Monetary Policy Facing Fiscal Indiscipline Under Generalized Timing of Actions[1]

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Abstract

The paper analyzes the interactions between monetary and fiscal policies, both in a single country and a monetary union setting. Focusing on the case of excessively 'ambitious' governments who run structural deficits (not just as a response to a downturn), we examine under what circumstances the fiscal excesses may spill over and threaten monetary policy outcomes. For that purpose we develop a novel game theoretic framework that allows for an arbitrary, possibly *stochastic timing* of policy actions. In the framework policy moves can occur with some ex-ante probability distribution, not necessarily with certainty every period as implicitly assumed in most existing models. This enables us to model various degrees of long-run *monetary commitment* as well as *fiscal rigidity,* the latter potentially heterogeneous across the union member countries. We examine a number of specifications in discrete and continuous time including the widely-used Calvo probabilistic timing. Our main policy contribution lies in deriving the *necessary and sufficient degree* of (long-run) monetary commitment that eliminates socially inferior equilibria. Interestingly, such a strong monetary commitment does not only ensure high credibility of the central bank, but it also indirectly *disciplines* the fiscal policymaker(s) by reducing their payoff from excessive fiscal policies. In contrast, if monetary commitment is insufficiently strong relative to fiscal rigidity and ambition than undesirable outcomes are likely to spill over and occur for both policies - similarly to the intuition of Sargent and Wallace's (1981) unpleasant monetary arithmetic or Leeper's (1991) active fiscal policy. We conclude by calibrating the model with European Monetary Union data to provide some quantitative predictions regarding the required strength of the European Central Bank's long-run commitment.

Keywords: fiscal-monetary policy interaction, commitment, monetary union, rigidity, Calvo timing, inflation targeting, dynamic games, asynchronous moves, stochastic timing, coordination games, Battle of the sexes, Game of chicken

JEL classification: E61, C70, E42, C72

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1. Introduction

Fiscal and monetary policies are strongly inter-related, as the actions of one policy affect the outcomes of the other policy. This is true even if the central bank is formally and legally independent. Such inter-dependence implies the following two questions that have concerned central bankers in many countries (including the European Union and United States), and that will be the main focus of the paper:

1) Can persistently excessive spending of fiscal policy compromise the anti-inflation credibility of monetary policy, and threaten price stability?

2) Can the central bank's institutional design indirectly discipline the government's behavior, and induce an improvement in the long-run stance of fiscal policy?

To examine these policy interactions - in both a single country and a monetary union setting - we propose a game theoretic framework that generalizes the *timing* of policy actions. The existing literature has, explicitly or implicitly, studied the policy interaction as a standard repeated game.[4] In such a setting all policy moves are: (i) deterministic, ie they occur with certainty at a pre-specified time, (ii) repeated every period, and (iii) simultaneous, ie unobservable by the opponent in real time.

Our framework relaxes these three assumptions that can be viewed as unrealistic in the macroeconomic policy context. It allows for the timing of the policies' moves to be *stochastic*, ie only occur with some probability, and only in some periods. Together with a fully general probability distribution, we also depict in more detail uniform, normal, and binomial distributions of policy moves, the latter following the popular timing of Calvo (1983).[5]

In order to separate the effect of stochastic timing of policy actions from the effect of a stochastic macroeconomic environment, our interest lies in the medium/long-run outcomes of the interaction, *not* the short-run fluctuations. Arguably, these are the first order welfare effects that Sargent and Wallace (1981), Alesina and Tabellini (1987), Nordhaus (1994) and the subsequent literatures were interested in.[6]

Allowing for general timing means that the policies sometimes move sequentially in an asynchronous fashion. We believe this captures an important aspect of the real world, in which policymakers may often not be able to act as they wish due to various institutional, structural, and political constraints.

Our dynamic timing enables us to model the effects of such constraints and postulate the concepts of *long-run monetary commitment* and *fiscal rigidity.* Both terms refer to the respective policymaker's *inability to move*, ie reconsider the previously chosen (long-run) stance. These concepts can be related to the *explicitness* with which the policy regime and its various settings/targets are legislated. For example, a numerical inflation target stated in the central banking law/statutes is more difficult and costly to be altered at will, and hence implies a stronger

[4]See for example Adam and Billi (2008), Eusepi and Preston (2008), Benhabib and Eusepi (2005), Dixit and Lambertini (2003), Leeper (1991), or Sargent and Wallace (1981). For a number of additional references refer to Section 2.2.

[5]It is worth mentioning that despite the frequent use of the Calvo (1983) timing in macroeconomic models, this is usually limited to price/wage setting behaviour. The policymakers are still assumed (either explicitly or implicitly) to be able to alter their policy instruments every period. This is true under *discretion, timeless perspective commitment* of Woodford (1999), as well as *quasi commitment* of Schaumburg and Tambalotti (2007). The latter two concepts place restrictions on *how* policy actions can be adjusted, but not the fact that they *can* be adjusted every period.

[6]While some papers, including Leeper (1991) and the Fiscal theory of the price level, looked at the stabilization of shocks, their focus was also on *permanent* changes in the policy reactions and behaviour due to the policy interactions. Our long-run focus further implies that by excessive fiscal spending we do *not* mean the governments' responses to the developments in the financial markets in 2007-9, but rather the behaviour that occured prior to the crisis - the persual of *structural* budget deficits.

monetary commitment over the long-term. Similarly, the fact that many structural settings that lead to excessive spending and debt accumulation (such as health/welfare/pension schemes) are legislated implies a higher degree of fiscal rigidity.

In answering question 1) it is demonstrated that the macroeconomic outcomes of the policy interaction crucially depend on the degree of monetary commitment *relative* to the degree of fiscal rigidity and ambition. If monetary commitment is sufficiently strong (explicit), ie above a certain necessary and sufficient threshold we derive, then monetary policy credibility and outcomes will *not* be threatened by excessively ambitious fiscal policymakers. Relating this outcome to the literature, it can be roughly thought of as the situation of dominant monetary policy in Sargent and Wallace (1981), active fiscal/passive monetary policy in Leeper (1991), or a Ricardian regime in Woodford (1995).

If however the degree of monetary commitment relative to fiscal rigidity is insufficient, the central bank is likely to miss its price stability objective - even if it is formally independent from the government and targets the natural rate of output. The intuition is comparable to one of a dominant fiscal regime in Sargent and Wallace (1981), accommodating monetary policy in Sims (1988), active monetary/passive fiscal policy in Leeper (1991), or a non-Ricardian regime in Woodford (1995).

The fact that the threshold commitment degree is a function of the structure of the economy, and of the society's preferences, offers valuable insights. Specifically, it is shown to be *increasing* in (i) the degree of fiscal rigidity and ambition of each member country, (ii) their economic size (ie larger countries carry a greater weight), (iii) the magnitude of the 'conflict cost' associated with the central bank fighting (counter-acting the actions of) an ambitious government, and (iv) the degree of the central banker's impatience.

In relation to question 2), we show that unless the government's ambition is very high, or there exists a substantial moral hazard problem in the monetary union, a sufficiently strong long-term monetary commitment may be able to *discipline* fiscal policies. The reason for such a 'disciplining effect' is two-fold. First, a more strongly committed central bank will counter-act the expansionary effects of excessive fiscal spending more vigorously. Second, such behavior reduces, or fully eliminates, the short-term political benefits of excessive spending to the government, and hence provides stronger incentives for fiscal consolidation. In the Leeper (1991) framework this can be thought of as an active monetary policy forcing, through the incentives created by its institutional design, fiscal policy to be passive.

This 'disciplining' result seems robust as it holds under all timing distributions of our scenario of interest, and has been derived in Libich et al. (2007) in a different setting.[7] That paper includes a case study in relation to this finding written by Dr Don Brash, the Governor of the Reserve Bank of New Zealand during 1988-2002, in which he argues that *'New Zealand provides an interesting case study illustrating the arguments in the article'*. He describes the policy developments in New Zealand shortly after strengthening monetary commitment by adoption of an explicit inflation target. When the government brought down an excessively expansionary budget in the pre-election period of mid-1990, he was forced to tighten monetary conditions in order to offset the budget's effect, and honour the bank's commitment to the newly legislated inflation target. He documents that these events had a *'profound effect on thinking about fiscal policy in both major parties in Parliament.'* Among other, he recalls that:

> *'Some days later, an editorial in the "New Zealand Herald", New Zealand's largest daily newspaper, noted that New Zealand political parties could no longer buy elections because, when they tried to do so, the newly instrument-independent*

[7] Empirical evidence of this finding from an estimated DSGE model is discussed in Section 8.

central bank would be forced to send voters the bill in the form of higher mortgage rates'.

The rest of the paper proceeds as follows. Section 2 presents the monetary-fiscal policy interaction as a simple game, focusing on scenarios in which there exists a coordination problem between the two policies, and/or an outright conflict between them. Section 3 postulates a game theoretic framework that allows for any deterministic and stochastic timing of moves. Section 4 reports a general result on the outcomes of the interaction for an arbitrary probability distribution of timing, as well as their arbitrary combinations. Section 5 then demonstrates the intuition using specific probability distributions and reports several additional insights. Section 6 shows how our theoretical results can be taken to the data. It first provides a real world interpretation of the main concepts - monetary commitment and fiscal rigidity, and then calibrates the most familiar (Calvo) setup to the case of the European Monetary Union. Section 7 examines four extensions of the analysis, and then reports a fully general result that nests these extensions. Section 8 then summarizes and concludes.

2. The Fiscal-Monetary Interaction As a Game

There exist a monetary policymaker, $\mathcal{M}$ (male), and N independent fiscal policymakers, denoted by $\mathcal{F}_n$ (females), where $n \in \{1, 2, ..., N\}$.[8] In the single country setting we have $N = 1$, whereas in the monetary union setting we have $N > 1$.

In a union, the relative weights of the members (expressing their economic size/influence) will be denoted by $w_1, w_2, \ldots, w_N$, such that $\sum_{n=1}^{N} w_n = 1$. Then the overall payoff of the $\mathcal{M}$ policymaker is a *weighted average* of the payoffs obtained from interactions with each individual $\mathcal{F}_n$, using the member's weight w_n. The payoff of each independent government is determined by its own actions and those of the common central bank.[9]

2.1. Game Theoretic Representation.

In order to make the game theoretic analysis more illustrative we will examine the policy interaction as a 2x2 game, summarized in the following payoff matrix.

		$\mathcal{F}_n$	
		l	h
$\mathcal{M}$	L	a, w	b, x
	H	c, y	d, z

We can interpret the L and l levels as medium/long-run *discipline*, and the H and h levels as medium/long-run *indiscipline*. In a reduced form model the reader can think of L and H as low and high *average* inflation, and l and h as a *structurally* balanced budget and deficit respectively.

