Endogenous Monetary Commitment[1]

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Abstract

The paper examines whether central banks should be committed to achieving price stability, and how strong their long-term monetary commitment should be. Specifically, we ask how explicitly, if at all, monetary policy should commit to a numerical target for average inflation. For that purpose we use a dynamic game theoretic framework that enables us to model various degrees of commitment, as well as its endogenous determination. Our main policy contribution consists in showing that the socially optimal degree (explicitness) of long-term monetary commitment depends on: (i) its benefit in terms of higher credibility and better anchored expectations, (ii) its short-term cost, if any, in terms of reduced stabilization flexibility, (iii) agents' expectations formation, (iv) the government's ambition in terms of output, and (v) the strictness of the regime in terms of short-term inflation control. The latter point implies that explicit inflation targeting does not necessarily need to be strict as explicitness and strictness of the monetary regime are shown to be partial substitutes, not complements as often thought.

Keywords: Commitment, price stability, endogenous timing, monetary policy mandate, explicit goals, strict vs flexible inflation targeting
JEL classification: E52, C72, E61

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1. Introduction

The literature has long asked whether monetary policy should adopt some kind of commitment, and if so, what the optimal degree of commitment should be. We attempt to contribute to this debate by formally examining the following question: *How strongly, if at all, should monetary policy be committed to long-term price stability (a low-inflation target)?*[4]

While the paper follows a similar agenda to the influential work by Rogoff (1985), we are interested in a commitment to a different target, and at a different horizon. Therefore, our commitment concept differs from Rogoff's. It relates to how *explicitly* monetary policy should commit in the *long-run* (LR), rather than how *strict (conservative)* the policy should be in terms of *short-run* (SR) stabilization. An advantage of such approach is the ability to derive the optimal degree (explicitness) of monetary commitment for any given level of monetary conservatism (strictness), and study the relationship between these LR and SR aspects of monetary policy design.

To formalize the distinction between an explicit and a strict monetary regime (see eg Svensson (1999)), we use a game theoretic framework developed in Libich and Stehlík (2010) that generalizes the timing of the players' actions. In contrast to the standard repeated game setup, in which the players move simultaneously every period, the actions of the policymaker and the public only occur with a certain constant frequency. Importantly, these frequencies are allowed to *differ across players*, and be *endogenously* determined.

Specifically, denoting time by t, we consider the following timing (see Figure 1 for an example). The central bank can reconsider its target for average inflation every $r_m > 0$ periods, and its short term interest rate instrument (in a way on average consistent) every $r_i \in (0, r_m]$ periods. The public can update inflation expectations every $r_p > 0$ periods. This implies that a one-shot version of the game, which is static in the standard framework with $r_p = r_i = r_m$, becomes a *dynamic* (extensive form) game if at least one r differs from the others.

For most of the paper we focus on the LR horizon of the game in which average trend outcomes are determined. Our main attention will be on the r_m variable, which expresses the *degree of LR monetary commitment*. The higher the r_m value, the more the policymaker's hands are tied in terms of altering the target for average inflation. We believe it can also be interpreted as the *degree of explicitness* with which LR price stability (a low-inflation target) is stated in the central banking legislation/statutes. This is because an explicit legislated inflation objective is 'institutionalized', and can thus be altered less frequently than an implicit one - for reputational, accountability, and legislative reasons.

Our analysis shows that a more explicit LR commitment (higher r_m) can improve steady-state outcomes. In particular, it delivers average inflation and expectations on target (ie high credibility) even in situations of lacking central bank conservatism and/or independence, in which an inflation bias would otherwise occur. This is because LR commitment increases the length of the public's punishment of the central bank for an inflation surprise, and as such it reduces the policymaker's temptation to stimulate the

[4] Let us state from the outset that price stability will be broadly defined in our analysis - the inflation target will not necessarily be limited to consumer prices.

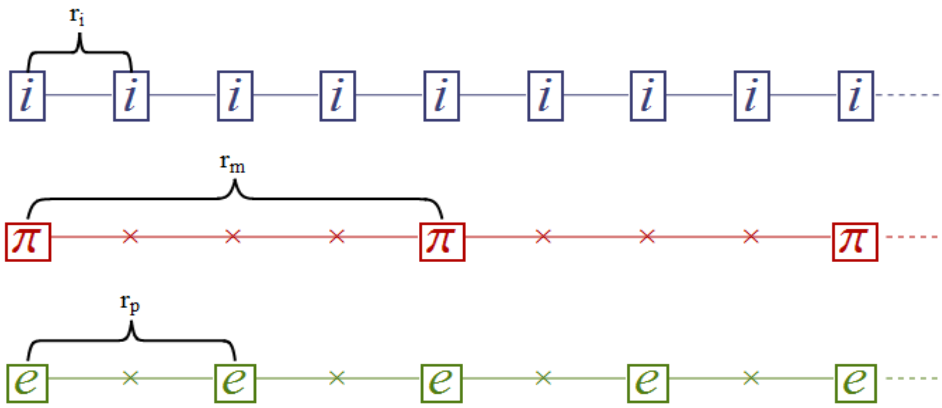

FIGURE 1. An example of the timing with $r_i = 1, r_m = 4$, and $r_p = 2$.

economy beyond potential output. In game theoretic terms, a higher r_m increases the proportion of time the policymaker acts as a leader in the game, and the public as the follower, which helps the policymaker tie his hands and use it to his own as well as the society's advantage. The intuition of this result is similar to that of some recent contributions, eg Schaumburg and Tambalotti (2007) or Debortoli and Nunes (2008).

