Monetary Policy Facing Fiscal Indiscipline under Generalized Timing of Actions

by

Jan Libich and Petr Stehlik*

The paper analyzes interactions between monetary and fiscal policies, both in a single-country and in a monetary-union setting. As the policy interactions are strategic, we use game-theoretic methods. Specifically, we develop a framework that allows for an arbitrary, possibly stochastic timing of moves. Our analysis identifies a number of institutional and policy variables that influence the interplay and outcomes of monetary and fiscal policies, such as the average levels of inflation and debt, and that determine the likelihood of an unpleasant monetarist arithmetic. We then calibrate the model with European Monetary Union data. (JEL: E61, C70, E42, C72)

1 Introduction

Fiscal and monetary policies are strongly interrelated, as the actions of each kind affect the outcomes of the other. This is true even if the central bank is formally and legally independent. Such interdependence implies the following question that has concerned central bankers in many countries (including the European Union and the United States), and that will be the main focus of the paper: What factors determine whether or not excessive fiscal spending constitutes a problem for monetary policy?

Our emphasis is on the *strategic* aspect of the monetary–fiscal interactions – both in a single country and in a monetary union.[1] Therefore, we use game-theoretic

---

[1] As Leeper (2010) and many others have argued, given the dire $\mathcal{F}$ projections in many countries, it is important to understand how the strategic policy interactions may

methods. In particular, we propose a game-theoretic framework that generalizes the *timing* of the policy actions. The existing literature has, explicitly or implicitly, studied the policy interaction as a standard repeated game (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). In such a setting all policy moves are: (i) deterministic, i.e., they occur with certainty at a prespecified time, (ii) repeated every period, and (iii) simultaneous, i.e., unobservable by the opponent in real time.

Our framework relaxes these three assumptions, which can be viewed as unrealistic in the macroeconomic policy context. It allows for the timing of the policies' moves to be *stochastic*, i.e., only occur with some probability, and only in some periods. 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.

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- to 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 investigators were interested in.[2] Because of that, we will not use a specific macroeconomic model. Instead, we will use a 2×2 game-theoretic representation that nests the intuition of a number of micro-founded models in the literature (which is discussed in detail in section 2.2). 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 2007–2009, but rather the behaviour that occured prior to the crisis – the persuance of structural budget deficits.

Our analysis is therefore best interpreted as a big-picture view of the monetary–fiscal interactions. Such a perspective follows Blanchard (2008, p. 27), who calls for "the re-legalization of shortcuts and of simple models." Its value lies in being able to identify common (real-world-relevant) features of influential papers, and offer some common insights despite the fact that the papers use very different macroeconomic frameworks.

To give a simple example of the policy interaction we find most relevant, think of the battle-of-the-sexes scenario. This game embodies two realistic features: a coordination problem and a policy conflict. Each policy has two available medium-run choices, labeled *discipline* and *indiscipline*. Both the monetary and the fiscal policymaker prefer to coordinate their actions to avoid a tug of war between them, which would lead to higher macroeconomic volatility (as in the German situation after reunification). Therefore, in a standard one-shot game there are two pure-strategy

---

play out in the future, and what institutional forces may affect and improve the outcomes.

[2] While some papers, including Leeper (1991) and those on 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.

Nash equilibria, (discipline, discipline) and (indiscipline, indiscipline). Nevertheless, each policymaker prefers a different equilibrium: the central bank the former, to ensure price stability, and the government the latter, to buy votes through popular spending. Therefore, in the simultaneous-move game the mixed Nash equilibrium, which leads to inferior outcomes for both policymakers, is a real possibility.[3]

The commonly offered solution is to allow for commitment – Stackelberg leadership – of one policy. Moving first is an advantage in this game, as it allows a player to force the opponent to cooperate. It therefore ensures that the preferred outcome of the leader will be the unique subgame-perfect Nash equilibrium.

The main shortcoming of this simple solution is that the leader "wins" and the followers "lose" the battle of the sexes or the game of chicken under *all* circumstances, i.e., regardless of the exact payoffs and discount factors. Therefore, such a solution cannot be used to make policy predictions about the outcomes of the monetary–fiscal interactions following a change in some structural, institutional, or preference parameter. This is where our main (nonmethodological) contribution lies: our framework refines the conventional insights into the effect of commitment, and enables us to show how macroeconomic outcomes depend on various details of the underlying setup and the timing of the players' actions. The framework even offers a simple way to endogenize the timing.

To motivate the generalized timing, consider the situation in some country with an explicit inflation target. The central bank is committed (on average over the business cycle) to achieve the target, which can only be altered infrequently, as it is legislated.[4] In contrast, the government has the opportunity to alter its medium-term fiscal stance every year when proposing the budget. In addition, there also exists some positive probability that the fiscal stance can also be changed within the fiscal year: either through election of a new government, through macroeconomic developments such as shocks and crises, or because of shifts in public opinion.

Our framework can capture such timing, and in fact allow for an arbitrary probability distribution of such revision opportunities. This paper first derives the outcomes of the policy interactions under a general probability distribution, and then depicts in more detail uniform, normal, and binomial distributions of policy moves, the last following the popular timing of Calvo (1983). This is to demonstrate the usability of the framework, which can be applied in many different contexts in macro- and microeconomics.

This paper shows that the outcomes of the policy interaction crucially depend on the degree of *monetary commitment* (which measures the inability of the central bank to change its long-run inflation target) *relative* to the degree of *fiscal rigidity* (which measures the inability of the government to put fiscal finances on a sustainable path).

---

[3] The widely used game of chicken is analogous: the only difference is that players prefer *not* to cooperate, the pure Nash equilibria being (discipline, indiscipline) and (indiscipline, discipline).

[4] 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 this occurs only when one of them changes.

If relative monetary commitment is sufficiently strong (explicit), i.e., above a certain necessary and sufficient threshold $\bar{R}$ that 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 (below $\bar{R}$), the central bank is likely to miss its price stability objective. This is due to the spillovers from fiscal policy, and occurs even if the central bank is formally independent from the government and targets the natural rate of output. The intuition is comparable to that 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).