Any (analytically solvable) macroeconomic model of policy interaction can be truncated into such a 2x2 game theoretic representation. The working paper version of this article contains a simple macroeconomic model and performs such truncation in the way suggested by Cho and Matsui (2005).[10]

The policymakers' payoffs $\{a, b, c, d, w, x, y, z\}$ are then some functions of the deep parameters of the underlying macroeconomic model, ie there is a *unique mapping* between the selected model and the game theoretic representation. As our focus in this paper is on the game theoretic insights under generalized timing of policy actions, that are applicable to a range of macroeconomic

[8] To simplify the notation we will use $\mathcal{F}$ and $\mathcal{M}$ to denote the respective policymakers as well as their policies.

[9] This is the direct effect. Indirectly, the actions of other governments also impact each government's payoff since they determine the action of the central bank, as well as the equilibrium outcomes.

[10] The authors truncate their macro model by setting the L and l levels to the socially optimal values (that are time-inconsistent and do not constitute the equilibrium of their underlying model), whereas the H and h levels to the actual equilibrium (ie time-consistent) levels, that are however socially inferior.

models, we will not pursue this avenue here. Nevertheless, we will later discuss the interpretation of these payoffs.

2.2. **Scenarios of Interest.** Naturally, if both policymakers are benevolent and there exist no market imperfections then the socially optimal (L, l) outcome will be the unique Nash equilibrium (NE) of the above long-run game, and this is regardless of the timing of policy actions. However, if some frictions exist and/or (one of) the policymakers have idiosyncratic objectives, then departures from this outcome are likely to occur. This is true in most macroeconomic models of policy interaction, under a range of circumstances.

Following the literature our interest lies in the case in which the government is *ambitious*, ie it attempts to boost output excessively (beyond the potential level).[11] In contrast, the central bank is benevolent and *responsible* trying to achieve a low inflation target and stabilize output at potential.

Due to the distinct objectives, the policies may face a coordination problem, or perhaps even an outright conflict. In particular, we will examine three scenarios of interest arising from some (not necessarily all) macroeconomic models under some (not necessarily all) parameter values. Each of them features two pure and one mixed strategy NE (the following figure presents specific examples of each scenario, with the pure strategy NE indicated).

a) **A conflict:** (L, h) and (H, l) are the NE, and each policymaker prefers a different one, namely $\mathcal{M}$ the former and $\mathcal{F}$ the latter. The game has therefore the form of *the Game of chicken*. Specifically, the payoffs satisfy

$$(1) \qquad b > c > d > a \quad \text{and} \quad y > x > z > w,$$

where $(b - a)$ and $(y - w)$ express the players' *conflict costs*, whereas $(b - c)$ and $(y - x)$ are their *victory gains*. Papers that model the policy interaction in such way include Barnett (2001), Bhattacharya and Haslag (1999), Artis and Winkler (1998), and Alesina and Tabellini (1987).

b) **A coordination problem:** (L, l) and (H, h) are the NE, and both policymakers prefer the former. The game has therefore the form of a *Pure coordination game*. Specifically, the payoffs satisfy

$$(2) \qquad a > d > \max\{c, d\} \quad \text{and} \quad w > z > \max\{x, y\},$$

where $(a - b)$ and $(z - x)$ express the players' *mis-coordination costs*, whereas $(a - d)$ and $(z - w)$ are their *coordination gains*. A number of papers on policy interaction feature some type of coordination problem, for example Eusepi and Preston (2008), Chadha and Nolan (2007), Persson et al. (2006), Benhabib and Eusepi (2005), Gali and Monacelli (2005), Eggertsson and Woodford (2004), Dixit and Lambertini (2003) and (2001), van Aarle, et al. (2002), Nordhaus (1994), Alesina and Tabellini (1987), or Petit (1989).

c) **A conflict combined with a coordination problem:** (L, l) and (H, h) are the NE, and each policymaker prefers a different one, namely $\mathcal{M}$ the former and $\mathcal{F}$ the latter. The game has therefore the form of *the Battle of the sexes*. Specifically, the payoffs satisfy

$$(3) \qquad a > d > \max\{c, d\} \quad \text{and} \quad z > w > \max\{x, y\},$$

where $(a - b)$ and $(z - x)$ express the players' *conflict costs*, whereas $(a - d)$ and $(z - w)$ are their *victory gains*. A large body of literature points to this type of policy interaction, eg Adam and Billi (2008), Branch, et al. (2008), Resende and Rebei (2008), Hughes Hallett and Libich (2007), Benhabib and Eusepi (2005), Dixit and Lambertini (2003) and (2001), Blake and Weale

[11] $\mathcal{F}$ ambition may be coming from a desire to get re-elected (and the existence of lobby groups, myopia, unionization, naïve voters etc), as well as from preexisting structural fiscal settings that require deficit financing such as unaffordable welfare/health/pension schemes, or high debt servicing. The latter implies that $\mathcal{F}$ ambition may be 'inherited' (not always something the government has control over), and hence highly persistent.

(1998), Nordhaus (1994), Sims (1994), Woodford (1994), Leeper (1991), Wyplosz (1991), Petit (1989), Alesina and Tabellini (1987), or Sargent and Wallace (1981).

As the references demonstrate, each of the three scenarios may arise from (fundamentally) different types of macroeconomic models. Therefore, each model can potentially provide a different mechanism for the possible departure from the socially optimal (L, l) outcome, and a justification for why even a formally independent central bank may find it optimal to monetize the debt to some extent.

One common explanation is the unpleasant monetary arithmetic of Sargent and Wallace (1981), in which seigniorage revenues are required in order to prevent the government from defaulting on its debt. Similarly, in Leeper (1991) and the subsequent literature on the Fiscal theory of the price level, an active $\mathcal{F}$ policy forces $\mathcal{M}$ policy to be passive, and the price level then reacts to $\mathcal{F}$ shocks rather than being autonomously determined by $\mathcal{M}$ policy.[12]

Alternatively, since the policies are substitutes in affecting output in many of the above models (see also Jones (2009) for some empirical evidence), H may be selected to offset some imperfections in the economy and minimize tax distortions, ie 'spread the load' between the policies (see eg Adam and Billi (2008) or Resende and Rebei (2008)). Finally, in Hughes Hallett, et al. (2009), H may under some circumstances (depending on the relative effectiveness of the policies) partly offset the expansionary effect of the deficit, and hence better stabilize output around potential. If the central banker also cares about output stabilization, he may sacrifice some deviation from its inflation target to achieve a less variable output.

All these interpretations imply a conflict as well as a coordination problem, and thus favour the 'Battle scenario' over the other two.[13] Furthermore, Libich et al. (2007) show that the 'Chicken scenario' is unlikely to obtain under a responsible central banker, since he has no structural temptation to inflate if the government is disciplined in the long-term. Because of that, in our discussion of the intuition we will focus on the Battle scenario. Nevertheless, we will also report the results for the remaining scenarios.

2.3. **Outcomes Under Standard Commitment.** Due to the existence of multiple NE in all three scenarios, there exist equilibrium selection problems. While in the 'Coordination scenario' the focal point argument can be used to select the socially optimal NE, in the remaining two scenarios it is not the case. Since each policymaker prefers a different pure NE standard game theoretic techniques (including evolutionary ones) cannot select between them.

To get sharper predictions the policy interaction has often been studied allowing for commitment - the *Stackelberg leadership* of one player. The following statement is true in all three scenarios considered above, and will provide a benchmark for comparison: Under the standard *static* game theoretic notion of commitment, the game has a unique outcome that is preferred by the committed player - *regardless* of his discount factor and the exact payoffs (within the constraints (1)-(3) defining each scenario).

Specifically, in the Battle scenario if $\mathcal{M}$ is the Stackelberg leader and $\mathcal{F}$ the follower (often called $\mathcal{M}$ dominance), $\mathcal{M}$'s preferred outcome (L, l) results. This happens for all parameter values satisfying (3), and even if the central banker is impatient and heavily discounts the future.

In the rest of the paper we examine the outcomes of the interaction allowing for a more general timing of moves, and hence a more general - *dynamic* - concept of commitment. It will

[12]The (L, l) outcome can then be interpreted as obtaining under active $\mathcal{M}$ and passive $\mathcal{F}$ policy, the (H, h) outcome under passive $\mathcal{M}$ and active $\mathcal{F}$ policy, and the mixed NE under the policies changing in the active/passive roles.

[13]Probably the closes model to our game theoretic representation is by Nordhaus (1994). Similarly to our setup, in his macroeconomic model (i) $\mathcal{M}$ is responsible and $\mathcal{F}$ is ambitious, (ii) the focus is on a deterministic steady-state, (iii) a one-shot game in analyzed, and (iv) three possible equilibria arise, one preferred by $\mathcal{M}$, one by $\mathcal{F}$, and one inferior for both players (these are comparable to our pure and mixed NE respectively).

become apparent that the conventional conclusions are refined and partly qualified, even if the assumption of a simultaneous initial move is preserved. In particular, whether the (L, l) outcome obtains will depend on the exact payoffs, as well as the discount rate of the committed player.

3. The Game Theoretic Setup with Generalized Timing of Moves

The framework extends the existing game theoretic literature on *asynchronous move games*, that has primarily examined the simple (deterministic) case of alternating moves.[14] Nevertheless, for comparability with the results of the standard repeated game, all our assumptions follow this conventional approach.

Assumption 1. *(i) The timing of all players' moves is exogenous and common knowledge. (ii) All past periods' moves can be observed (ie perfect monitoring). (iii) All players are rational, have common knowledge of rationality, and have complete information about the structure of the game and the opponents' payoffs. (iv) All players move, with certainty, simultaneously every $r \in \mathbb{N}$ periods - starting in time $t = 0$ (which will be continuous).*

Note that all these assumptions can be relaxed. For example, in Section 7.4 we discuss how the timing of moves can be endogenized, ie optimally selected by the players. Let us introduce some terminology regarding the timing of moves and the classification of players.

Definition 1. ***Standard moves*** *refer to moves made with certainty every $r \in \mathbb{N}$ periods, and* ***non-standard moves*** *refer to those made in between standard moves. A player that can, in expectation: (i) make non-standard moves will be called the* ***reviser****, (ii)* ***only*** *make standard moves will be called the* ***committed player*** *or the* ***rigid player*** *- with r expressing his degree of* ***commitment*** *or* ***rigidity****.*[15]

While a game theorist will think in terms of commitment (since his interest lies in the *effect* on the outcomes of the game), a macroeconomist may find it natural to interpret r as either commitment or rigidity (based on the *source* of the inability to move). We will throughtout talk about $\mathcal{M}$ commitment, but $\mathcal{F}$ rigidity.

Throughout the paper we assume at least one of the players to be the committed player.[16] This is to provide a benchmark for the other players' moves, and examine the timing differences in relative terms (which simplifies the analysis). As our focus is on a monetary union with a common central bank but multiple independent $\mathcal{F}$ policymakers, $\mathcal{M}$ will usually have the role of the committed player. Nevertheless, in a single country setting we will also report results for the opposite situation of $\mathcal{F}$ being the rigid player.