In addition to this widely accepted *LR benefit of explicit commitment*, academics and central bankers have brought forward some possible *SR costs and benefits* as well. In terms of the costs, Kohn (2003), Greenspan (2003), or Friedman (2004) have expressed the view that an explicit inflation target may lead to a reduction in the policymaker's flexibility to stabilize the real economy, and hence a greater volatility of some real variables. On the other hand, the potential benefits of an explicit LR commitment discussed include an improvement in accountability (eg King (1998), Walsh (2003)), reduction of the private sector's monitoring costs (eg Svensson (1997), Hughes Hallett and Libich (2007)), and most importantly the anchoring effect on expectations and wages (eg Gürkaynak, et al. (2005), Orphanides and Williams (2005), Mishkin (2004), Bernanke (2003), or Goodfriend (2003)). It is argued that due to this effect the policy flexibility may in fact increase rather than decrease, as anchored expectations give the policymaker greater leverage over the real interest rate.

Intuitively, the relative magnitude of these SR *net*-costs, $c(r_m)$, vis-à-vis the above LR benefit will determine how strongly, if at all, the monetary policymaker commits. Generically, three types of regime may arise depending on $c(r_m)$: full-commitment, no-commitment, and partial-commitment.[5] We analytically identify the circumstances for each of these outcomes. Importantly, in addition to $c(r_m)$ we uncover several other

[5]This is in contrast to Rogoff (1985). obtained only the partial-commitment case. This is because he focused solely on SR stabilization issues and the case $\frac{\partial c(r_m)}{\partial r_m} > 0$.

variables that influence the optimal degree (explicitness) of LR monetary commitment r_m^*.

The r_m^* degree is shown to also depend on: (i) the slope of the aggregate supply relationship, (ii) the way and frequency with which private agents' form expectations, (iii) the strictness of the regime in terms SR inflation stabilization, and (iv) the degree of central bank goal-independence from the government.

The above implies that the explicitness of the price stability objective is likely to differ across countries. Most interestingly, point (iii) implies *substitutability* between explicit inflation targeting and strict inflation targeting. This is in contrast to the view of inflation targeting opponents that an explicit numerical inflation target necessarily leads to strict(er) monetary policy, ie that there exists some complementarity between these two features.

Let us acknowledge that in order to be able to highlight the intuition of the game theoretic analysis with endogenous commitment, and *analytically* derive the exact value of r_m^* (in contrast to Rogoff (1985)), we have made some concessions in terms of the macroeconomic environment. First, we use a simple reduced-form version of the New Keynesian model rather than a fully articulated micro-founded model. Second, long-term price stability is broadly defined in our analysis. The framework does not attempt to identify how exactly it should be specified - whether as a LR inflation target for consumer prices, or whether it should also include asset prices to some extent.[6]

Third, the SR costs and benefits of explicit LR commitment are not modelled directly; they are summarized by the parameter $c(r_m)$. The advantage of such approach is the fact that our findings are applicable to various underlying macroeconomic settings, not only the model we utilize. The disadvantage is that we cannot provide an a full answer in regards to the optimal degree of LR commitment, it is reported only as a function of $c(r_m)$. To fill this gap we formally model the SR flexibility and anchoring effects of LR commitment in Libich (2008a). Nevertheless, further research is required to fully understand the SR effects in a range of different models.[7]

The rest of the paper is structured as follows. Sections 2 and 3 present the macroeconomic model and the game theoretic framework respectively. Section 4 reports the results. Section 5 summarizes and concludes.

2. The Model

In order to demonstrate the intuition in the most illustrative way and derive analytical solutions we will use a reduced-form New Keynesian model - a simplified version of Clarida et al. (1999). Since the micro-foundations of this framework are well-known

[6] Real world inflation targeting countries have formulated their inflation targets in terms of consumer price inflation (see for example Bernanke et al. (1999) or Blejer, et al. (2000)), but the global financial crisis of 2007-9 points to the potential problems of ignoring asset prices.

[7] The SR stabilization effects of an explicit inflation target have been subject of a heated debate in the literature and central banking circles. McCallum (2003) summarized the state of affairs as follows: *'The extent to which inflation targeting regimes impair central bank flexibility is a matter of professional dispute. There is probably no way that this disagreement can be settled in the present state of economic knowledge'.* Libich (2008s) shows that c may not be monotone in r_m, which perhaps explains this disagreement. It is likely that c is sensitive to the model used, and hence uncovering its 'true' specification is largely an empirical matter.