Importantly, what produces valuable insights unobtainable under the standard timing is the fact that the threshold degree of relative commitment, $\bar{R}$, is a function of the structure of the economy and of the preferences of the policymakers. Specifically, in addition to (i) the degree of fiscal rigidity and ambition of each member country, it is also *increasing* in (ii) the country's economic size (i.e., larger countries carry a greater weight in the monetary union), (iii) the magnitude of the conflict cost associated with the central bank fighting an ambitious government (which is a function of the deep parameters of the underlying macroeconomic model), and (iv) the degree of the central banker's impatience (which is a function of various institutional characteristics of the central banking design).

Perhaps most interestingly, we show that a sufficiently strong long-term monetary commitment may be able to *discipline* fiscal policies. The reason for such a disciplining effect is twofold. First, a more strongly committed central bank will counteract the expansionary effects of excessive fiscal spending more vigorously. Second, such behaviour 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 in that it holds under all timing distributions of our scenario of interest. We discuss the formal empirical evidence for it in section 8; here let us mention the narrative of Brash (2010), the Governor of the Reserve Bank of New Zealand during 1988–2002. The author describes the policy developments in New Zealand shortly after strengthening monetary commitment by adoption of an explicit inflation target. He offers a number of observed examples of the disciplining effect, concluding that:

> "I have not the slightest doubt that having legislation which requires government and central bank to formally agree, and disclose to the public, the inflation rate which the central bank must target has a most useful role in creating strong incentives for good fiscal policy."

We conclude by discussing a free-riding problem likely to occur in a monetary union, which makes it harder or even impossible for the common central bank to discipline national fiscal policies – especially in the small member countries. This is that the potential (political) benefits of excessive fiscal policy are enjoyed predominantly by the undisciplined country itself, whereas the central bank's punishment via higher interest rates is spread across all member countries, including the disciplined ones. Therefore, if a member country largely ignores the negative externality it imposes on other members, then even an infinitely strong future punishment may be insufficient to discipline its fiscal policy. These insights can be related to (and in fact had predicted) the debt crises currently under way in Greece and other countries in the European Monetary Union.

The rest of the paper proceeds as follows. Section 2 presents the monetary–fiscal policy interaction as a 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 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 $n \in \{1, 2, \ldots, N\}$.[5] In a single-country setting we have $N = 1$, whereas in a monetary-union setting we have $N > 1$.

In the latter, the relative weights of the union members (expressing their economic 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 policymaker $\mathcal{M}$ 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 directly determined by its own actions and those of the common central bank. Indirectly, the actions of other governments will be shown to also have an influence, since they determine the action of the central bank, and hence the equilibrium outcomes.

---

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

2.1 Game-Theoretic Representation

In order to make the game-theoretic analysis more illustrative, we will examine the policy interaction as a 2×2 game, summarized in Table 1.

Table 1
Game-Theoretic Representation

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

We can interpret the levels L and l as medium–long-run *discipline*, and the levels H and h 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 (determinate) macroeconomic model of policy interaction can be truncated into such a 2×2 game-theoretic representation. The policymakers' payoffs $\{a, b, c, d, w, x, y, z\}$ are then some functions of the deep parameters of the underlying macroeconomic model, i.e., there is a *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, which are applicable to a range of macroeconomic models, we will not examine a specific macroeconomic model here (for an example of the mapping see Libich, Hughes Hallett, and Stehlik, 2007). Nevertheless, we will later discuss an interpretation of these payoffs.[6]

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 (abbreviated as 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 interactions, under a range of circumstances.

---

[6] Real-world optimal $\mathcal{M}$ and $\mathcal{F}$ policies are state-dependent and time-variant, and they have been modeled as such in the literature. Nevertheless, this is because the focus has primarily been on optimal short-run stabilization of shocks. Our attention is, in contrast, on *average* outcomes over the business cycle (medium run). In doing so we implicitly assume that shocks have a zero mean over the medium run, so their stabilization would not affect the average policy stance.

Following the literature, our interest lies in the case in which the government is *ambitious*, i.e., it tends to spend excessively. 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 (Table 2 presents specific examples of each scenario, with the pure-strategy NE indicated in italics).

(a) A Conflict. (L, h) and (H, l) are the NEs, 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

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

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 this 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 NEs, and both policymakers prefer the former. The game has therefore the form of a pure coordination game. Specifically, the payoffs satisfy

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

where $a - b$ and $z - x$ express the players' *miscoordination 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), Eggertsson and Woodford (2006), Persson, Persson, and Svensson (2006), Benhabib and Eusepi (2005), Gali and Monacelli (2005), Dixit and Lambertini (2003 and 2001)), Van Aarle, Engwerda, and Plasmans (2002), Nordhaus (1994), Petit (1989), or Alesina and Tabellini (1987).

(c) A Conflict Combined with a Coordination Problem. (L, l) and (H, h) are the NEs, and each policymaker prefers a different one, namely $\mathcal{M}$ for the former and $\mathcal{F}$ for the latter. The game has therefore the form of the battle of the sexes. Specifically, the payoffs satisfy

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

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, e.g., Adam and Billi (2008), Branch, Davig, and McGough (2008), Resende and Rebei (2008), Hughes Hallett and Libich (2007), Benhabib and Eusepi (2005), Dixit and Lambertini (2003 and 2001), Blake and Weale (1998), Nordhaus (1994), Sims

Table 2
Three Policy Interaction Scenarios of Interest

(a) Game of Chicken

		$\mathcal{F}_n$	
		l	h
$\mathcal{M}$	L	0, 0	2, 1
	H	1, 2	0, 0

(b) Pure Coordination

		$\mathcal{F}_n$	
		l	h
$\mathcal{M}$	L	2, 2	0, 0
	H	0, 0	1, 1

(c) The Battle of the Sexes

		$\mathcal{F}_n$	
		l	h
$\mathcal{M}$	L	2, 1	0, 0
	H	0, 0	1, 2

(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 slightly different mechanism for the possible departure from the socially optimal (L, l) outcome, and a explanation for why even a formally independent central bank may find it optimal to monetize the debt to some extent.