The above specification implies that the game consists of a sequence of (potentially different) dynamic games, each r periods long. In order to better develop the intuition of our framework we will first examine the r-period game in which the committed player only moves once, and abstract from further repetition. In Section 7.3 we extend the framework into a (finitely or

[14]See Cho and Matsui (2005), Wen (2002), Lagunoff and Matsui (1997), or Maskin and Tirole (1988). These papers provide a strong justification and motivation for our general approach; for example, Cho and Matsui (2005) argue that: *'[a]lthough the alternating move games capture the essence of asynchronous decision making, we need to investigate a more general form of such processes'*. Let us stress that our framework with stochastic timing of moves is very different from the so-called stochastic games, in which the random element is some 'state' (see eg Neyman and Sorin (2003) or Shapley (1953)). Let us also note that Kamada and Kandori (2009) also allow for stochastic revision of actions (the first draft of their paper is dated November 25, 2008, and we became aware of it in August 2009). Nevertheless, the authors use a very different setting and type of analysis.

[15]It is however important to note that due to our focus on the long-run outcomes the 'moves' of $\mathcal{M}$ policy should *not* be interpreted as choosing the interest rate, but instead as deciding on a certain *long-run* stance - eg an average level of inflation. A detailed discussion of this follows in Section 6.1.

[16]In libich et al (2007) this is not imposed, but due to tractability only a simple deterministic case is examined.

infinitely) repeated dynamic setting and show that all of our findings carry over. In fact, it will be evident that we can think of the results from the r-period dynamic game as the *worst case scenario*, in which repetition does not help the players to coordinate.

Let us now focus on the key aspect of our framework - the timing of the non-standard moves of the reviser(s). In particular, one of these moves is of special interest.

Definition 2. *The reviser(s)' **first** non-standard move following each standard move will be called the **Revision**. All other non-standard moves will be called **further-revisions**.*

The Revision will have a particular role since it provides the revisers with the *first opportunity to react* to the committed player's move - observing it. Therefore, the revisers first get a chance to alter their previous action made under imperfect information and potentially punish or reward the committed player.

It is evident that the timing of further-revisions plays no role in determining the equilibrium outcomes of the r-period dynamic game, unlike that of the Revisions. In any further-revision the revisers would, regardless of their discount factor, leave their preceding Revision unchanged, since it was made under identical circumstances. Therefore, in the rest of this section we focus on the timing of Revisions.

The probability distribution of an arbitrary (deterministic and stochastic) timing of a Revision can be fully described by a *probability density function,* PDF for short.[17] In terms of the determination of the committed player's payoff and hence equilibrium selection, the following concept will play a crucial role.

Definition 3. *The **individual Revision function***

$$F_n(t) : [0, r] \to [0, 1], \text{ where } F_n(0) = 0, \tag{4}$$

*is an arbitrary non-decreasing function summarizing the timing of the n'th reviser's Revision. It is the **cumulative distribution function (CDF)** of the underlying PDF, ie it expresses the probability that the reviser has had the opportunity to respond. In the $N > 1$ case, the **overall Revision function** $F(t)$ is the **weighted sum of individual CDFs**, denoted **wCDF**, with w_n being the weights.*[18]

Several specific examples of $F_n(t)$ are examined below and graphically depicted in Figures 1-4 and 7. These also present some related concepts introduced in this section.

Definition 4. *The integral $\int_0^r F(t)\mathrm{d}t$ describes the overall **reaction speed** of the revisers. The weighted **complementary CDF***

$$\int_0^r (1 - F(t))\, \mathrm{d}t = r - \int_0^r F(t)\mathrm{d}t, \tag{5}$$

*expresses the **overall degree of commitment** or **rigidity** of the revisers. Therefore,*

$$\frac{r}{\int_0^r (1 - F(t))\, \mathrm{d}t} \in [1, \infty) \tag{6}$$

*is the degree of the committed/rigid player's **relative commitment** or **relative rigidity**.*

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[17] For a discrete random variable a *probability mass function* is also used, but in order to shorten the exposition, we will describe even discrete distributions by PDFs. Note that (i) this can be done using Dirac delta functions; and (ii) in the rest of the paper we work with cumulative distribution functions so this choice doesn't play any role.

[18] The wCDF is usually called the *probability mixture* in statistics. Let us also note that while we define $F(t)$ on a closed interval $[0, r]$ for ease of exposition, the function relates to the first non-standard move (Revision) only - the standard moves are not included.

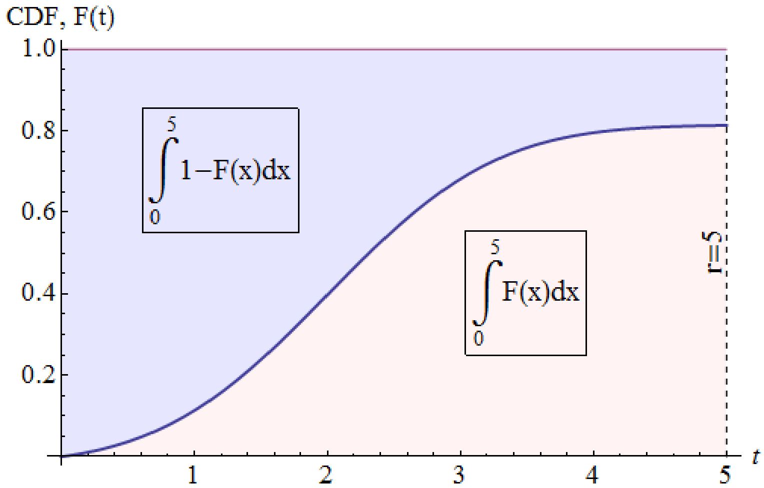

FIGURE 1. An example of $F(t)$, ie a wCDF, under $r = 5$, with the (overall) reaction speed of the reviser(s) indicated.

These concepts are shown graphically in Figure 1. Note that unlike in a standard simultaneous move game, in which only one player can be committed as the Stackelberg leader, in our setup the revisers may also be committed. Nevertheless, the degree of their commitment is always less than that of the committed player, since they can move more frequently (at least in expectation terms).

The way we will go about solving the game is determined by the specific results we are interested in. It is *not* our goal to fully describe all the equilibria of the game under all circumstances. Instead, our interest lies in circumstances under which unique equilibrium selection occurs in our three scenarios with originally multiple equilibria. Specifically, throughout the paper we will be deriving the *necessary and sufficient conditions* under which the dynamic r-period game has a *unique subgame perfect Nash equilibrium* (SPNE) - one that is *Pareto-efficient.*[19] In doing so we will use the following terminology.

Definition 5. *The committed player will be called to **win the game** if the dynamic r-period game has a unique SPNE, and that SPNE has the committed player's **preferred** (highest payoff) outcome uniquely on its equilibrium path. Specifically, $\mathcal{M}$'s winning in the Battle scenario will also be referred to as $\mathcal{M}$ policy **disciplining** the $\mathcal{F}$ policymaker(s).*

Note that in all three scenarios if a player wins the game then the other (possibly inefficient) outcomes of the static game are eliminated from the set of equilibria.

4. Results: Arbitrary Timing of Moves

To make the analysis more illustrative let us streamline it in two ways. First, we will in Sections 4-7.1 abstract from the committed player's discounting the future, and only incorporate it in Section 7.2. Second, since $\mathcal{M}$ is assumed to be benevolent and his preferred outcome (L, l) the socially optimal one in the Battle scenario, we will throughout focus on the circumstances under which $\mathcal{M}$ wins the game and disciplines $\mathcal{F}$ policymaker(s).

[19]Subgame perfection is a conventional equilibrium refinement that eliminates non-credible threats. A SPNE is a strategy vector (one strategy for each player) that forms a Nash equilibrium after any history.

This section will first report a general result that holds for any timing of non-standard moves. The subsequent Section 5 will then demonstrate the intuition by examining several specific scenarios, and offer additional insights. This will be complemented by Section 6 which first discusses the real world interpretation of our main concepts, and then reports a calibrated example: the case of the European Monetary Union.

The following proposition reports the results for the dynamic r-period game under fully patient policymakers. Theorem 1 in Section 7 shows that its qualitative nature is unchanged if repetition and discounting are incorporated.

Proposition 1. *Consider the r-period dynamic game without discounting described by either (1), (2), or (3), and by an arbitrary timing of the reviser(s) moves summarized by $F(t)$. The committed/rigid player wins the game if and only if his relative commitment/rigidity is sufficiently high,*

$$\frac{r}{\int_0^r (1 - F(t))\,\mathrm{d}t} > \bar{r} > 1. \tag{7}$$

The threshold $\bar{r}$ in the Battle scenario is, under $\mathcal{M}$ and $\mathcal{F}$ being the committed/rigid players respectively,

$$\bar{r} = \frac{a-b}{a-d} \quad \text{and} \quad \bar{r} = \frac{z-x}{z-w}, \tag{8}$$

ie increasing in his conflict cost relative to the victory gain, but independent of the revisers' payoffs.[20]

Proof. The committed player only makes one move in the dynamic r-period game. To prove the result it therefore suffices to show that the committed player finds it uniquely optimal to play the action of his preferred outcome regardless of the revisers' simultaneous standard move at $t = 0$. For example if $\mathcal{M}$ is the committed player it suffices to show that L is the unique best response to both l and h simultaneously played by the $\mathcal{F}$ policymaker(s). This is because then $\mathcal{F}$(s) will, in all three scenarios, play their unique best response to L in their every node on the equilibrium path, including the initial move. This is what Definition 5 calls $\mathcal{M}$ policy winning the game.

Focus on the Battle scenario with $\mathcal{M}$ being the committed player. Using backwards induction, it was discussed that any further-revisions would be equivalent to the Revision as they are made under identical circumstances. Moving backwards and considering the Revision, we know that when a particular $\mathcal{F}$ policymaker first gets a chance to respond to $\mathcal{M}$'s move, she will play the very same level played by $\mathcal{M}$. This is because (i) $w > x$ and $z > y$ from (3), and because (ii) $\mathcal{F}$ knows that $\mathcal{M}$ will not be able to alter his action until the end of the r-period dynamic game. In other words, $\mathcal{F}$ will play the static best response to the currently occurring move of $\mathcal{M}$.