(see eg Woodford (2003)), and their presentation would not add new insights, we do not reproduce them here.

2.1. **Policy Preferences.** The monetary policymaker's single period utility function is as follows[8]

$$u_t = -(x_t - x^T)^2 - a\left(\pi_t - \pi^T\right)^2 - c(r_m), \tag{1}$$

where $t \geq 0$ denotes (discrete or continuous) time, $a > 0$ denotes the degree of monetary policy strictness (conservatism), and $c(r_m)$ is the per-period SR net-cost of explicit LR commitment. The variable π^T denotes a low-inflation target that is consistent with LR price stability. The variable $x^T \geq 0$ denotes the policymaker's output gap target.

The literature has identified several possible reasons for $x^T \neq 0$, such as (i) mismeasurement of potential output (eg Orphanides (2001)), (ii) market imperfections (eg Barro and Gordon (1983)), (iii) a shortcut for an asymmetry in the policy preferences (eg Cukierman and Gerlach (2003)), or (iv) political economy reasons on the fiscal policy side (eg Faust and Svensson (2001)).

We will adopt the latter justification. Specifically, we will assume that x^T is a weighted average of the central banker's output target, x_b^T, and the government's output target, x_g^T, with the weight being the degree of central bank goal-independence, $CBI \in [0, 1]$. This can be due to direct political pressure, and/or indirect spillovers from excessive fiscal policy to monetary policy. Further, we follow Faust and Svensson (2001) in assuming that the central banker is responsible (prefers potential output), whereas the government aims at output above potential (where x_g^T expresses the degree of its ambition). Formally:

$$x^T = CBI x_b^T + (1 - CBI)x_g^T, \quad \text{where} \quad x_g^T > x_b^T = 0. \tag{2}$$

Naturally, $CBI = 1$ denotes full-independence, $CBI = 0$ denotes no-independence, and $CBI \in (0, 1)$ denotes partial-independence.

2.2. **Economy.** The supply side of the economy is described by a simple Phillips curve

$$\pi_t = \lambda x_t + e_t + v_t, \tag{3}$$

where $\lambda > 0$, x expresses the output gap, v is an inflation shock with a zero mean, and e denotes inflation expectations. We do not specify a lag structure on the e variable since its timing will be an important ingredient of the game theoretic analysis, see Section 3. Nevertheless, private agents are assumed to be forward looking and act rationally, and the same is true for the policymaker. Both players are also aware of the rationality of the opponent, and have complete information about all features of the game.

In the standard one-shot static game, in which the players move every period, it is straightforward to check that our model yields the conventional equilibrium outcomes (denoted by asterisk throughout)

$$\pi_t^* = \pi^T + \frac{(1 - CBI)x_g^T}{a\lambda} + \frac{1}{1 + a\lambda^2}v_t \quad \text{and} \quad x_t^* = -\frac{a\lambda}{1 + a\lambda^2}v_t. \tag{4}$$

Equation (4) shows that the shock v does not affect the steady-state levels of inflation and output. Since we are primarily interested in these LR levels, we will not model the stabilization of shocks directly, and treat π as the choice variable of the policymaker (see

[8]We will not consider discounting for parsimony - without affecting our conclusions.

Clarida et al. (1999) for more discussion of such a shortcut). Instead, all SR stabilization issues will be summarized indirectly through the variable $c(r_m)$.

2.3. **Short-Term Net-Cost of Long-Term Monetary Commitment.** The SR net-cost c will naturally be assumed some function of the degree of commitment r_m. A wide range of specifications of $c(r_m)$ come to mind as plausible. In order to illustrate the intuition we postulate the SR net-cost as follows

$$c(r_m) = \gamma(r_m)^k, \tag{5}$$

where $\gamma \in \mathbb{R}$ and $k \in (0, \infty)$. If the SR cost of LR commitment exceeds the SR benefit we have $\frac{\partial c}{\partial r_m} > 0$, and if the reverse is true we have $\frac{\partial c}{\partial r_m} < 0$. Let us note that this nests all reasonable specifications of the cost: *concave,* $k \in (0, 1)$, *linear,* $k = 1$, as well as *convex,* $k > 1$, the latter including the natural *quadratic* case, $k = 2$. Nevertheless, in Appendix B we examine a general $c(r_m)$.

For reasons explained in the introduction the presented paper does not formally model $c(r_m)$, it treats it as exogenous (for formal modelling see Libich (2008a)). Let us note two issues. First, due to the LR focus $c(r_m)$ is assumed time-invariant, and hence can be interpreted as some average cost. Second, $c(r_m)$ in the real world arguably depends on a number of variables describing the economy and the policy setting which we do not model. For example, it is likely to be affected by the specification of the target in terms of its horizon. Throughout the paper, we assume the policymaker to be targeting LR price stability, ie have a low-inflation target for average inflation, which is the case of most inflation targeters from industrial countries (see Mishkin and Schmidt-Hebbel (2001)). If however the horizon is shorter - for example the two-year specification of the Bank of England - both the inflexibility cost and the anchoring benefit are likely to increase.