One 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.[7]

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, i.e., "spread the load" between the policies (see, e.g., Adam and Billi, 2008, or Resende and Rebei, 2008). Finally, in Hughes Hallett, Libich, and Stehlik (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 bank also cares about output stabilization, it 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.[8] Furthermore, Libich, Hughes Hallett, and Stehlik (2007) show that the chicken scenario is unlikely to obtain under

---

[7] 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 if the policies change between the active and passive roles.

[8] Probably the closest model to the above 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 is analyzed as a starting point, 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 NEs, respectively).

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 NEs 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 (L, l), in the remaining two scenarios that is not the case. Since each policymaker prefers a different pure NE, neither standard nor evolutionary game-theoretic techniques can 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 (Stackelberg leadership), the game has a unique outcome that is preferred by the committed player (leader). This is 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 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 not only on the relative degrees of commitment, but also on the exact payoffs and 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*, which has primarily examined the simple (deterministic) case of alternating moves (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, p. 21) 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." Furthermore, 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, e.g., Neyman and Sorin, 2003, or Shapley, 1953). Recently, Kamada and Kandori

(2009) have also allowed 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). Their "revision game" is, however, static in the sense that the payoffs do not accrue over time. Therefore, the intuition, analysis, and applications differ substantially from those in our dynamic revision game. 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 (i.e., we have 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 at (continuous) time $t = 0$.*

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

DEFINITION 1 *Moves made in between the simultaneous moves will be referred to as* revisions. *A player that can make a revision with: (i) some positive probability will be called the* reviser, *and (ii) with zero probability will be called the* committed player *or the* rigid player *– with r expressing his degree of commitment or rigidity.*

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 therefore 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.[9] This is to provide a benchmark for the other player's moves, and examine the timing differences in relative terms. 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 dynamic games, each r periods long and potentially different. 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 infinitely) repeated setting and show that all of our findings carry over. In fact, it will be evident that we can

---

[9] In Libich, Hughes Hallett, and Stehlik (2007) this is not imposed, but for reasons of tractability only a simple deterministic case is examined. Also note that the committed player's deterministic moves every r periods can be thought of in terms of the *expected* frequency of moves, i.e., $r = 1/(1 - \theta)$, where θ is the probability that he cannot reconsider its long-term stance in any one period.

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 revisions. In particular, one of these moves is of special interest.

DEFINITION 2 *The reviser's or revisers'* first *revision following each simultaneous move will be labeled the* Revision *(with a capital letter). All other revisions will be called* further revisions.

The Revision will have a particular role in that 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 is orthogonal 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).[10] 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

$$F_n(t) : [0, r] \to [0, 1], \; where \; F_n(0) = 0 \,,$$

is an arbitrary nondecreasing function summarizing the timing of the n th reviser's Revision. It is the cumulative distribution function (CDF) *of the underlying probability distribution, i.e., it expresses the probability that the reviser has had the opportunity to revise no later than time t. 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.*[11]

Several specific examples of $F_n(t)$ are examined below and graphically depicted in Figures 1–3 and 7. These figures also present some related concepts introduced in this section.

---

[10] 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 does not play any role.

[11] 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 Revisions only – the simultaneous moves are not included.

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

$$(4) \qquad \int_0^r (1 - F(t))\mathrm{d}t = r - \int_0^r F(t)\mathrm{d}t$$

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

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

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

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 are also committed (unless $\int_0^r F(t)\mathrm{d}t = 1$). Nevertheless, the degree of their commitment is less than that of the committed player, since they can, at least in expectation, move more frequently (unless $\int_0^r F(t)\mathrm{d}t = 0$, which is the case of the standard repeated game).

Figure 1
CDF with the (Overall) Reaction Speed of the Reviser(s) Indicated
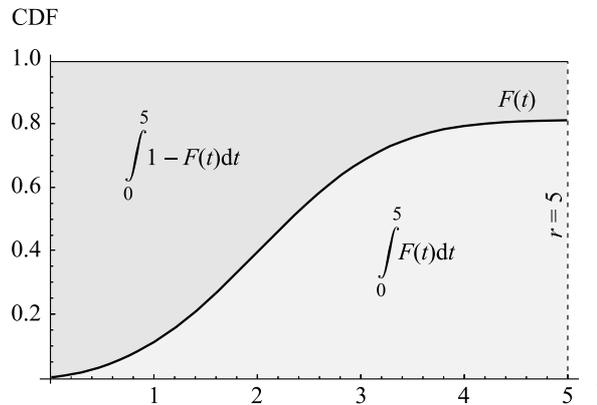
The way we will go about solving the game is determined by the specific results we are interested in. It is *not* our goal to fully describe all the equilibria of the game under all circumstances. Instead, our interest lies in circumstances under which unique equilibrium selection occurs in our three 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.*[12] In doing so we will use the following terminology.

DEFINITION 5 *The committed player will be said 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* $\mathcal{F}$ policy.

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

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, showing that the qualitative nature of the results is unchanged. Second, since $\mathcal{M}$ is assumed to be benevolent and his preferred outcome (L, l) is the socially optimal one in the battle scenario, we will throughout focus on the circumstances under which $\mathcal{M}$ wins the game and disciplines $\mathcal{F}$ policy.

This section will first report a general result that holds for any timing of Revisions. 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.

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 moves summarized by F(t). The committed or rigid player wins the game if and only if his relative commitment or rigidity is sufficiently high,*

$$(5) \qquad \frac{r}{\int_0^r (1 - F(t))\mathrm{d}t} > \bar{R} > 1 \, .$$

The relative commitment threshold $\bar{R}$ *in the battle scenario is, under* $\mathcal{M}$ *and* $\mathcal{F}$ *being the committed or rigid players respectively,*

$$\bar{R} = \frac{a - b}{a - d} \ \ or \ \ \bar{R} = \frac{z - x}{z - w} \, ,$$

i.e., it is increasing in his conflict cost relative to the victory gain, but independent of the revisers' payoffs.[13]

---

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

[13] The remaining thresholds are the following: in the chicken scenario $\bar{R} = (b - a)/(b - c)$ and $\bar{R} = (y - w)/(y - x)$ (i.e., it is also the conflict cost relative to the

PROOF As the proof demonstrates the intuition of our framework, we report it here rather than in the Appendix. 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 NE regardless of the revisers' simultaneous 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 the $\mathcal{F}$ or $\mathcal{F}$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 the $\mathcal{M}$ policy winning the game.

