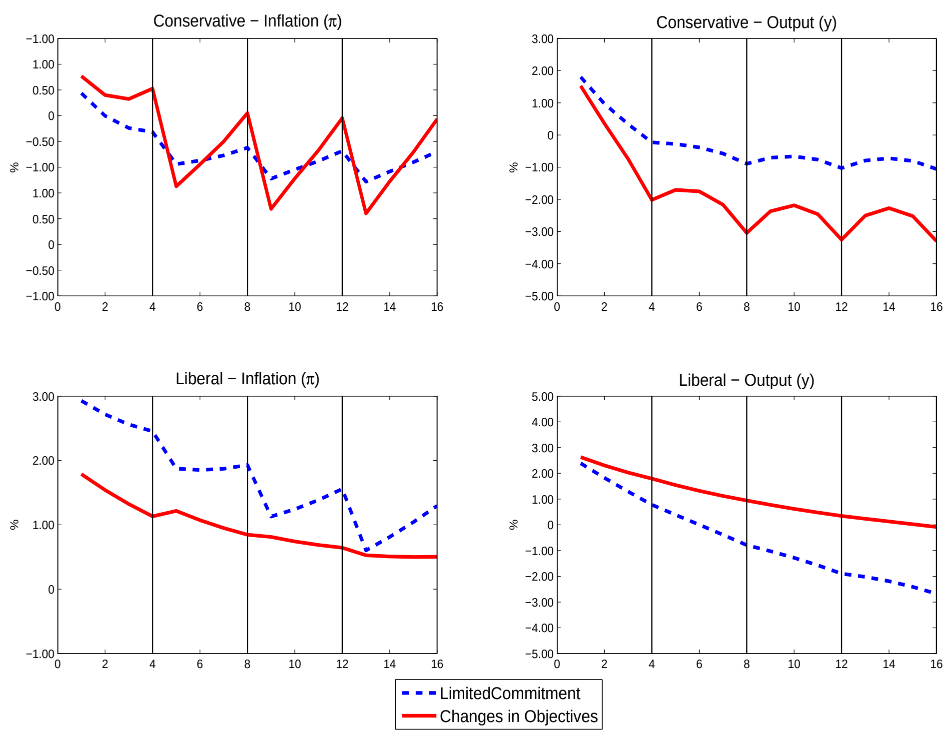
For notational convenience only, we consider a purely forward looking Phillips curve and we abstract from the presence of uncertainty other than the one regarding the policy objective changes.

Proposition 1 *Being λ the vector of lagrange multipliers associated with the constraints (4) and (5), problem (3) can be written as a saddle point functional equation (SPFE) as follows:*

$$W(\gamma) = \min_{\lambda \geq 0} \max_{\{\pi_t, y_t\}_{t=0}^{T-1}} \{h^m(\{\pi_t, y_t\}_{t=0}^{T-1}, \lambda, \gamma)\} + \beta(1-q)V^{ij} + \beta q W(\gamma')\}$$

$$s.t. \quad \gamma' = \lambda, \quad \gamma_0 = 0$$

Figure 4: Changes in relative weights of inflation stabilization



Note: This figure refers to the model where objectives can can change every 4 periods. The upper two panels plot the policy functions (inflation and output gap) of a conservative central bank, and the lower two panels refer to a liberal central bank. Objectives changes (in weight on output stabilization) can only occur every four periods - marked with continuous vertical lines. The case with objective changes and limited commitment is plotted with a continuous line. The case of no objective changes and limited commitment is plotted with a dashed line. In all panels the horizontal axis refers to the number of periods elapsed after the last change in objectives/reoptimization.

where

$$h^m(\{\pi_t, y_t\}_{t=0}^{T-1}, \lambda, \gamma) \equiv \ell(\{\pi_t, y_t\}_{t=0}^{T-1}) + \lambda g_1(\{\pi_t, y_t\}_{t=0}^{T-1}) + \gamma g_2(\{\pi_t, y_t\}_{t=0}^{T-1})$$

$$\ell(\{\pi_t, y_t\}_{t=0}^{T-1}) \equiv \sum_{t=0}^{T-1} \beta^t \left[{\pi_t}^2 + w^i(y_t - \widetilde{y})^2\right]$$

$$g_1(\{\pi_t, y_t\}_{t=0}^{T-1}) \equiv \begin{bmatrix} \pi_0 - \kappa y_0 - \beta\pi_1 \\ \vdots \\ \pi_{T-2} - \kappa y_{T-2} - \beta\pi_{T-1} \\ \pi_{T-1} - \kappa y_{T-1} - \beta(1-q)\pi_T^j \end{bmatrix}$$

$$g_2(\{\pi_t, y_t\}_{t=0}^{T-1}) \equiv \begin{bmatrix} 0 \\ \vdots \\ 0 \\ \pi_0^i \end{bmatrix}$$