3. Timing of Moves

The introduction and equation (4) imply that the policymaker's actions can be broken into two components - the steady-state part (ie the LR policy stance), and the SR stabilization part. Our focus is on the former, whereby the bank is able to alter the average inflation level (target) every $r_m > 0$ periods.

The public is able to reconsider expectations of inflation level every $r_p > 0$ periods. Intuitively, the reason for infrequent updating are various costs associated with gathering and processing information. To focus on the policy commitment, we will restrict our attention to the case of interest[9]

$$r_m = nr_p, \tag{6}$$

where $n \geq 1$. Let us impose two assumptions to make the analysis more illustrative. First, to keep the focus on the optimal degree of policy commitment r_m^*, we will treat r_p as exogenous. Second, to restrict the amount of asynchrony in the game, and make the game closer to the standard repeated game, we assume $n \in \mathbb{N}$. This implies that the players make a simultaneous move every r_m periods, and the public can also move in

[9] Appendix A allows for $n \in (0, 1)$, ie the $r_m < r_p$ case, and shows that this does not alter any of our results.

between these moves.[10] It further implies that the *dynamic stage game* has a length of r_m periods, and is regularly repeated. This is in contrast to the standard *static game* with length of one period only.

Let us now summarize the timing of LR moves - an example of a time line featuring two repetitions of the dynamic stage game is in Figure 1:

(1) At the beginning of the game, in period $t = 0$, the policymaker chooses r_m, observing r_p.
(2) Observing r_m, the public and the policymaker make a simultaneous move of their choice variables e and π in period $t = 0$.
(3) The public and the policymaker then move every r_p and r_m periods choosing e and π respectively, observing all moves made in past periods (ie a game of perfect monitoring).
(4) The payoffs accrue every period.

The following definition categorizes the outcomes in terms of r_m.

Definition 1. *The variable r_m expresses the **degree of long-term commitment** of monetary policy, whereby we will distinguish three main cases: (i) **full-commitment,** $r_m = \infty$, (ii) **partial-commitment,** $r_m \in (r_p, \infty)$, and (iii) **no-commitment,** $r_m = r_p$.[11] The ratio $\frac{r_m}{r_p}$ will be referred to as the degree of **relative commitment.***

The fact that we allow for various *degrees* of the target's explicitness addresses the criticism of the existing literature on inflation targeting (see eg Gertler (2003)), which has grouped countries into two categories only: targeters and non-targeters. This has lead to inconclusive empirical findings.

4. Results

In line with the backwards induction solution of the game, this section first examines the effect of explicit commitment on the steady-state inflation outcome, π^* - treating r_m as exogenous. Taking it into account, the section then investigates the optimal degree of commitment, r_m^*.

4.1. Effect of Long-Term Monetary Commitment on Policy Performance.

Our first result shows how explicit LR commitment alters the incentives of the central bank, and improves the steady-state inflation outcome.

Proposition 1. *A stronger (more explicit) LR monetary commitment reduces the inflation bias, if any. It is however the degree of **relative commitment,** rather than its absolute level, that has an effect.*

Proof. Restricting our attention to Markov perfect equilibria we can focus solely on the dynamic stage game and abstract from its further repetition. At its beginning, in time

[10] While we do not impose it, the reader can think of the case $r^p = 1$ throughout the paper, ie the representative agent absorbs and uses information without delays. Libich and Stehlík (2010) formally demonstrate that the $n = \mathbb{N}$ case is representative of the more asynchronous cases with $n \notin \mathbb{N}$, in which both players act as the Stackelberg leader at some stage of the game.

[11] The no-commitment case is the lowest considered level of r_m. Therefore, if we also allow for $r_m \in [0, r_p)$, see Appendix A, this case is re-defined as $r_m = 0$.

$t=0$, the players move simultaneously, and then the public gets a chance to reconsider its action every r_p, observing the policymaker's initial move. This dynamic stage game finishes just before the players make their second simultaneous LR moves.

Solving by backwards induction, we know that once the public gets to respond to the policymaker's initial move in period r_p, expectations of *average* inflation will be set rationally at that very same level, and will remain at that level for the rest of the dynamic stage game. Formally, $e^*_{t\in(0,r_m)} = \pi_0$.