Focus on the battle scenario with $\mathcal{M}$ being the committed player. Using backward 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 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 simultaneous 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, i.e., for the central bank to find it optimal to enter into conflict with an undisciplined government, the following *necessary and sufficient* condition needs to be satisfied:

$$(6) \qquad \underbrace{b \int_0^r (1 - F(t))\mathrm{d}t}_{(L,h)} + \underbrace{a \int_0^r F(t)\mathrm{d}t}_{(L,l)} > \underbrace{dr}_{(H,h)}.$$

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 (6) 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 (6) 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 that 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

---

victory gain), and in the coordination scenario $\bar{R} = (a - b)/(a - d)$ and $\bar{R} = (w - y)/(w - z)$ (i.e., the miscoordination cost relative to the coordination gain). Obviously, if the payoffs are symmetric, then the two $\bar{R}$ values within each scenario are equivalent. For instance, using the specific payoffs in Table 2, all six thresholds $\bar{R}$ equal 2.

given by the area *above* $F(t)$. Similarly, the payoff 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 (4) and rearranging (6), 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.   *Q.E.D.*

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 relative to the reviser, 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 this is about the cost of the potential conflict or miscoordination 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. Thus, our framework may provide valuable information to the policymakers, as they can consider their optimal degree of commitment. We will in section 7.4 briefly examine such endogenous determination of commitment and timing.

The proposition further highlights the importance of *relative* commitment or rigidity – what matters is how frequently or 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 (e.g., Schaumburg and Tambalotti, 2007).

For completeness, let us discuss what happens if the condition in (5) is *not* satisfied, i.e., if neither player's relative commitment or rigidity is sufficient. Then neither player wins the game according to Definition 5, as the dynamic r-period game has multiple SPNEs. 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 one with (H, h) throughout the equilibrium path. In addition, there are potentially (iii) other SPNEs featuring some (pure or mixed) combination of (L, l, H, h) on the equilibrium path, dependent on the exact values of the players' commitment or rigidity and their payoffs.

This implies that if (5) does not hold, the socially optimal outcomes may or may not obtain. Considering the multiplicity region is beyond the scope of the present paper, but intuitively, in an evolutionary setting, the higher a player's relative

commitment or rigidity, the "closer" he gets to his preferred outcome, since its basin of attraction is larger.[14]

5　Results: Specific Timing Distributions

In order to further develop the intuition and provide additional insights, we will examine several timing specifications summarized in Table 3.

Table 3
Specific Timing Distributions

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 setting with a single $\mathcal{M}$ and any number N of independent $\mathcal{F}$ policymakers. The latter can be heterogeneous not only in their degree of $\mathcal{F}$ rigidity, but also in their economic size 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 taken – both mathematically and graphically. First, the underlying probability distributions 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 (5) 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.[15] 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

---

[14]　For more, see Basov, Libich, and Stehlik (2009), who examine stochastically stable states in a similar framework.

[15]　Tobin (1982, p. 31) 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 […]".

Figure 2
The Timeline and $F(t)$ of Case 1
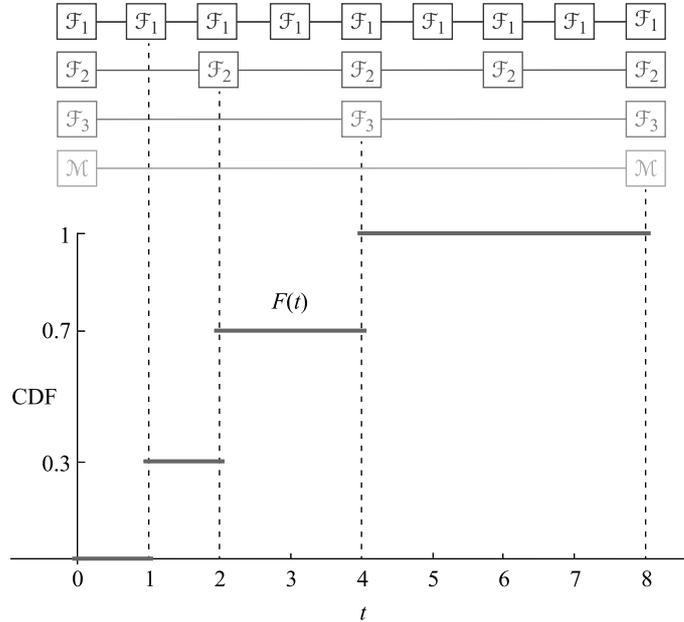
$\lfloor r/r_n^{\mathcal{F}} \rfloor = r/r_n^{\mathcal{F}}$, $\forall n$.[16] The last assumption, that the floor equals the integer value, implies $r_n^{\mathcal{F}} \leq r$, as well as synchronization of the simultaneous moves across all policymakers, i.e., that assumption (iv) holds.

The individual and overall Revision functions, i.e., the CDFs and the wCDF, have the following specific form (see Figure 2, which graphically depicts these as well as the timeline of the game featuring $r = 8$, $\mathcal{M}$ as the committed player, and three $\mathcal{F}$ policymakers with weights $w_1 = 0.2$, $w_2 = 0.5$, $w_3 = 0.3$ and rigidities $r_1^{\mathcal{F}} = 1, r_2^{\mathcal{F}} = 2, r_3^{\mathcal{F}} = 4$):

$$(7) \qquad F_n(t) = \begin{cases} 0 & \text{if } t < r_n^{\mathcal{F}}, \\ 1 & \text{if } t \geq r_n^{\mathcal{F}}, \end{cases} \quad \text{and} \quad F(t) = \sum_{n:r_n^{\mathcal{F}} \leq t}^{N} w_n \,.$$

Integrating $F(t)$ from (7) over $[0, r]$, we obtain

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

---

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

Using (4) implies the specific form of the necessary and sufficient condition in (5), namely

(8)
$$\frac{r}{\sum_{n=1}^{N} w_n r_n^{\mathcal{F}}} > \bar{R} .$$

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

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

where $r/r^{\mathcal{F}}$ 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. Both thresholds $\bar{R}$ are obviously identical to those reported in Proposition 1 for the battle scenario.