Moving further backwards, $\mathcal{M}$ takes these anticipated $\mathcal{F}$ Revisions, as well as the expected $\mathcal{F}$ action at $t = 0$, into account in choosing his own initial action. The fact that L is the unique best response to l played in the initial standard move is obvious since $a > c$. Intuitively, there is no policy conflict as the government plays discipline from the outset. However, for L to also be the unique best response to h, ie for the central bank to find it optimal to enter into conflict with an indisciplined government, the following *necessary and sufficient* condition needs to be

[20] The remaining thresholds are the following: in the Coordination scenario $\bar{r} = \frac{a-b}{a-d}$ and $\bar{r} = \frac{w-y}{w-z}$ (ie miscoordination cost relative to the coordination gain), and in the Chicken scenario $\bar{r} = \frac{b-a}{b-c}$ and $\bar{r} = \frac{y-w}{y-x}$ (ie the conflict cost relative to the victory gain). Obviously, if the payoffs are symmetric then the two $\bar{r}$ values for each scenario are equivalent. For instance, using the specific payoffs in Figure **??** all six thresholds $\bar{r}$ equal 2.

satisfied

$$\underbrace{b\int_0^r (1-F(t))\,\mathrm{d}t}_{(L,h)} + \underbrace{a\int_0^r F(t)\mathrm{d}t}_{(L,l)} > \underbrace{dr}_{(H,h)}. \tag{9}$$

The left-hand side (LHS) and the right-hand side (RHS) of this condition report $\mathcal{M}$'s payoffs, under h, from playing L and H respectively. Specifically, the RHS of (9) states that from playing H, $\mathcal{M}$ will get the payoff d throughout the game (in which case there is no policy conflict as $\mathcal{M}$ concedes without a fight).

In contrast, the LHS of (9) states that if $\mathcal{M}$ plays L he will get the conflict payoff b for interactions with $\mathcal{F}$s that have not been able to revise yet, and the victory payoff a with those who have (and have therefore switched to their best response l). The two elements on the LHS can be thought of as $\mathcal{M}$'s initial investment to win, which is costly, and a subsequent reward for winning the game. Specifically, b expresses the magnitude of the cost and $\int_0^r (1-F(t))\,\mathrm{d}t$ expresses the duration of the cost as given by the area *above* $F(t)$. Similarly, a expresses the magnitude of the reward and $\int_0^r F(t)\mathrm{d}t$ expresses the duration of the reward as given by the area *below* $F(t)$. Both of these are relative to what $\mathcal{M}$ would have received by avoiding the conflict and accommodating excessive $\mathcal{F}$ policy from the start, dr on the RHS.

Using (5) and rearranging (9) we obtain $\frac{r}{\int_0^r (1-F(t))\mathrm{d}t} > \frac{a-b}{a-d}$ as claimed in the Proposition. Realizing that the necessary and sufficient conditions for the other scenarios, as well as for the case of $\mathcal{F}$ being the rigid player are derived analogously, and hence only differ in the value of the threshold $\bar{r}$, completes the proof. □

Unlike in the case of standard static commitment discussed in Section 2.3, the committed player may not always win the game. To do so he needs to be *sufficiently strongly* committed, where the threshold $\bar{r}$ is a function of his payoffs and hence various deep parameters of the macroeconomic model. In the game theoretic representation it is about the cost of the potential conflict or mis-coordination relative to the gain of securing the preferred outcome.

This implies that allowing for dynamics refines the conclusions made under the standard concept of commitment, where the outcomes are not contingent on the exact payoffs. As such, our framework may provide valuable information to the policymakers, as they can consider their 'optimal' degree of commitment. We will below briefly examine such endogenous determination of commitment and timing.

The proposition further highlights the importance of *relative* commitment/rigidity - what matters is how frequently/likely a player can move relative to the opponent(s). Graphically, it is about the relative size of the areas below and above $F(t)$ as shown in Figure 1. Note that this insight is obtained neither under the standard commitment concept, nor in models on optimal $\mathcal{M}$ commitment that abstract from $\mathcal{F}$ policy (eg Schaumburg and Tambalotti (2007)).

For completeness, let us discuss what happens if the condition in (7) is *not* satisfied, ie if neither player's relative commitment/rigidity is sufficient. Then neither player wins the game according to Definition 5 as the dynamic r-period game has *multiple SPNE*. Specifically in the Battle scenario, there will be (i) the socially optimal SPNE with (L, l) uniquely on the equilibrium path, but also (ii) the socially inferior with (H, h) throughout the equilibrium path. In addition, there are potentially (iii) other SPNE featuring some (pure or mixed) combination of (L, l, H, h) on the equilibrium path, dependent on the exact values of the players' commitment/rigidity and their payoffs.

This implies that if (7) does not hold the socially optimal outcomes *may* or *may not* obtain. Considering the multiplicity region is beyond the scope of the presented paper, but intuitively in an evolutionary setting the higher a player's relative commitment/rigidity the 'closer' he gets to his preferred outcome since its basin of attraction is larger.

5. Results: Specific Timing Distributions

In order to further develop the intuition and provide additional insights, we will examine several cases of interest. These will feature various timing specifications, PDFs, and are summarized in the following table.

Case	Moves	Time
1	deterministic	discrete
2	uniformly distributed	continuous
3	binomially distributed (Calvo)	discrete
Ext 1	combinations (including normally distributed)	continuous

In each case we first examine the *monetary union* case with a single $\mathcal{M}$ and any number N of independent $\mathcal{F}$ policymakers. These can be heterogenous not only in terms of their degree of $\mathcal{F}$ rigidity, but also in terms of their economic size (influence) w_n. The conditions for the special case of a *single country* setting with $N = 1$ is then also reported (as it is nested in the general solution such sequencing will minimize the number of equations).

In each case the following steps will be made - both mathematically and graphically. First, the underlying PDFs of the timing of the Revisions are postulated. Second, the individual and overall Revision functions $F_n(t)$ and $F(t)$ are summarized. Third, their integrals are derived. Fourth, these are rearranged and substituted into the general condition (7) to obtain the specific condition for each case.

5.1. **Case 1: Deterministic Moves.** This case provides a benchmark, and in line with Tobin (1982) it allows for the *frequency of moves* to differ across players.[21] Specifically, each $\mathcal{F}$ policymaker n moves with a *constant frequency* - every $t = jr_n^{\mathcal{F}}$ periods, where $j \in \mathbb{N}, r_n^{\mathcal{F}} \in \mathbb{N}$, and $\lfloor r/r_n^{\mathcal{F}} \rfloor = r/r_n^{\mathcal{F}}, \forall n$. The latter assumption that the floor equals the integer value implies $r_n^{\mathcal{F}} \leq r$, as well as synchronization of the standard moves across all policymakers, ie Assumption 1(iv) to hold.[22]

The individual and overall Revision functions, ie the CDFs and the wCDF, have the following specific form (see Figure 2 that graphically depicts these as well as the timeline of the game)

$$F_n(t) = \begin{cases} 0 & \text{if} \quad t < r_n^{\mathcal{F}}, \\ 1 & \text{if} \quad t \geq r_n^{\mathcal{F}}, \end{cases} \qquad \text{and} \qquad F(t) = \sum_{n: r_n^{\mathcal{F}} \leq t}^{N} w_n. \tag{10}$$

Integrating $F(t)$ from (10) over $[0, r]$ we obtain

$$\int_0^r F(t)\mathrm{d}t = w_1(r - r_1^{\mathcal{F}}) + w_2(r - r_2^{\mathcal{F}}) + \ldots + w_N(r - r_N^{\mathcal{F}}) = r - \sum_{n=1}^{N} w_n r_n^{\mathcal{F}}.$$

Using (5) implies the specific form of the necessary and sufficient condition in (7), namely

$$\frac{r}{\sum_{n=1}^{N} w_n r_n^{\mathcal{F}}} > \bar{r}. \tag{11}$$

[21]In his Nobel lecture Tobin observed that '*Some decisions by economic agents are reconsidered daily or hourly, while others are reviewed at intervals of a year or longer. It would be desirable in principle to allow for differences among variables in frequencies of change...*'.

[22]Note that this case nests the conventional repeated game under $r_n^{\mathcal{F}} = r, \forall n$.

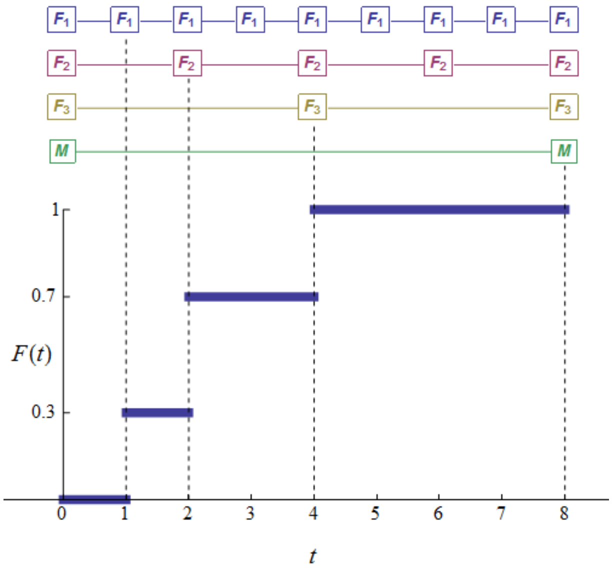

FIGURE 2. The timeline and $F(t)$ of Case 1 featuring $r = 8, \mathcal{M}$ as the committed player, and three $\mathcal{F}$ policymakers with weigths $w_1 = 0.2, w_2 = 0.5, w_3 = 0.3$ and rigidities $r_1^{\mathcal{F}} = 1, r_2^{\mathcal{F}} = 2, r_3^{\mathcal{F}} = 4$.

In a single country setting, $N = 1$, the condition becomes

$$\frac{r}{r^{\mathcal{F}}} > \bar{r} = \frac{a-b}{a-d},$$

where $\frac{r}{r^{\mathcal{F}}}$ expresses $\mathcal{M}$'s relative commitment in Case 1. Analogously, if the roles are reversed and $\mathcal{F}$ is the rigid player, for her to win the necessary and sufficient condition becomes

$$\frac{r}{r^{\mathcal{M}}} > \bar{r} = \frac{z-x}{z-w},$$

where $r^{\mathcal{M}}$ is the analog of $r^{\mathcal{F}}$ defined above.

5.2. **Case 2: Uniformly Distributed Moves.** Consider some g_n and h_n, such that $0 \leq g_n < h_n \leq r, \forall n$, as the minimum and maximum $\mathcal{F}$ rigidity of the n'th country respectively. Further assume that each $\mathcal{F}$ policymaker n can first-respond with uniformly distributed probability on the interval $[g_n, h_n] \subseteq [0, r]$.