It therefore follows, in combination with (3), that $x_t = 0, \forall t \in [r_p, r_m]$. Put differently, the only period of time in which there *may* be an inflation surprise is the initial $t \in [0, r_p)$. Substituting this information and (3) into (1), the policymaker's utility over the dynamic stage game can be written as

(7)
$$u = -r_p\left[\frac{(\pi - e)}{\lambda} - (1 - CBI)x_g^T\right]^2 - (r_m - r_p)\left[-(1 - CBI)x_g^T\right]^2 - r_m a(\pi - \pi^T)^2 - r_m c\,(r_m)\,.$$

Note that the first component features r_p, whereas the last two feature r_m. This is because unlike the possible output gain from a policy surprise, the costs of deviating from the inflation target and of explicit commitment accrue for the whole dynamic stage game. Put differently, π is constant (ie not a function of time) on the interval $(0, r_m)$, whereas e is constant on the intervals $(0, r_p)$ and (r_p, r_m).

Moving backwards, the policymaker takes this into account when making his initial decision. Differentiate (7) with respect to inflation and set equal to zero

$$\frac{\partial u}{\partial \pi} = -\frac{2}{\lambda}\left[\frac{(\pi - e)}{\lambda} - (1 - CBI)x_g^T\right] r_p - 2a(\pi - \pi^T)r_m = 0. \tag{8}$$

Under rational expectations and complete information we will have no surprise even in the initial period since $e_0^* = \pi_0$. Therefore, steady-state output is always on potential, $x_t^* = 0, \forall t$. Using this and rearranging (8) yields

$$\pi^* = \pi^T + \frac{(1 - CBI)x_g^T}{a\lambda}\frac{r_p}{r_m}. \tag{9}$$

The expression shows that the inflation bias obtains, due to $x_g^T > 0$, for all $CBI < 1$. The fact that the bias is, for all assumed parameter values, a decreasing function of the relative commitment of monetary policy, $\frac{r_m}{r_p}$, completes the proof. □

Note that our analysis nests the standard simultaneous repeated game specification. Specifically, under $r_p = r_m$ the expression in (9) becomes $\pi^* = \pi^T + \frac{(1-CBI)x_g^T}{a\lambda}$, which is the conventional steady-state value of the New Keynesian model under discretion reported in (4).

Intuitively, the potential bias is - for a given strictness of the regime a - reduced due to a smaller temptation to surprise inflate caused by a more explicit LR commitment. This happens since the public has a better chance to punish the policymaker for such behaviour in comparison to a standard simultaneously repeated game. Importantly, such punishment is the public's optimal choice, not an arbitrary rule (trigger strategy) of the Barro-Gordon type.

Note that (9) also reports a conventional result about the magnitude of the potential bias - it is decreasing in CBI. This is in line with empirical findings reported by a number of papers, eg Cukierman, et al. (1992) and Alesina and Summers (1993).

4.2. **The Optimal Degree of Long-Term Commitment.** The next proposition reports the main result of our analysis, answering the question posed in the introduction: How explicitly, if at all, should monetary policy be committed to a LR inflation target?

Proposition 2. *(i) Whether or not the policymaker commits depends on* $k, r_p, x_g^T, CBI, \gamma, \lambda$, *and* a. *(ii) The optimal degree (explicitness) of long-term monetary commitment,* r_m^*, *is weakly increasing in* r_p, x_g^T, *and decreasing in* CBI, γ, λ, a. *The latter implies substitutability between explicit and strict inflation commitment.*

Proof. All calculations of the proof of Proposition 1, derived under exogenous r_m, still apply under its endogeneity. Now move backwards and consider the optimal choice of r_m. In contrast to (7) where the policymaker's utility is written out for the whole dynamic stage game, let us write it in single period terms. Using (7) and $x_t^* = 0, \forall t$ we have

$$u = -\left[-(1-CBI)x_g^T\right]^2 - a\left[\pi^T + \frac{(1-CBI)x_g^T}{a\lambda}\frac{r_p}{r_m} - \pi^T\right]^2 - c\left(r_m\right).$$

Differentiating with respect to the degree of LR commitment we get

$$\frac{\partial u}{\partial r_m} = \frac{2a\left[\frac{(1-CBI)x_g^T}{a\lambda}r_p\right]^2}{r_m^3} - \frac{\partial c}{\partial r_m}. \tag{10}$$

Consider first the $\frac{\partial c}{\partial r_m} > 0$ (ie $\gamma > 0$) case. Setting (10) equal to zero and rearranging yields

$$\overline{r}_m = \sqrt[k+2]{\frac{\frac{2}{a}\left[\frac{(1-CBI)x_g^T}{\lambda}r_p\right]^2}{\gamma k}}. \tag{11}$$

If this *unique maximum* $\overline{r}_m$ is attained for $r_m \leq r_p$ then the no-commitment outcome obtains, ie the policymaker chooses the lower bound $r_m^* = r_p$ (see Definition 1). Solving $\overline{r}_m = r_p$ for γ yields the following threshold

$$\bar{\gamma} = \frac{\frac{2}{a}\left[\frac{(1-CBI)x_g^T}{\lambda}\right]^2}{kr_p^k}. \tag{12}$$

It follows that if $\gamma \geq \bar{\gamma}$ then the policymaker does not commit at all as it is too costly. In contrast, if $\gamma < \bar{\gamma}$ then the policymaker (at least partially) commits since $\overline{r}_m > r_p$. The fact that $\bar{\gamma}$ in (12) is a function of all the above variables proves claim (i).