5.2 Case 2: Uniformly Distributed Moves

Consider some g_n and h_n, such that $0 \le g_n < h_n \le r$, $\forall n$, as the minimum and maximum $\mathcal{F}$ rigidity of the nth country, respectively. Further assume that each $\mathcal{F}$ policymaker n has a Revision with a 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 6), featuring $r = 8$ and two revisers. They have $w_1 = 0.4$, $w_2 = 0.6$, $g_1 = 1$, $h_1 = 2$, $g_2 = 3$, $h_2 = 6$, i.e., uniformly distributed probability of Revisions on intervals $[1, 2]$ and $[3, 6]$ respectively. The solid line in the timeline denotes moves with probability 1 in a given period, and the dashed line moves with probability less than 1. We have

(9)
$$F_n(t) = \begin{cases} 0 & \text{if } t \in [0, g_n), \\ \frac{t - g_n}{h_n - g_n} & \text{if } t \in [g_n, h_n), \quad \text{and} \quad F(t) = \sum_{n=1}^{N} w_n F_n(t) . \\ 1 & \text{if } t \in [h_n, r], \end{cases}$$

Integrating $F(t)$ from (9) over $[0, r]$, we get

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

Using (4) implies the specific form of the necessary and sufficient condition in (5), namely

(10)
$$\frac{r}{\frac{1}{2} \sum_{n=1}^{N} w_n(g_n + h_n)} > \bar{R} .$$

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

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

If $\mathcal{F}$ is the rigid player, the condition is the same with g and h relating to player $\mathcal{M}$.

5.3 Case 3: Binomially Distributed Moves

The Calvo (1983) timing has become increasingly used in the macroeconomic literature when modelling the moves of agents.[17] We believe it is also useful in modelling 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.[18]

The individual and overall Revision functions have the following specific form (see Figure 3 for a graphical depiction featuring $r = 8$, $\mathcal{M}$ as the committed player, and one $\mathcal{F}$ policymaker with $\theta = 1/2$):

(11)

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

Integrating $F(t)$ from (11) over $[0, r]$, we obtain

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

Using (4) implies the specific form of the necessary and sufficient condition in (5), namely

(12)

$$\frac{r}{\sum_{n=1}^{N} w_n \frac{1 - \theta_n^r}{1 - \theta_n}} > \bar{R}.$$

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

$$\frac{r}{1 + \theta + \theta^2 + \cdots + \theta^{r-1}} > \bar{R}.$$

By inspection of (8), (10), and (12), the minimum r value that satisfies these conditions 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, $(g_n + h_n)/2$ in Case 2, and θ_n in Case 3. The following proposition summarizes these findings.

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

---

[17] 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 the *discretion, timeless-perspective commitment* of Woodford (1999), as well as the *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.

[18] 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 to the conventional repeated game. If $\theta_n = 0$, we get Case 1 with $r_n^{\mathcal{F}} = 1$.

Figure 3
The Timeline and $F(t)$ of Case 3
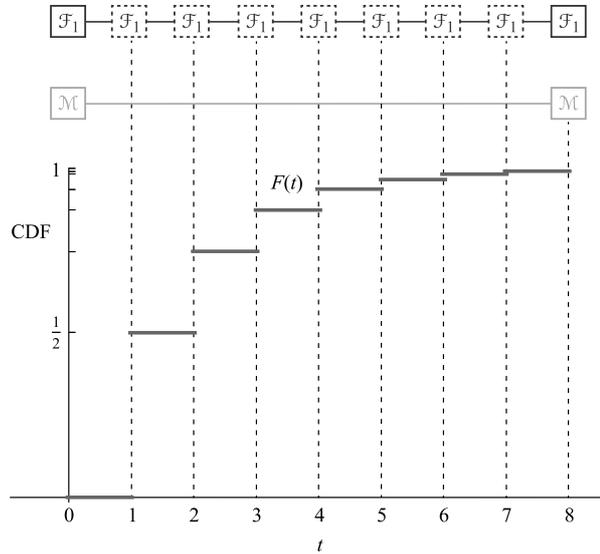
PROOF Rewriting the condition (6) in terms of $F_n(t)$ rather than $F(t)$, one obtains

$$(13) \qquad \sum_{n=1}^{N} w_n \left(b \int_0^r (1 - F_n(t))\mathrm{d}t + a \int_0^r F_n(t)\mathrm{d}t \right) > dr .$$

Rearranging and using $\bar{R} = (a - b)/(a - d)$ yields

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

The fact that the denominator is increasing (and hence the whole fraction decreasing) in w_n completes the proof by inspection. *Q.E.D.*

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 counteracting their expansionary effect.

6 Real-World Interpretation and Application

We have kept the focus on the game-theoretic insights in terms of the policy inter-action – 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 focused on medium- and long-run outcomes of such policy interaction in order to separate the effect of stochastic timing from a stochastic macroeconomy (shocks).

Such focus implies 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 to 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 (central-banking statutes). The underlying assumption is that the more explicitly a certain policy setting or 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. The Act also states that the Governor may be fired if inflation deviates 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, there are various political-economy reasons (lobby groups, myopia, unionization, naïve voters) and structural features (aging population, pay-as-you-go health and pension systems, welfare schemes, 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.[19]

6.2 Calibration: The EMU

$\mathcal{M}$ policy in the EMU is conducted by a common $\mathcal{M}$ authority, the European Central Bank (ECB). In contrast, each country has an independent $\mathcal{F}$ policy.[20] In order to consider multiple $\mathcal{F}$ policymakers, the ECB will be taken as the committed player.

As of the writing of this paper, there are fifteen member countries that have adopted the common euro currency (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. The first is the economic size, which differs greatly across the member countries. The second and more crucial 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 (12), namely

$$(14) \qquad \frac{r}{\sum_{n=1}^{N} w_n \frac{1-\theta_n^r}{1-\theta_n}} > \bar{R} = \frac{a-b}{a-d}.$$

In this case θ_n can be interpreted as the probability that $\mathcal{F}$ is *unable* to consolidate her actions, even if it is her optimal play (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 to a government's consolidating its $\mathcal{F}$ actions and putting them on a sustainable path, even if it wishes to do so.