The individual and overall Revision functions have the following specific form (see Figure 3 for a plot)

$$F_n(t) = \begin{cases} 0 & \text{if} \quad t \in [0, g_n), \\ \frac{t-g_n}{h_n-g_n} & \text{if} \quad t \in [g_n, h_n), \\ 1 & \text{if} \quad t \in [h_n, r], \end{cases} \qquad \text{and} \qquad F(t) = \sum_{n=1}^{N} w_n F_n(t). \tag{12}$$

Integrating $F(t)$ from (12) over $[0, r]$ we get

$$\int_0^r F(t)\mathrm{d}t = \sum_{n=1}^{N} w_n[r - \frac{1}{2}(g_n + h_n)] = r - \frac{1}{2}\sum_{n=1}^{N} w_n(g_n + h_n), \tag{13}$$

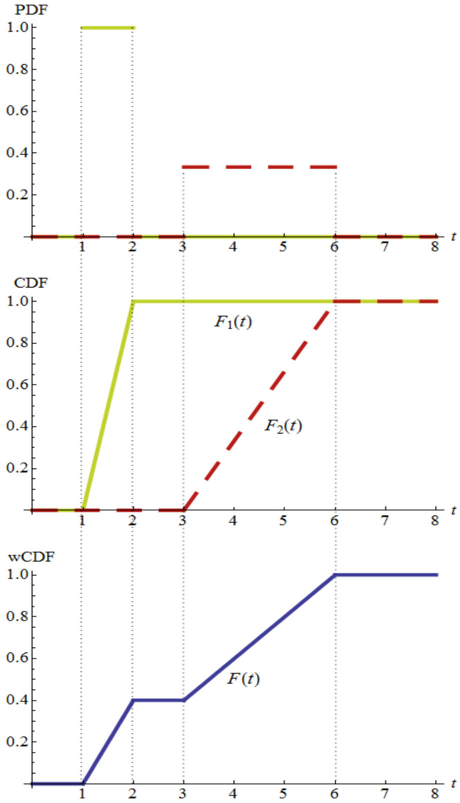

FIGURE 3. The PDFs, $F_n(t)$ (ie CDFs), and $F(t)$ (ie wCDF) of Case 2 featuring $r = 8$ and two revisers. These have $w_1 = 0.4, w_2 = 0.6, g_1 = 1, h_1 = 2, g_2 = 3, h_2 = 6$, ie uniformly distributed probability of Revisions on intervals $[1, 2]$ and $[3, 6]$ respectively.

Using (5) implies the specific form of the necessary and sufficient condition in (7), namely

$$\frac{r}{\frac{1}{2}\sum_{n=1}^{N} w_n(g_n + h_n)} > \bar{r}. \tag{14}$$

In a single country setting, $N = 1$, the condition becomes

$$\frac{r}{\frac{1}{2}(g + h)} > \bar{r}.$$

If F is the rigid player the condition is the same with g and h relating to player M.

5.3. **Case 3: Binomially Distributed Moves.** The Calvo (1983) timing has become increasingly used in the macroeconomic literature when modelling the moves of the price/wage-setters. We believe it is also useful in modeling the timing of policy actions, and will therefore use it for calibration in Section 6.2. Assume that each $\mathcal{F}$ policymaker n moves every uniformly distributed discrete period t (for example $t \in \mathbb{N}$), but only with probability $(1 - \theta_n)$. This probability is independent across time and players.[23]

[23]Note that if $\theta_n = 1, \forall n$, then we get $F(t) = 0$, which corresponds to Case 1 under $r_n^{\mathcal{F}} = r, \forall n$, and hence the conventional repeated game. If $\theta_n = 0$ we get Case 1 with $r_n^{\mathcal{F}} = 1$.

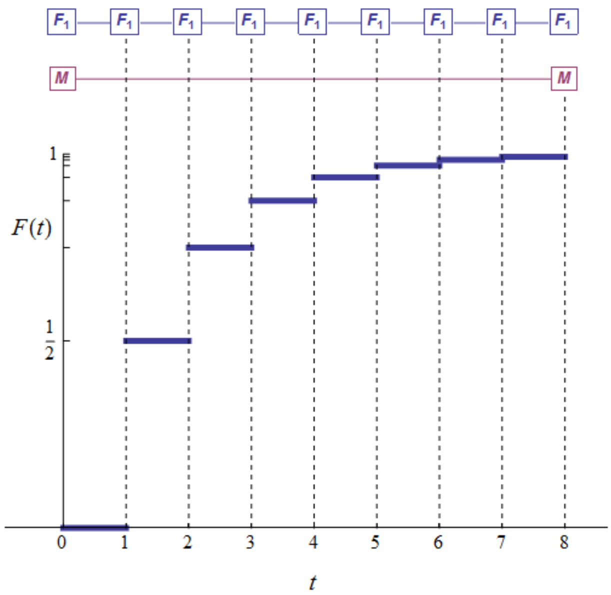

FIGURE 4. The timeline and $F(t)$ of Case 3 featuring $r = 8$, $\mathcal{M}$ as the committed player, and one $\mathcal{F}$ policymaker with $\theta = \frac{1}{2}$.

The individual and overall Revision functions have the following specific form (see Figure 4 for a graphical depiction)

$$(15)\quad F_n(t) = \sum_{i=0}^{\lfloor t \rfloor - 1} \theta^i (1-\theta) = 1 - \theta^{\lfloor t \rfloor} \quad \text{and} \quad F(t) = \sum_{i=0}^{\lfloor t \rfloor - 1} \sum_{n=1}^{N} w_n (1-\theta_n)\, \theta_n^i = 1 - \sum_{n=1}^{N} w_n \theta_n^{\lfloor t \rfloor}.$$

Integrating $F(t)$ from (15) over $[0, r]$ we obtain

$$(16)\quad \int_0^r F(t)\mathrm{d}t = r - \sum_{i=0}^{r-1} \sum_{n=1}^{N} w_n \theta_n^i = r - \sum_{n=1}^{N} w_n \frac{1-\theta_n^r}{1-\theta_n}.$$

Using (5) implies the specific form of the necessary and sufficient condition in (7), namely

$$(17)\quad \frac{r}{\sum_{n=1}^{N} w_n \frac{1-\theta_n^r}{1-\theta_n}} > \bar{r}.$$

In a single country setting, $N = 1$, the condition becomes

$$(18)\quad \frac{r}{(1 + \theta + \theta^2 + \ldots + \theta^{r-1})} > \bar{r}.$$

The following proposition summarizes the insights of the above three specific timing distributions.

Proposition 2. *The greater the* ***economic size*** *of the member country w_n, the more her $\mathcal{F}$* ***rigidity*** *(and hence ambition) increases the necessary and sufficient degree of relative $\mathcal{M}$ commitment $\bar{r}$ under which $\mathcal{M}$ wins the game and disciplines the $\mathcal{F}$ policymaker(s).*

Proof. By inspection of (11), (14), and (17), the threshold $\bar{r}$ is increasing in the country's weight w_n as well as in the degree of $\mathcal{F}$ rigidity, which is $r_n^{\mathcal{F}}$ in Case 1, $\frac{(g_n+h_n)}{2}$ in Case 2, and θ_n in Case

3. The fact that this is true for any distribution can be demonstrated by rewriting condition (9) in terms of $F_n(t)$ rather that $F(t)$

$$\sum_{n=1}^{N} w_n \left(b \int_0^r (1 - F_n(t))\, \mathrm{d}t + a \int_0^r F_n(t) \mathrm{d}t \right) > dr. \tag{19}$$

Rearranging yields

$$\frac{r}{\sum_{n=1}^{N} w_n \int_0^r (1 - F_n(t))\, \mathrm{d}t} > \bar{r} = \frac{a-b}{a-d},$$

and completes the proof by inspection. □

Intuitively, the greater a union member's economic influence, and the more fiscally rigid the member is, the more she increases the required degree of $\mathcal{M}$ commitment that will discipline her, and other member countries. This is in order to provide sufficient incentives for $\mathcal{F}$ consolidation - sufficiently strong punishment for $\mathcal{F}$ indiscipline. Such punishment will discourage the government(s) from running structural deficits by strongly counter-acting their expansionary effect.

6. Real World Interpretation and Application

We have kept the focus on the game theoretic insights in terms of the policy interaction - allowing for various (deterministic and stochastic) timing scenarios. This section will attempt to bring them to life. It will first provide a real world interpretation of the main variables of our analysis. It will then apply the results to the case of the European Monetary Union (EMU) - by calibrating Case 3 with the EMU data.

6.1. **Interpretation.** Our analysis up to this point has been general enough to be applicable to a wide range of macroeconomic models of $\mathcal{M}$-$\mathcal{F}$ policy interaction. We have only assumed, in line with most of the literature surveyed in Section 2.2, that (i) the $\mathcal{M}$ policymaker is responsible, whereas the $\mathcal{F}$ policymaker is excessively ambitious, and, because of that (ii) there exist a coordination problem and/or a policy conflict. Further, our attention has been on medium/long-run outcomes of such policy interaction in order to separate the effect of stochastic timing from a stochastic macroeconomy (shocks).

Such focus implied that the instrument of $\mathcal{M}$ policy should not be interpreted as a choice of the interest rate, but instead as deciding on a certain *average stance* - average level of inflation. Similarly, the $\mathcal{F}$ policy instrument represents choosing the long-run stance of F policy, which includes (but is not limited to) the average size of the budget deficit and debt.

This points to the interpretation of our main concepts - $\mathcal{M}$ commitment and $\mathcal{F}$ rigidity. They both relate the players' inability to alter their previous long-run stance, and hence the question one needs to answer is the following: What are the real world factors that prevent the policymakers from changing the long-run stance at will?

It can be argued that such inability is due to the fact that some important features affecting the policy decisions are *legislated.* Therefore, $\mathcal{M}$ commitment and $\mathcal{F}$ rigidity can be interpreted as the degree of *explicitness* with which the settings and/or targets of the respective policies are stated in the legislation or central banking statutes. The underlying assumption is that the more explicitly a certain policy setting/goal is grounded and visible to the public, the less frequently it can be altered (in a deterministic sense), or the less likely it is to be altered (in a probabilistic sense).

In terms of $\mathcal{M}$ policy, one example of an explicit $\mathcal{M}$ commitment used by a number of countries is a legislated numerical inflation target. Such commitment means that the central bank cannot reconsider the *long-run* inflation level arbitrarily. For example, the 1989 Reserve Bank of New Zealand Act states that the inflation target may only be changed in a Policy Target Agreement between the Minister of Finance and the Governor, and that this can only be done on *pre-specified regular* occasions (eg when a new Governor is appointed).[24] The Act also states that the Governor may be fired if inflation were to deviate from the target in the medium-term.

In terms of $\mathcal{F}$ policy, there are a number of factors that make an excessively ambitious stance rigid (persistent). For example, it is various political economy reasons (lobby groups, myopia, unionization, welfare schemes, naïve voters) or structural features (aging population, pay-as-you-go health and pension systems, high outstanding debt etc). All these determine the degree of $\mathcal{F}$ ambition, and the extent to which these are grounded in the legislation (or political culture) then affects the degree of $\mathcal{F}$ rigidity, which is postulated quantitatively in the next section.[25]

6.2. **Calibration: the EMU.** This section will apply the above theory to a real world situation - the world's largest monetary union: the EMU. While $\mathcal{M}$ policy in the EMU is conducted by a common $\mathcal{M}$ authority, the European Central Bank (ECB), each country has an independent $\mathcal{F}$ policy.[26] In order to consider multiple $\mathcal{F}$ policymakers the ECB will be the committed player that can reconsider its long-run stance every r periods.[27]

As of the writing of this paper, there are fifteen member countries that have adopted the common currency Euro (the so-called Eurozone), namely Austria, Belgium, Cyprus, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, the Netherlands, Portugal, Slovenia, and Spain. Therefore, we set $N = 15$.