Whether commitment will be partial or full can be seen in (10). The first fraction on the right hand side is always non-negative, which implies that if $\gamma \leq 0$ then $\frac{\partial u}{\partial r_m} > 0$ for all $\gamma, x_g^T, a, k, r_p, CBI$. From this it follows that in such case the policymaker selects

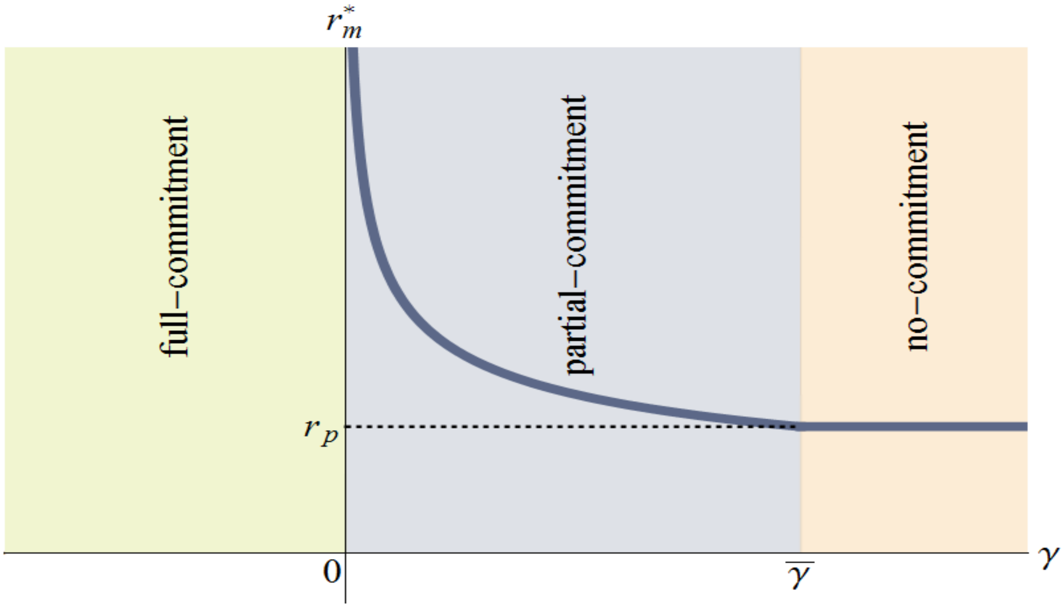

FIGURE 2. A graphical example of the optimal degree of LR monetary commitment, r_m^*, as a function of its marginal SR net-cost γ - the plot of (13).

full-commitment, $r_m^* = \infty$. If however $\gamma \in (0, \bar{\gamma})$ then $\overline{r}_m > r_p$ and hence the partial-commitment scenario obtains, $r_m^* = \overline{r}_m$.[12] Summarizing these results the equilibrium degree of LR monetary policy commitment can be written as

$$(13) \qquad r_m^* = \begin{cases} \infty & \text{(full-commitment)} \quad \text{if} \quad \gamma \leq 0, \\ \sqrt[k+2]{\dfrac{\frac{2}{a}\left[\frac{(1-CBI)x_g^T}{\lambda} r_p\right]^2}{\gamma k}} & \text{(partial-commitment)} \quad \text{if} \quad \gamma \in (0, \bar{\gamma}), \\ r_p & \text{(no-commitment)} \quad \text{if} \quad \gamma \geq \bar{\gamma} \geq 0, \end{cases}$$

which completes the proof. □

Figures 2–3 offer graphical examples of the results of Proposition 2. The former focuses on the effect of $\gamma \in \mathbb{R}$, whereas the latter depicts the influence of a, x_g^T and CBI, restricting the attention on the $\gamma > 0$ values.

Figure 2 shows that if $\gamma \leq 0$, ie if the potential cost of reduced flexibility is more than outweighed by the benefit of anchored expectations, then explicit LR commitment does not constitute a SR stabilization tradeoff. Obviously, the policymaker commits as strongly/explicitly as possible in such case. In contrast, if the SR net-cost of explicit commitment is positive and too large, $\gamma \geq \bar{\gamma} \geq 0$, than the policymaker will not commit at all. Finally, if the cost is positive but within a certain range, $\gamma \in (0, \bar{\gamma})$, than the policymaker does commit, but only to some extent that reflects the associated tradeoff.

[12]Note that due to the technical restriction in (6), r_m^* must be rounded to the nearest r_m satisfying (6)with $n \in \mathbb{N}$.