The question of how to best calibrate θ_n in (14) therefore amounts to the following: What is the probability that the government of country n will embark on an $\mathcal{F}$ policy stance that is balanced over the long term – conditional upon deciding that it is the optimal thing to do? We believe that that probability can best be derived from $\mathcal{F}$ outcomes of the (recent) past. In order to provide a lower-bound estimate of the $\mathcal{F}$ rigidity, we will focus on the period prior to the global financial crisis. Obviously, the fiscal position of the Eurozone countries has deteriorated significantly since the start of the crisis. Using the precrisis numbers below aims to demonstrate that the structural fiscal problems, and the implied threat for monetary policy, had existed before the crisis.

---

[19] Leeper (2010) 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.

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

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

$$(15) \qquad \theta_n = \begin{cases} \frac{\alpha S_n}{\alpha S_n - 1} & \text{if } S_n \le 0, \\ 0 & \text{if } S_n > 0, \end{cases}$$

where α is some positive constant (which 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). 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 post-2007 data, in order to exclude the effects of the global financial crisis.[21]

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's 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 (15) – see Figure 4 for a plot that shows the resulting θ_n values for the EMU countries (dashed gray lines depict $\alpha = 2$ and $\alpha = 1/2$, respectively). Such parametrization implies that a country such as Austria with an average pre-2007 deficit of 1% of GDP, $S_n = -1$, has a 50% probability each year ($\theta_n = 1/2$) of putting $\mathcal{F}$ finances on a sustainable path, whereas countries with $S_n = -3$ such as Germany or France only have a 25% probability each year of doing so ($\theta_n = 3/4$). For obvious reasons, θ_n in (15) is truncated by zero from below for countries with a surplus on average, $S_n > 0$. This means that the four such countries in the sample – Finland, Ireland, Luxembourg, and Spain – are assigned the value $\theta_n = 0$.

If the reader, like the authors, finds the values implied by $\alpha = 1$ overly optimistic with regard to the $\mathcal{F}$ consolidation opportunities – i.e., if the driving forces of $\mathcal{F}$ indiscipline are more persistent – then 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 4, which also depicts $\alpha = 2$ and $\alpha = 1/2$).

For 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

---

[21] Including the pre-2007 size of each country's debt as a percentage of GDP in the specification of S_n would not change the quantitative nature of the results. Obviously, including the post-2007 deficit and debt data and including expected liabilities for bailouts of financial institutions would significantly increase the measure of $\mathcal{F}$ rigidity in most countries (especially Greece, Ireland, Spain, etc.). Let us therefore reiterate that our $\mathcal{F}$ rigidity measure should be interpreted as a lower bound, reflecting the situation prior to the financial crisis.

Figure 4

Dependence of $\mathcal{F}$ Rigidity θ_n on the Budget-Surplus-to-GDP Ratio S_n (See (15))
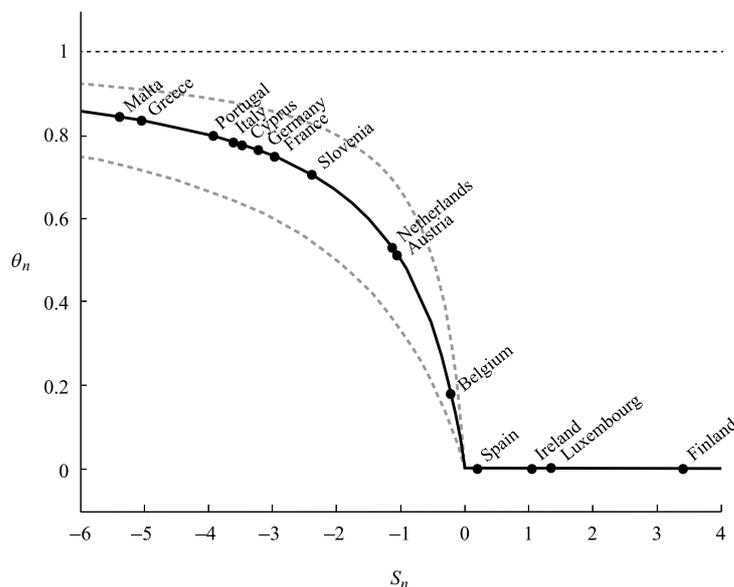
EMU member country over 2001–2006, and divide it by the EMU's average over that period (see Appendix).

As discussed in section 2.1, the fraction $(a - b)/(a - d)$ 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, Hughes Hallett, and Stehlik (2007) demonstrate, following the approach of Cho and Matsui (2005).[22]

This paper uses 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 a 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.

The first 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. The second factor is the relative weights assigned to inflation and output stabilization

---

[22] For a different example of the mapping technique applied to the well-known time-inconsistency game see Libich and Stehlik (2011).

in the policy loss function (the degree of conservatism of the two policymakers), as well as the degree of the government's ambition. 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 $(a - b)/(a - d) \in [3/2, 3]$, but report the threshold in Figure 5 for a larger interval, and for $\alpha \in \{1/2, 1, 2\}$. The $\mathcal{M}$ commitment values r above the solid lines ensure the ECB's achievement of the inflation target on average, and discipline the member governments. The r-values below the solid lines are likely to be insufficient to achieve that, as they lead to multiple SPNEs. The calibration implies the following conclusion (which would still obtain – and only be reinforced – if post-2007 deficit and debt data were included).