Among them, two types of heterogeneity are arguably the most important. First, it is the economic size that differs greatly across the member countries. Second and more crucially, it is the degree of $\mathcal{F}$ rigidity and ambition. As both types of $\mathcal{F}$ heterogeneity are present in Case 3, and the Calvo probabilistic timing is the most widely used type of rigidity in the literature, we will utilize it here (the other cases yield comparable outcomes).

Recall that the necessary and sufficient condition for $\mathcal{M}$ to discipline the $\mathcal{F}$ policymakers in the Calvo setting and the Battle scenario is reported in (17), namely

$$\frac{r}{\sum_{n=1}^{N} w_n \frac{1-\theta_n^r}{1-\theta_n}} > \bar{r} = \frac{a-b}{a-d}, \tag{20}$$

In this case θ_n can be interpreted as the probability that $\mathcal{F}$ is *unable* to discipline her actions and consolidate, even if it is her optimal play (ie after observing the central bank's determination to fight regardless of the associated costs). As the previous section discussed there exist a number of obstacles for a government to consolidate its $\mathcal{F}$ actions and put them on a sustainable path, even if it wishes to do so.

The question of how to best calibrate θ_n in (20) therefore amounts to the following: What is the probability that the government of country n will embark on a $\mathcal{F}$ policy *stance* that is

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[24]Since late 1990 the PTA was 'renegotiated' (but not necessarily altered) five times, ie roughly every three years. For more discussion see Libich (2008).

[25]Leeper (2009) makes strong arguments for improvements in the design of $\mathcal{F}$ policy along the lines of those implemented in $\mathcal{M}$ policy over the past two decades. These would have two effects in our framework. First, legislating them would make the long-run stance more rigid (ie increase the value of θ in Case 3). Second, it would eliminate $\mathcal{F}$ ambition and the incentive of governments to run structural deficits. Therefore, the latter change would yield a game in which (L, l) is the outcome in both the static and dynamic game. Put differently, our analysis implies that if both policymakers are responsible then there is no policy conflict, and hence the relative degrees of $\mathcal{M}$ commitment and $\mathcal{F}$ rigidity do not affect *long-term* macroeconomic outcomes.

[26]While the Maastricht criteria provide some constraints on the independence of the member goverments, these are neither strict nor, as past experience shows, strictly binding.

[27]One can think of r as the *expected* length of time, and convert it into stochastic terms as $r = \frac{1}{1-\theta_{\mathcal{M}}}$, where $\theta_{\mathcal{M}}$ is the probability in any one period.

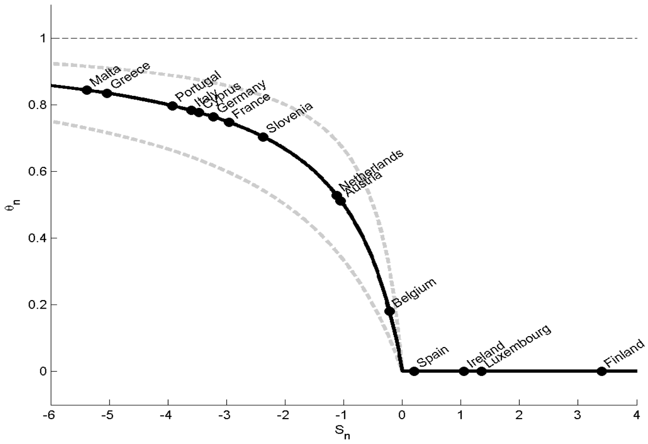

FIGURE 5. Dependence of F rigidity θ_n on budget surplus S_n, see (21), depicting the EMU countries. The solid line reports the baseline case $\alpha = 1$, the upper and lower lines depict $\alpha = 2$ and $\alpha = \frac{1}{2}$ respectively.

balanced over the long-term - conditional upon deciding that it is the optimal thing to do? We believe such probability can best be derived from $\mathcal{F}$ outcomes in the (recent) past.

Specifically, we propose the following matrix for assigning a θ_n value to the EMU members

$$\theta_n = \begin{cases} \frac{\alpha S_n}{\alpha S_n - 1} & \text{if} \quad S_n \leq 0, \\ 0 & \text{if} \quad S_n > 0, \end{cases} \tag{21}$$

where α is some positive constant (that determines the exact slope of θ_n), and S_n is the arithmetic *mean* of country n's $\mathcal{F}$ surplus as a percentage of the gross domestic product (GDP) over the period 2001-2006 (inclusive) using Eurostat data, see Appendix A. This implies that $S_n > 0, S_n < 0$, and $S_n = 0$ indicate an *average* surplus, deficit and balanced budget respectively. We start the sample in 2001 rather than in 1999 (the year in which the Euro was officially adopted) in order to exclude the idiosyncratic effects of the Maastricht criteria on $\mathcal{F}$ policy outcomes around the time of the Euro's adoption. Similarly, we do not include the 2007-8 data in order to exclude the effects of the global financial crisis. Nevertheless, this time frame seems sufficient to suggest the medium/long-run stance of $\mathcal{F}$ policy in these countries.[28]

The choice of the most realistic α depends on the interpretation of the length of each period, t, and the frequency of the central bank's long-run moves, r. It was stressed above that we examine the trend outcomes of the policy interaction. Therefore, we interpret t as one *year*, which is the frequency of the government proposing and implementing the budget, and hence getting a chance to become fiscally sound from that point onwards.

As a baseline we set $\alpha = 1$ in (21) - see Figure 5 for a plot that shows the resulting θ_n values for the EMU countries. Such parametrization implies that a country with $S_n = -1$ (such as Austria) has a 50% probability ($\theta_n = \frac{1}{2}$) of consolidating $\mathcal{F}$ finances each year, whereas a country with $S_n = -3$ (such as Germany or France) only has a 25% probability of doing so each year ($\theta_n = \frac{3}{4}$). For obvious reasons, θ_n in (21) is truncated by zero from below for countries with

[28]Including the size of each country's debt as a percentage of GDP into the specification of S_n would not change the quantitative nature of the results.

a surplus on average, $S_n > 0$. This means that the four such countries in the sample - Finland, Ireland, Luxemburg, and Spain - are assigned the value of $\theta_n = 0$.

If the reader, like the authors, finds the values implied by $\alpha = 1$ overly optimistic in terms of the $\mathcal{F}$ consolidation opportunities, ie if $\mathcal{F}$ indiscipline is more persistent, s/he may want to select some $\alpha > 1$, which will increase the value of θ_n. Conversely, a lower value of α will imply a more favourable outlook (see Figure 5 that also depicts $\alpha = 2$ and $\alpha = \frac{1}{2}$).

In terms of the weights w_n, we use each country's real GDP share of the EMU's total. Specifically, using Eurostat data, we calculate the average annual GDP for each EMU member country over 2001-2006, and divide it by the EMU's average over that period (see Appendix A).

As discussed in Section 2.1, the fraction $\frac{a-b}{a-d}$ is some function of the deep parameters of the underlying macroeconomic model. Since each of our three scenarios can be generated via fundamentally different models, it is not possible to provide general mapping between the deep parameters and payoffs. Nevertheless, it can be done for a specific macroeconomic model, as Libich et al. (2007) demonstrate, following the approach of Cho and Matsui (2005).

They use a simple reduced-form model reminiscent of Nordhaus (1994), in which both policymakers have the standard quadratic utility over inflation and output stabilization, but they differ in the level of their output target. Specifically, as assumed above the central bank targets the potential output level whereas the government aims at a higher level. The analysis implies that our payoffs $\{a, b, c, d, w, x, y, z\}$ depend on two broad factors.

First, it is the policymakers' (and society's) costs of output variability relative to inflation variability. These in turn depend on the structure of the economy and the extent of various rigidities present at the micro-foundations level. For example, a greater rigidity in price and/or wage setting will increase this cost in most models. Second, it is the relative weights assigned to inflation and output stabilization in the policy loss function (the degree of conservatism of the two policymakers), as well as the degree of the government's ambition in stimulating output. In the real world these are functions of various political economy or structural factors mentioned above.

The discussion implies that these payoffs are difficult to calibrate in a way encompassing different underlying macroeconomic models. We believe that reasonable per-period values of the conflict cost relative to the victory gain for the central bank lie in the interval $\frac{a-b}{a-d} \in \left[\frac{3}{2}, 3\right]$, but report the threshold in Figure 6 for a larger interval. The $\mathcal{M}$ commitment values r to the left of the solid line ensure the ECB's achievement of the inflation target on average, and discipline the member governments. The r values to the right of the solid line are likely to be insufficient to achieve that as they lead to multiple SPNE. The calibration implies the following *tentative* conclusion.

Remark 1. *Given the degree of $\mathcal{F}$ rigidity and ambition of the EMU countries implied by their past outcomes, the required degree (explicitness) of the ECB's long-run commitment to low inflation may be substantial.*

Specifically, such commitment should be explicit enough for all parties to believe that it will not be 'reconsidered' for at least 3-5 years, and perhaps significantly more.[29]

Obviously, a monetary union is subject to a possible *moral hazard* by individual governments. It can be argued that the potential benefits of excessive $\mathcal{F}$ policy accrue primarily in the indisciplined country, whereas the punishment by the common central bank in the form of higher interest rates is spread across all the member countries. Therefore, if member countries do

[29] In stochastic terms, the percieved probability $\theta_{\mathcal{M}}$ that the central bank will not be able to 'reconsider' its (explicit or implicit) preferred average inflation level at its monthly meeting has to be (substantially) less than 2-3%.

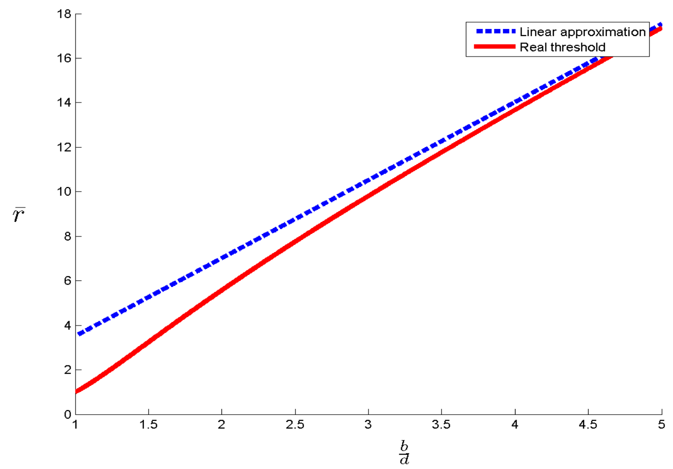

FIGURE 6. Dependence of the required degree of $\mathcal{M}$ commitment in the EMU on the ECB's conflict cost relative to the victory gain, $\frac{a-b}{a-d}$ using (20).

not internalize the cost imposed on other members, a stronger punishment may be required to discipline them than in a single country setting.