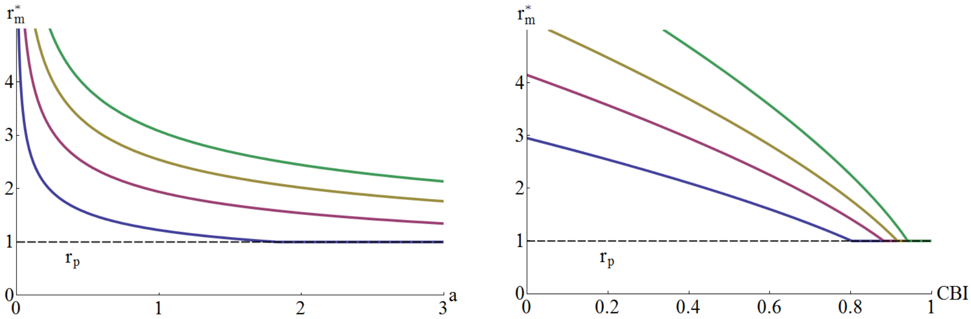

FIGURE 3. The optimal partial-commitment r_m^* as a function of the regime strictness a (left) and CBI (right) for values $\gamma > 0$. The increasing curves indicate increases in the government's ambition x_g^T.

As the reported variables $k, \lambda, r_p, a, x_g^T$ and CBI affect this tradeoff, they determine the exact shape of the r_m^* curve in the figure.

Figure 3 presents the effects of strictness a (left panel) and CBI (right panel) on r_m^*. As (13) shows, r_m^* is decreasing in both a and CBI. Interestingly, while the former relationship is convex, the latter is concave. This implies that the marginal benefit of explicit LR commitment is not constant, and that it depends on various circumstances.

Further note the implication of (12): a and CBI not only reduce the optimal degree of commitment, but they also reduce the parameter space under which the policymaker commits at all (ie they increase $\bar{\gamma}$). Finally, both parts of Figure 3 show that a greater ambition of the government requires a stronger commitment, other things equal.

There are two main implications of the findings presented in Figure 3. First, countries with initially lower degree of goal CBI have an incentive to be more explicitly committed in the LR. There exists some empirical evidence of this substitutability between an explicit monetary commitment and central bank (goal) independence. In particular, using various indices Briault, et al. (1997), Haan, et al. (1999) and Sousa (2002) report a negative correlation between (goal) independence and accountability (arguably a proxy of LR commitment).[13]

Second, countries that commit more explicitly in the LR do not necessarily need to commit more strictly in the SR. This is in contrast to the conjecture of inflation targeting opponents, who have often argued that a more explicit commitment to a numerical inflation target would mean a stricter and less flexible policy.

An important issue is the sign and magnitude of γ. The existing empirical evidence seems to imply the case $\gamma \leq 0$. In particular, it shows that the adoption of explicit inflation targets has been associated with (i) better anchored expectations (see eg Kuttner and Posen (1999), Levin, Natalucci and Piger (2004), Gürkaynak, Sack and Swanson

[13] For more see Libich (2008b) in which this relationship is examined in more detail. Note that since CBI relates to the policy preferences, this refers primarily to *goal*-independence, not *instrument*-independence; for this important distinction see Debelle and Fischer (1994)). It should also be noted that using indices of these institutional variables is not without potential empirical issues. The findings therefore need to be taken as indicative rather than conclusive.

(2005), but (ii) no change or a decrease in output volatility (eg Corbo, Landerretche and Schmidt-Hebbel (2001)), Arestis, Caporale and Cipollini (2002), Fatas, Mihov and Rose (2004)). The same is implied by the theoretical results of Orphanides and Williams (2005), Adam (2008), and Libich (2008). Nevertheless, this issue is far from resolved and requires further research to establish the robustness of these results - many would still argue that $\gamma > 0$. Because of that, we have not constrained the value of γ and derived r_m^* for any $\gamma \in \mathbb{R}$.

5. Summary and Conclusions

The paper follows in the footsteps of Rogoff (1985) trying to establish whether, and to what extent, monetary policy should be committed. Our focus is however on a different type of commitment, and over a different horizon. We are interested in an explicit commitment to long-term price stability (inflation target), rather than a strict commitment to short-term inflation stabilization. Therefore, our game theoretic framework uses a novel dynamic concept of commitment.

Specifically, the framework generalizes the timing of the players' moves. It allows for the fact that players do not necessarily move every period, and not necessarily in a simultaneous fashion. Naturally, the longer a player is unable to reconsider his previous action, ie the lower the frequency of his moves, the stronger the player's commitment.

This form of commitment has three main advantages over the standard game theoretic commitment concept. First, it allows us to study *concurrent commitment*, whereby all players can be committed at the same time. Second, it offers a way to model *partial commitment*, in which the players can be committed only to a certain degree (that can differ across players). Third, it enables us to consider *endogenous commitment,* ie one optimally selected by the players. Furthermore, our commitment is compatible with the popular macroeconomic concept of commitment - the timeless perspective rule - popularized by Woodford (1999). This is because it does not impose a particular way in which the decisions need to be made.