Figure 5
The $\mathcal{M}$ Commitment Threshold
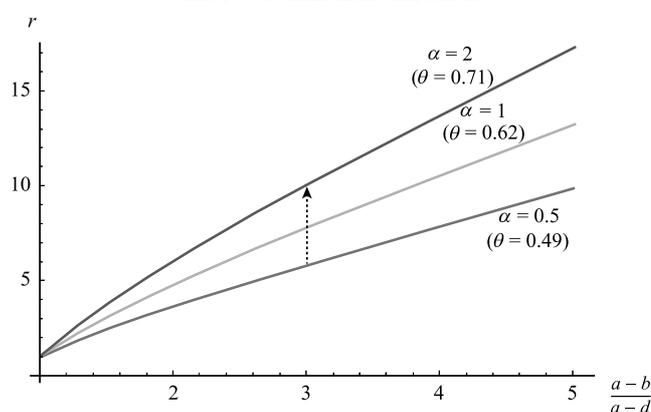
REMARK 1 *Given the degree of $\mathcal{F}$ rigidity and ambition of the EMU countries implied by their past outcomes, the required degree (explicitness) of the ECB's long-run commitment to low inflation is substantial.*

Specifically, such commitment should be explicit enough for all parties to believe that it will not be reconsidered for at least 3–5 years, but more likely significantly longer.[23] Naturally, if post-2007 data and the future $\mathcal{F}$ projections are included, the picture in terms of $\mathcal{M}$ policy enforcing $\mathcal{F}$ discipline looks much bleaker still.[24]

---

[23] 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%.

[24] The fiscal stimuli of 2008–2010 only form a small part of the observed fiscal stress facing advanced countries. For example, IMF (2009) estimate that in G20 coun-

Including these would only increase the value of $\mathcal{F}$ rigidity in the EMU, substantially increase the $\mathcal{M}$ commitment threshold, and hence further highlight the threat of fiscal spillovers onto monetary policy.

6.3 Free Riding

Given the high degree of the ECB's long-term commitment, the question is why it has not been sufficient to discipline some member governments. This can be attributed to the fact that a monetary union is subject to *free riding* by individual governments. It can be argued that the potential benefits of excessive $\mathcal{F}$ policy accrue primarily in the undisciplined 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 not internalize the negative externality cost they impose on other members, a stronger punishment may be required to discipline them than in a single-country setting.

Such free riding 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, (14) shows that an even stronger $\mathcal{M}$ commitment will be required to discipline governments under such free riding.

It may in some models be the case that if the free-riding problem is sufficiently severe, some individual governments' best response to L may be h, i.e., we have $x > w$, similarly to the chicken scenario. Our analysis implies that in such a case, reminiscent of the situation in Greece and some other member countries, even an infinitely strong $\mathcal{M}$ commitment cannot discipline such governments. The same is true, even without free riding, 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.[25]

7 Extensions

7.1 Combinations of Probability Distributions Using Mean Values

This section reports a statistical result that 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 probability distribution, without reference to its other moments. This also means that we can obtain analytical

---

tries the average contribution of the global financial crisis to the long-term $\mathcal{F}$ imbalance is only 10.8% of the contribution of factors related to aging populations. United Nations data show that between 1960 and 2040 the old-age dependency ratio in advanced economies is predicted to more than triple on average, with most of the rise yet to come. This implies dramatic increases in pensioner/worker ratios, and hence substantial amounts of $\mathcal{F}$ stress in the pipeline.

[25] For this reason, our framework does not offer a tool to escape inefficient equilibria in some classes of game, e.g., the prisoners' dilemma.

solutions for combinations of distributions that are very different in nature (unlike in Cases 1–3, in which all the $\mathcal{F}$ revisers within each case had the same type of distribution).

Let us denote by μ_n the mean value of the underlying probability distribution of the nth reviser. The following is a known result in statistics; see, e.g., Lemma 2.4 in Kallenberg (2002).

LEMMA 1 *Consider F(t) from Definition 3 such that*

(16)
$$F(r) = 1 \, .$$

Then

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

Let us mention the interpretation of (16): it ensures that (all) reviser(s) have the opportunity to make a revision. The Lemma implies that, if (16) holds, even probability distributions expressing very complicated timing of moves can be summarized without loss of generality by their first moments. Put differently, if (16) is satisfied, then μ_n fully describes the degree of commitment or rigidity of each reviser.

The following result uses the Lemma to express Proposition 1 in an alternative fashion. Note, however, that while it is easier to use in combining different probability distributions, it is not as general as Proposition 1, since (16) is required to hold for every underlying distribution.[26]

PROPOSITION 3 *Consider the dynamic r-period game of policy interaction described by either* (1)*,* (2)*, or* (3)*, whereby the $\mathcal{F}$ rigidity of each member n is described by an arbitrary probability distribution 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,* (5)*, can be written as*

(17)
$$\frac{r}{\sum_{n=1}^N w_n \mu_n} > \bar{R} \, .$$

PROOF Substituting the Lemma into (13) yields (17). *Q.E.D.*

To demonstrate the usefulness of this shortcut, let us report an example that combines the above Case 2 with normally distributed moves.

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

(a) country 1: *uniformly* distributed moves of Case 2, $F_n(t)$ from (9);

---

[26] For example, the functions $F(t)$ depicted in Figures 1 and 3 do not satisfy the condition, and hence the following result is not applicable to them.

(b) country 2: *normally* distributed moves, such that

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

where

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

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

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

where $\mu_1 = (g + h)/2$ is the mean value of the probability distribution of Case 2.

For a graphical depiction see Figure 7, 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). Let us note two things. First, the condition (16) is satisfied for both countries. Second, the standard deviation σ does not determine the threshold value of r.

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 Revision 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 to coordinate and win the game.[27]

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* $\mathcal{M}$'s *relative commitment to win the game is*

$$(18) \qquad \frac{\int_0^r e^{-\rho t} \, dt}{\int_0^r e^{-\rho t}(1 - F(t)) \, dt} > \bar{R},$$

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

---

[27] 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.