Proof. of Proposition 1 Define the real valued function $r(\cdot)$ as follows:

$$r(\{\pi_t, y_t\}_{t=0}^{T-1}) \equiv -\frac{1}{2}\sum_{t=0}^{T-1} \beta^t \left[\pi_t^2 + w^i(y_t - \widetilde{y}^i)^2\right] + \beta^T(1-q)V^{ij}$$

Moreover, $g_1(\cdot)$ and $g_2(\cdot)$ are defined as in the second part of the proposition. Problem (3) is therefore equivalent to:

$$\begin{aligned} V^i = & \max_{\{\pi_t, y_t\}_{t=0}^{\infty}} E_0 \sum_{m=0}^{\infty} (\beta^T q)^m r(\{\pi_{mT+t}, y_{mT+t}\}_{t=0}^{T-1}) \\ s.t. \quad & g_1(\{\pi_{mT+t}, y_{mT+t}\}_{t=0}^{T-1}) + g_2(\{\pi_{(m+1)T+t}, y_{(m+1)T+t}\}_{t=0}^{T-1}) \geq 0 \\ & \forall m = 0, 1, ..., \infty \end{aligned}$$

This formulation fits the definition of Program 1 in Marcet and Marimon (1998). We can therefore write the problem as a saddle point functional equation in the sense that there exists a unique function satisfying:

$$
\begin{aligned}
W(\gamma) &= \min_{\lambda \geq 0} \max_{\{\pi_t, y_t\}_{t=0}^{T-1}} h(\{\pi_t, y_t\}_{t=0}^{T-1}, \lambda, \gamma) + \beta q W(\gamma')\} \\
s.t. \quad & \gamma' = \lambda, \quad \gamma_0 = 0
\end{aligned}
$$

where:

$$
h(\{\pi_t, y_t\}_{t=0}^{T-1}, \lambda, \gamma) = r(\{\pi_t, y_t\}_{t=0}^{T-1}) + \lambda g_1(\{\pi_t, y_t\}_{t=0}^{T-1}) + \gamma g_2(\{\pi_t, y_t\}_{t=0}^{T-1})
$$

or in a more intuitive formulation define:

$$
\begin{aligned}
h^m(\{\pi_t, y_t\}_{t=0}^{T-1}, \lambda, \gamma) &\equiv \ell(\{\pi_t, y_t\}_{t=0}^{T-1}) + \lambda g_1(\{\pi_t, y_t\}_{t=0}^{T-1}) + \gamma g_2(\{\pi_t, y_t\}_{t=0}^{T-1}) \\
\ell(\{\pi_t, y_t\}_{t=0}^{T-1}) &\equiv \sum_{t=0}^{T-1} \beta^t \left[{\pi_t}^2 + w^i (y_t - \widetilde{y})^2 \right]
\end{aligned}
$$

and the saddle point functional equation is:

$$
\begin{aligned}
W(\gamma) &= \min_{\lambda \geq 0} \max_{\{\pi_t, y_t\}_{t=0}^{T-1}} \{h^m(\{\pi_t, y_t\}_{t=0}^{T-1}, \lambda, \gamma)\} + \beta(1-q)V^{ij} + \beta q W(\gamma')\} \\
s.t. \quad & \gamma' = \lambda, \quad \gamma_0 = 0
\end{aligned}
$$

■

Proposition 2 *For any type of policy objectives $i = \ell, c$ the solution of problem (3) is a tenure invariant function $\psi(\gamma)$, such that:*

$$
\begin{aligned}
\psi(\gamma) = \arg \min_{\lambda \geq 0} \max_{\{\pi_t, y_t\}_{t=0}^{T-1}} \{h^m(\{\pi_t, y_t\}_{t=0}^{T-1}, \lambda, \gamma)\} + \beta(1-q)V^{ij} + \beta q W(\gamma')\} \\
\gamma' = \lambda, \ \gamma_0 = 0
\end{aligned}
$$

Proof. of Proposition 2: Using Proposition 1, this proof follows directly from the results of Marcet and Marimon (1998). ■