Using a reduced-form New Keynesian macroeconomic model has enabled us to show circumstances under which the monetary policymaker will and will not commit. In addition, and unlike Rogoff (1985), we have been able to analytically identify several determinants of the *optimal degree (explicitness) of long-term monetary commitment* r_m^*, showing their direction and magnitude.[14]

In particular, r_m^* is a function of the structure of the economy, the frequency with which agents update expectations, and the potential SR costs and benefits of explicit long-term commitment (in terms of stabilization inflexibility and anchoring expectations respectively). Importantly, we also establish substitutability between explicit long-term commitment, strict commitment, and central bank goal-independence.

[14]Rogoff examined the case in which the SR net-cost of commitment is positive due to loss of stabilization flexibility (analogous to our $\frac{\partial c(r_m)}{\partial r_m} > 0$). This was because his commitment concept related to the strictness/conservatism of the policymaker, a. In a more complex macroeconomic setting, he was able to prove that (i) the policymaker will commit, and that (ii) his commitment will be partial (ie that the socially optimal a is higher than the society's but finite, which is analogous to our $r_m^* \in (r_p, \infty)$). However, an optimal degree (strictness) of commitment and its various determinants could not be derived in his setup, which is why we opted for a simpler model.

This result implies that explicit inflation targeting does not imply strict inflation targeting. It also offers a possible explanation for why it was primarily countries featuring relatively high inflation that have tended to commit more explicitly to price stability, ie legislate a unitary or hierarchical mandate with a numerical inflation target as opposed to the dual mandate without one.

More research is required to shed light on two related issues. First, the exact specification of long-term price stability is open for further investigation. For the past two decades most industrial countries have specified it as a low-inflation target for average consumer price inflation, with notable success. But this conventional practice - and the potential need to perhaps respond to various asset prices under some circumstances - may have to be re-examined carefully in light of the financial turbulences of 2007-9. Second, the short-run stabilization effects of an explicit LR commitment need further theoretic as well as empirical investigation before more definite policy recommendations can be drawn.

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Appendix A. Allowing For $n \in (0,1)$

The analysis of Section 4 implies that allowing for $r_m < r_p$ will make no qualitative or quantitative difference to the outcome. The only change in (13) will be the re-specification of the no-commitment outcome from $r_m = r_p$ to $r_m = 0$, see Definition 1.

Intuitively, under $r_m < r_p$ both the output gain from an inflation surprise, and the costs of inflation would last r_p periods, ie all the elements of (7) would feature r_p instead of r_m. Therefore, the equilibrium inflation level in (9) would not be a function of the degree of LR commitment. This implies the following:

Remark 1. *There exist no circumstances under which* $r_m^* \in (0, r_p)$*.*

If the SR net-cost of LR commitment is sufficiently large, $\gamma \geq \bar{\gamma}$, then the policymaker will select the lowest possible (no-commitment) value, which is now $r_m = 0$. Then r_m^* would no longer be a continuous function of γ as in Figure 2 - it would feature a jump at the r_p level.

Appendix B. General SR Net-Cost

While the polynomial growth specification of $c(r_m)$ postulated in (5) is rather broad - nesting among other linear, convex, and concave cases, let us discuss the results for a more general case.

Proposition 3. *Assume a general SR net-cost function* $c(r_m)$ *with a first derivative continuous and bounded on* $(0, \infty)$*. An equilibrium degree of LR commitment always exists, but it may not be unique in the partial-commitment case in some specifications.*

Proof. Let us first note that the full-commitment case can still obtain, which follows from the proof of Proposition 2. Since the first fraction on the right hand side of (10) is non-negative for all parameter values, under $\frac{\partial c}{\partial r_m} \leq 0$ we always have $\frac{\partial u}{\partial r_m} > 0$, and hence $r_m^* = \infty$.

In the $\frac{\partial c}{\partial r_m} > \varepsilon > 0$ case (where ε can be arbitrarily small) there exists $\overline{r}_m \in (0, \infty)$ such that $u(\overline{r}_m) \geq u(r_m), \forall r_m$. This is because: (i) $\frac{\partial u}{\partial r_m} > 0$ for small r_m since the first fraction in (10) approaches infinity as r_m tends to zero, and (ii) $\frac{\partial u}{\partial r_m} < 0$ for large r_m since the first fraction in (10) vanishes as r_m approaches ∞. Therefore, there must exist a maximum of u between 0 and ∞. Nevertheless, points (i) and (ii) imply that without further restrictions on the function $c(r_m)$ there may exist multiple local maxima on this interval. □

Various special cases can be considered. For example, it is straightforward to show that if the SR net-cost is positive and strictly convex, $\frac{\partial^2 c}{\partial r_m^2} > 0$, then the policymaker's utility has a unique maximum $\overline{r}_m \in (0, \infty)$, and hence there is a unique optimal degree of LR commitment. In the case of multiple local maxima the optimal degree of LR commitment will be some global maximum, or, if it is attained for $r_m \leq r_p$, then we have a corner solution in the form of the no-commitment outcome, $r_m^* = r_p$.