Such moral hazard can be modeled in our framework by increasing the conflict cost of the central bank $(a-b)$. The bank now has to fight the government harder, and hence it suffers a greater disutility from doing so. As one would expect, (20) shows that an even stronger $\mathcal{M}$ commitment will be required to discipline governments under such moral hazard.

It may in some models be the case that if the moral hazard problem is sufficiently severe some individual governments' best response to L may be h - like in the Chicken scenario and unlike in the Battle and Coordination scenarios. Our analysis implies that in such case even an infinitely strong $\mathcal{M}$ commitment cannot discipline such governments.

The same is true, even without moral hazard, in the case of a very high $\mathcal{F}$ ambition. If $x > w$ and $z > y$ then l is a strictly dominated strategy in the static game, and hence no amount of $\mathcal{M}$ commitment can possibly make the government(s) discipline their actions.

7. EXTENSIONS

7.1. **Combinations of PDFs Using Mean Values.** This section reports a statistical result which allows us, in some cases, to write the above necessary and sufficient conditions in a more elegant fashion. Specifically, it is done using solely the *mean value* of the underlying weighted PDF, without reference to its other moments. This also means that we can obtain analytical solutions for combinations of PDFs that are very *different* in nature (unlike in Cases 1-3 in which all the $\mathcal{F}$ revisers within each case had a similar type of PDF).

Let us denote μ_n to be the mean value of the underlying PDF of the n'th reviser. The following is a known result in statistics, see eg Lemma 2.4 in Kallenberg (2002).

Lemma 1. *Consider $F(t)$ from Definition 3 such that*

$$F(r) = 1. \tag{22}$$

Then

$$\int_0^r (1 - F(t))\,\mathrm{d}t = \mu. \tag{23}$$

Let us mention the interpretation of (22): it ensures that (all) reviser(s) have the opportunity to make at least one non-standard move between their standard moves. Lemma 1 implies that, if (22) holds, even PDFs expressing very complicated timing of moves can be 'summarized' without loss of generality by their first moments. Put differently, if (22) is satisfied then μ_n fully describes the degree of commitment/rigidity of each reviser.

The following result uses Lemma 1 to express Proposition 1 in an alternative fashion. Note however that while it is easier to use in combining different PDFs, it is not as general as Proposition 1 since (22) is required to hold for every underlying PDF.[30]

Proposition 3. *Consider the dynamic r-period game policy interaction described by either (1), (2), or (3), whereby $\mathcal{F}$ rigidity of each member n is described by an arbitrary PDF with a mean value of μ_n. Under $F_n(r) = 1, \forall n$, the necessary and sufficient condition for the committed player to win the game, (7), can be written as*

$$\frac{r}{\sum_{n=1}^{N} w_n \mu_n} > \bar{r}. \tag{24}$$

Proof. Substituting Lemma 1 into (19) yields (24). □

It is worth noting that the second moments of the PDFs do not play any role (in the absence of discounting). To demonstrate the usefulness of this 'shortcut', let us report an example that combines the above Case 2 with normally distributed moves.

Example 1. *Consider a monetary union consisting of two equally sized member countries, whose $\mathcal{F}$ policymakers' timing of moves has the following form:*

- *Country 1: uniformly distributed moves of Case 2, $F_n(t)$ from (12),*
- *Country 2: normally distributed moves, such that*

$$F_2(t) = \frac{\Phi_{\mu_2,\sigma^2}(t)}{\Phi_{\mu_2,\sigma^2}(r) - \Phi_{\mu_2,\sigma^2}(0)} \tag{25}$$

where

$$\Phi_{\mu_2,\sigma^2}(t) = \frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{t} e^{-\frac{(x-\mu_2)^2}{2\sigma^2}}\,\mathrm{d}x,$$

is the CDF of a normal distribution (truncated on the interval $[0, r]$), and where μ_2 and σ are its mean and standard deviation (and $x \in \mathbb{R}$). Then the necessary and sufficient degree of $\mathcal{M}$ commitment for $\mathcal{M}$ to win the game is

$$\frac{r}{\mu_1 + \mu_2} > \bar{r}, \tag{26}$$

where $\mu_1 = \frac{g+h}{2}$ is the mean value of the PDF of Case 2.

For a graphical depiction of see Figure 7. Let us note two things. First, the condition (22) is satisfied for both countries. Second,the standard deviation σ does not determine the threshold value of r.

[30]Note for example that the functions $F(t)$ depicted in Figures 1 and 4 do *not* satisfy the condition, and hence the following result is not applicable to them.

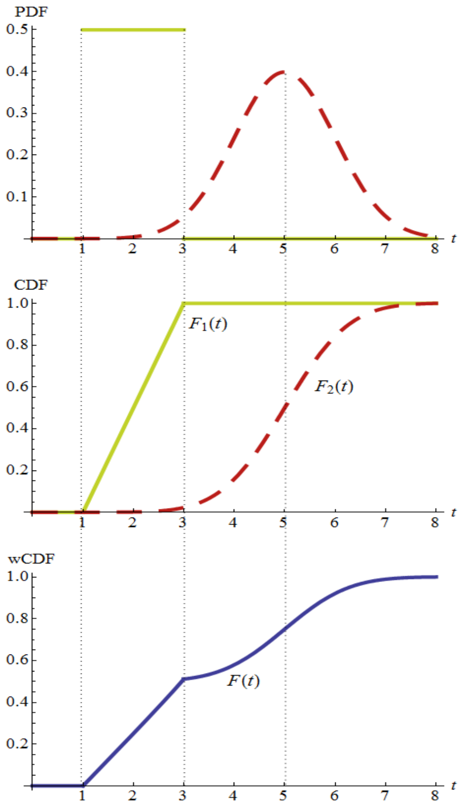

FIGURE 7. The PDFs, CDFs, and wCDF of Example 1 featuring $r = 8$ and two equally weighted revisers with the following Revision functions: uniformly distributed on $[1, 3]$ ($\mathcal{F}$ policymaker 1), and (truncated) normally distributed with $\mu = 5$ and $\sigma^2 = 1$ ($\mathcal{F}$ policymaker 2).

7.2. **Discounting.** It is apparent that discounting by the *reviser* has neither qualitative nor quantitative effect on the outcomes of the r-period dynamic game. This is because the revised action is a static best response to the observed action by the committed player. This section shows that while discounting by the committed player himself does have an effect, it is only a quantitative one. Specifically, the committed player's impatience works in the predicted direction of making it harder for the player to coordinate and win the game.[31]

Proposition 4. *Consider the dynamic r-period game of policy interaction described by either (1), (2), or (3), in which the committed player discounts the future by $e^{-\rho t}$, where $\rho \in [0, \infty)$. The necessary and sufficient degree of commitment to win the game is*

$$\frac{\int_0^r e^{-\rho t} \mathrm{d}t}{\int_0^r e^{-\rho t} (1 - F(t))\, \mathrm{d}t} > \bar{r}, \tag{27}$$

ie its strength is increasing in the degree of his discounting (impatience), ρ.

[31]The analysis of the committed player's discounting can be made more parsimonious by incorporating it into the function $F(t)$. We however do not do so in order to keep the intuition of $F(t)$ as a Revision function.

Proof. The fact that $\int_0^r (1 - F(t))\,\mathrm{d}t < r$ implies that the LHS of (27) is greater than one for all ρ. Therefore, the LHS (which now expresses discounted relative commitment) is decreasing in the value of ρ. □

The thresholds $\bar{r}$ are again identical to those reported in Proposition 1. If we interpret, similarly to the literature, ρ as a decreasing function of the central banker's *goal*-independence, the proposition implies its *substitutability* with explicit inflation targeting. For empirical evidence of this relationship see Libich (2008).[32] The following result summarizes the effects of discounting.

Corollary 1. *There exists sufficient thresholds $\overline{\rho}$ and $\hat{\rho}$ such that: for all $\rho < \overline{\rho}$ a finite $\bar{r}$ exists, but for all $\rho > \hat{\rho} \geq \overline{\rho}$ there exists no $\bar{r}$.*

Proof. Need it?? Implied by (27)... □

The first observation implies that our above findings are robust to discounting, as full patience of the committed player is not necessary for his win.[33] Nevertheless, the second observation is at odds with the outcome under standard commitment, in which Stackelberg leadership delivers a win to $\mathcal{M}$ regardless of his discount factor. In our dynamic setting, if the committed player is sufficiently impatient, $\rho > \hat{\rho}$, even an infinitely strong $\mathcal{M}$ commitment falls short of securing his win. This suggests that the static nature of the standard commitment concept can be a serious shortcoming. As most macroeconomic games are dynamic in nature, caution should be exercised in relying heavily on the results of the static commitment concept.

7.3. **Repetition.** Let us extend the analysis and allow for a longer horizon and a further (possibly infinite) repetition of the r-period dynamic game we have studied so far. It follows from Assumption 1 that the full repeated game consists of a sequence of (potentially different) r-period dynamic games. In order to introduce more *regularity* into the timing of non-standard moves, and better relate the results to standard repeated games, let us assume the following:

Assumption 2. *For an individual reviser, the timing of all non-standard moves within each pair of standard moves is identical throughout the game, ie described by* ***the same PDF****. The timing of non-standard moves across revisers can however differ arbitrarily.*

This implies that all the r-period dynamic games will be the same, and means that the r-period dynamic game is a *dynamic stage game*, and the whole game is a *repeated dynamic game*.

Lemma 2. *Under Assumption 2, if the r-period dynamic stage game has (i) a* ***unique SPNE*** *that is (ii)* ***Pareto-efficient****, ie if (7) holds, then the SPNE's payoffs and equilibrium path actions also uniquely obtain in the full repeated dynamic game - for any number of repetitions.*

Proof. Consider the dynamic stage game, and the effective minimax values of the players. These are the infima of the players' subgame perfect equilibrium payoffs (Wen (1994)). If the dynamic stage game has a unique SPNE (the first condition of Lemma 2), then we know that the effective minimax values are the payoffs that obtain from that SPNE.

If this unique SPNE is Pareto-efficient (the second condition of Lemma 2), then the effective minimax values of the repeated game will be equivalent to those of the dynamic stage game - since these cannot be improved upon. Put differently, since the outcome lies on the Pareto frontier the set of Pareto superior payoffs is empty. Noting that these values can only be achieved through one strategy profile, the unique SPNE, completes the proof. □

[32]Let us note that the Debelle and Fischer (1994) distinction between instrument and goal independence is important here, since the former is a *complement* (in fact a pre-requisite) of explicit inflation targeting.

[33]?? Thresholds in Fig 7??

Intuitively, under the conditions of Lemma 2 repeating the game will not alter the fact that the committed player wins the game. The uniqueness condition also means that, as long as (7) holds, our focus on pure strategies is without loss of generality - even in the repeated game. The result further implies that our paper joins the body of literature showing that *the Folk Theorem* may not apply in some asynchronous games, see eg Takahashi and Wen (2003).

As we noted above our results for the r-period dynamic game can be interpreted as the worst case scenario, in which repetition does not help the players to cooperate in coordination games. Combining the findings of Sections 7.2-7.3 with those of Section 4 proves the following generalization of Proposition 1.

Theorem 1. *Consider the r-period game described by either (1), (2), or (3) with any number of repetitions, and an arbitrary timing of the reviser(s) moves summarized by $F(t)$ under Assumption 2. The committed player wins the game if and only if (27) holds, where the thresholds $\bar{r}$ are as reported in Proposition 1.*

It is apparent that Assumption 2 is not necessary for this result to obtain. If we allow the timing of Revisions to differ between each pair of standard moves (implying multiple different $F_n(t)$ functions even for an individual reviser), the condition in (27) will simply have to hold for each of the resulting $F_n(t)$.

7.4. **Endogenous Timing of Moves.** It is straightforward to endogenize the degrees of commitment in our framework. One can include a per-period net-cost, which will summarize all the (unmodelled) costs and benefits of moving less frequently, and let the players choose their timing optimally (at the beginning of the game).[34]

The players may then face a trade-off; a greater commitment may improve their outcome, but it may be costly. Therefore, whether or not a player commits, and to what extent he does, will be a function of various variables describing the game. In terms of the above policy interaction, it is apparent that a sufficiently strong $\mathcal{M}$ policy commitment improves the payoff of the central bank. Therefore, if there is no cost involved in long-term committing the central bank will choose an r level such that its relative commitment is (well) above the threshold $\bar{r}$. If however committing is sufficiently costly that the central bank may not commit.

This is demonstrated in Libich and Stehlík (2009) in a different (New Keynesian) setting without $\mathcal{F}$ policy, where the optimal degree of long-run $\mathcal{M}$ commitment r^* to eliminate the time-inconsistency problem is shown to be a function of the structure of the economy, the frequency with which agents update expectations, and also the short-run costs in terms of stabilization inflexibility (if any), and the benefit of better anchored expectations (if any).

8. Summary and Conclusions

The paper models the interaction between fiscal ($\mathcal{F}$) and monetary ($\mathcal{M}$) policy - in a monetary union as well as in a single country setting. The aim is to consider under what circumstances, if any, excessive $\mathcal{F}$ policies can undermine the credibility and outcomes of $\mathcal{M}$ policy, and whether the design of $\mathcal{M}$ policy can indirectly induce a change in the undesirable $\mathcal{F}$ stance.

The paper's main contribution lies in examining the interaction of $\mathcal{M}$ policy and (any number of) $\mathcal{F}$ policies in a novel game theoretic setting, in which the timing of the policies' actions is no longer repeated every period in a simultaneous fashion. Our framework is general enough to allow for an arbitrary probability distribution of the policymakers' moves (both deterministic and stochastic), as well as an arbitrary combinations of probability distributions. For illustration we

[34]This is similar to Bhaskar (2002) who considers a simple way to endogenously determine Stackelberg leadership.

complement the results for a fully general setting by depicting several realistic scenarios, namely uniform, normal, and binomial distributions, that latter in line with the Calvo (1983) timing.

All settings show that if the central bank is sufficiently strongly (explicitly) committed in the long-term, it can resist $\mathcal{F}$ pressure and ensure the credibility of $\mathcal{M}$ policy and stable prices. Furthermore, unless $\mathcal{F}$ ambition is very high, or there exists a significant moral hazard problem in the $\mathcal{M}$ union, such strong $\mathcal{M}$ commitment has the potential of *disciplining* $\mathcal{F}$ policies. It does so by reducing the incentives of governments from excessive policies, and hence it improves the policy coordination and outcomes of both policies.[35]

All settings however also show that if $\mathcal{M}$ commitment is insufficient than $\mathcal{F}$ accesses may/will spill over and cause undesirable $\mathcal{M}$ outcomes with excessive inflation. In such a situation significant macroeconomic imbalances may built up over time with adverse consequences. In order to better understand how much $\mathcal{M}$ commitment is required to avoid such situations, we show that the required degree of $\mathcal{M}$ commitment is an increasing function of: (i) $\mathcal{F}$ rigidity and ambition of the member countries, (ii) their relative economic size, (iii) the cost of a policy conflict - relative to the gain of improvement in the policy coordination and long-term outcomes (affected by various deep parameters of the underlying macroeconomic model), and (iv) the central banker's impatience.

The latter implies that a *less* patient central bank needs to commit *more* strongly (explicitly) to ensure its credibility. Interpreting patience as an increasing function of the degree of central bank goal-independence, this offers an explanation for the fact that inflation targets were more explicitly grounded in countries originally lacking central bank goal-independence (such as New Zealand, UK, Canada, and Australia) than in those with a rather independent central bank (such as the US, Germany, and Switzerland).

Our findings are related to several existing literatures. First, our commitment concept is compatible with the timeless perspective commitment postulated by Woodford (1999) and frequently used since then. This is because our long-run notion of commitment does not place any restrictions on how stabilization policy should be conducted, ie how the short term (interest rate) policy instrument should be adjusted in response to shocks. In fact, our commitment does not even restrict *how* long-term decisions about the policy stance should be made, it only puts a constraint on *how often* they can be made. This also implies that if (and only if) the objective of $\mathcal{M}$ is postulated as a long-run goal - achievable on average of the business cycle, it does *not* require the central bank to become more conservative (strict) in achieving it, and does not compromise the flexibility in stabilizing the real economy in response to shocks (as in Rogoff (1985)).[36]

Second, the important work of Schaumburg and Tambalotti (2007) also examines the gains from $\mathcal{M}$ commitment (which they call quasi commitment as it lies anywhere between discretion and timeless perspective commitment). Similarly to our paper, the authors find that a stronger

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[35]Let us mention that while long-term $\mathcal{M}$ commitment has usually been specified in terms of an inflation target for consumer prices, our commitment concept is not limited to such a specification. Put differently, we do not impose a concrete *type* of $\mathcal{M}$ commitment to be pursued - our analysis reports the *degree* of $\mathcal{M}$ commitment required in the face of ambitious and rigid $\mathcal{F}$ policies. This is an advantage since the global financial crisis of 2007-9 brings back to the fore the question of whether central banks should respond to a broader measure of inflation, potentially also including various asset prices (which the existing literature commonly answered in the negative, eg Bernanke and Gertler (2001)).

[36]It should be noted that the explicit inflation target in almost all industrial countries has indeed been specified in such a medium/long-run fashion, see eg Mishkin and Schmidt-Hebbel (2001). As Svensson (2009) argues: *'Previously, flexible inflation targeting has often been described as having a fixed horizon, such as two years, at which the inflation target should be achieved. However, as is now generally understood, under optimal stabilization of inflation and the real economy there is no such fixed horizon at which inflation goes to target or resource utilization goes to normal.'* It should be noted that, as a temporary measure, some transition countries may opt for a short-run specification of the targeting horizon after adoption in order to build up the credibility of the target.

commitment leads to an improvement in $\mathcal{M}$ policy credibility and outcomes.[37] Their analysis however does not include $\mathcal{F}$ policy, and hence it is commitment in absolute terms. In contrast, our analysis highlights the fact that it is $\mathcal{M}$ commitment relative to $\mathcal{F}$ rigidity and ambition that matters.

Third, there exists a large empirical literature on the effects of explicit inflation targeting. While the findings are far from conclusive, there exists fair support for most of our results. Among other, explicit inflation targets have been shown to reduce the nominal interest rate (and hence inflation) and its volatility to a larger extent than non-IT countries (eg Siklos (2004), Neumann and von Hagen (2002)), without an increase in output volatility (eg Corbo, Landerretche and Schmidt-Hebbel (2001)), Arestis, Caporale and Cipollini (2002), Fatas, Mihov and Rose (2004)).

In terms of the disciplining effect of $\mathcal{M}$ commitment on $\mathcal{F}$ policy, the preliminary results of Franta et al. (2009) confirm the above findings. Using a measure of the degree of $\mathcal{F}$ dominance introduced by Resende and Rebei (2008), the paper estimates a DSGE model and shows that $\mathcal{F}$ dominance has decreased in countries that adopted explicit inflation targeting (such as New Zealand, Canada, UK, Sweden, Australia), whereas it remained unchanged or increased in non-targeting countries (such as the US or Switzerland).[38]

Nevertheless, more research is required to assess whether, and under what circumstances, a move towards institutionalizing a stronger $\mathcal{M}$ commitment of a long-term nature does indeed translate into an improvement in the long-term stance of $\mathcal{F}$ policy. In doing so, the issue of causality vs correlation has to be carefully examined, since both a stronger $\mathcal{M}$ commitment, and an improvement in $\mathcal{F}$ policy may be driven by an underlying common factor.

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[37] A different avenue with similar conclusions is pursued by Orphanides and Williams (2005), and informally such arguments have been made by eg Bernanke (2003), Goodfriend (2003), and Mishkin (2004).

[38] This is also consistent with the case study by Don Brash quoted in the introduction.

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Appendix A. EMU Data

We use the data from Eurostat to create our variables S, θ, and w for each member country n, reported in the following Table. The way these are created is described in the main text.[39] While the individual country values in the table are rounded to two or three decimal places, the Eurozone averages as well as the calculations in the main text have been done with nine decimal places.

Country n	Weight w_n	Surplus S_n	$\mathcal{F}$ Rigidity θ_n $(\alpha = 1)$
Austria	0.033	−1.05	0.51
Belgium	0.039	−0.22	0.18
Cyprus	0.001	−3.47	0.78
Finland	0.021	3.4	0
France	0.218	−2.95	0.75
Germany	0.327	−3.22	0.76
Greece	0.019	−5.04	0.83
Ireland	0.015	1.05	0
Italy	0.147	−3.6	0.78
Luxembourg	0.004	1.35	0
Malta	0.001	−5.38	0.84
The Netherlands	0.061	−1.12	0.53
Portugal	0.016	−3.92	0.8
Slovenia	0.003	−2.37	0.7
Spain	0.094	0.2	0
Average (non-weighted)	0.067	−1.75	0.5
Average (weighted)		−2.4	0.61

[39] The only exception is Greece, for which the 2001 budget balance is not stated in the Eurostat database, and hence the 2002-2006 period is averaged over to create S.