Figure 6
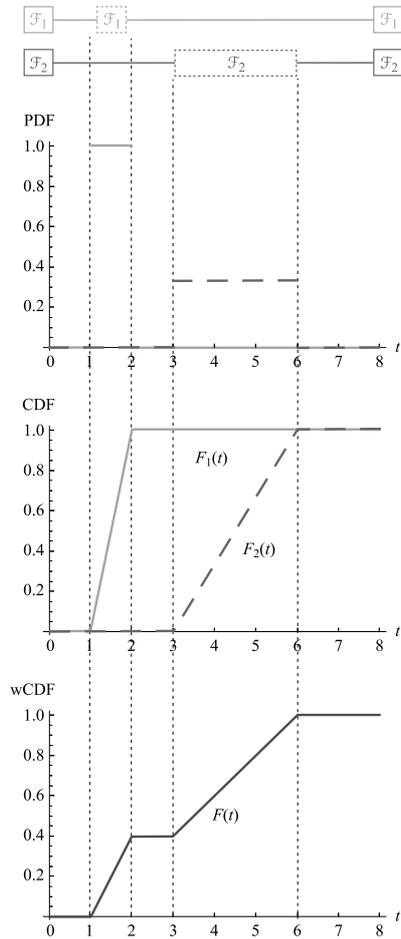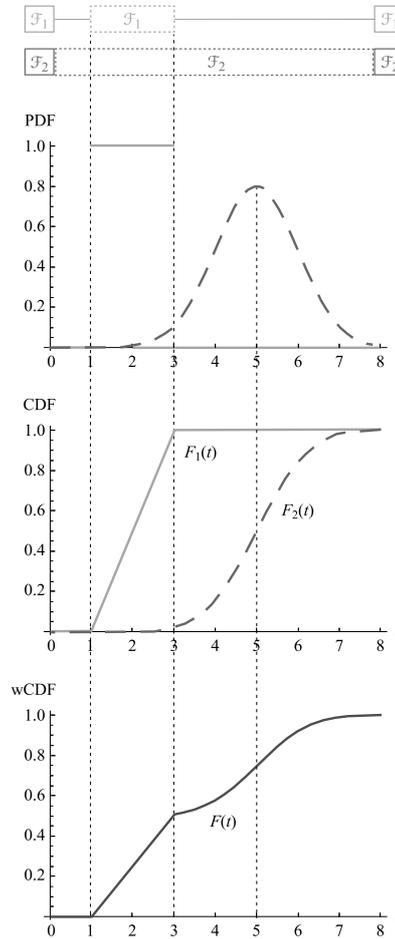The Timeline, PDFs, CDFs, and wCDF
of Case 2

Figure 7
The Timeline, PDFs, CDFs, and wCDF
of Example 1

PROOF The proof of this statement follows from the fact that $1 - F(t)$ is a decreasing function. Therefore, an increase in ρ decreases the integral in the numerator more than proportionally to the integral in the denominator. In other words, the increase of ρ decreases the fraction on the LHS. Consequently, in order to achieve the required value of relative commitment, $\bar{R}$, for greater ρ, the value of r must increase.   *Q.E.D.*

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).[28] The following result summarizes the effects of discounting.

COROLLARY 1 *There exists $\bar{\rho} > 0$ such that: (i) for all $\rho < \bar{\rho}(\bar{R})$ an r value satisfying (18) exists, whereas (ii) for all $\rho \geq \bar{\rho}$ even an infinitely strong commitment $r \to \infty$ does not satisfy the condition.*

PROOF For the sake of brevity, we perform the proof for continuous distributions $F(t)$ – discrete ones are analogous. Then there exists $p > 1$ such that $F(p) = q$ with $1/(1-q) < \bar{R}$. We can therefore express the value of the LHS of (18) in the following way:

$$\frac{\int_0^\infty e^{-\rho t} dt}{\int_0^\infty e^{-\rho t}(1 - F(t))dt} = \frac{\int_0^p e^{-\rho t} dt + \epsilon(\rho)}{\int_0^p e^{-\rho t}(1 - F(t))dt + \delta(\rho)}$$

$$< \frac{\int_0^p e^{-\rho t} dt + \epsilon(\rho)}{(1-q)\int_0^p e^{-\rho t} dt + \delta(\rho)}$$

$$\xrightarrow{\rho \to \infty} \frac{1}{1-q}$$

$$< \bar{R},$$

where $\epsilon(\rho)$ and $\delta(\rho)$ approach zero as $\rho \to \infty$. This, in combination with the monotone dependence of the required r on ρ (Proposition 4), competes the proof. *Q.E.D.*

Figure 8 plots the necessary and sufficient threshold of r as a function of various $\bar{R}$ and the discount factor ρ, indicating the $\overline{\rho}$-values for each $\bar{R}$. The r-values above the curves satisfy the condition (18).

The first implication of this section is that our above findings are robust to discounting, as full patience of the committed player is not necessary for his win. 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

---

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

Figure 8
Threshold of r as a Function of the Discount Factor ρ under Three $\bar{R}$'s
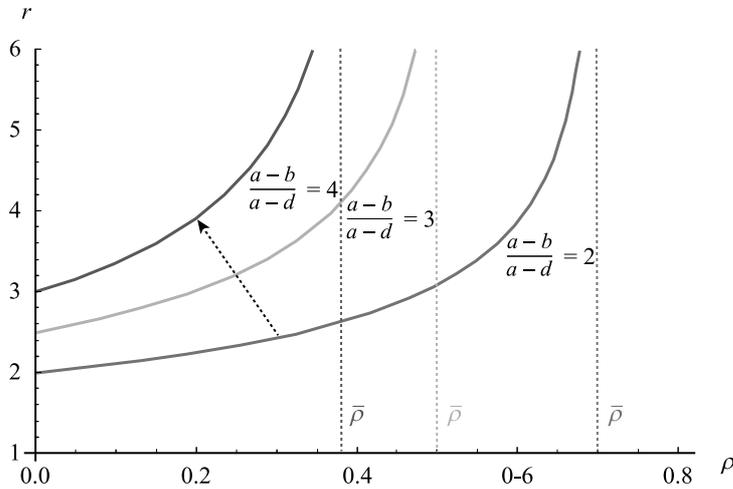
from assumptions (i)–(iv) that the full repeated game consists of a sequence of potentially different r-period dynamic games. Let us therefore introduce $F_n^m(t)$, where $m \in \mathbb{N}$, as an individual Revision function following the mth simultaneous move of the nth reviser.

Combining the findings of sections 7.2–7.3 with those of section 4 proves the following generalization of Proposition 1.

THEOREM *Consider the game described by either* (1)*,* (2)*, or* (3) *with any number of simultaneous moves and an arbitrary timing of Revisions summarized by $F_n^m(t)$. The committed player wins the game if and only if*

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

where the thresholds $\bar{R}$ are as reported in Proposition 1.

The only difference from (18) is the fact that if repetition is allowed, the above-derived necessary and sufficient condition has to hold for each and every part of the r-period game. If this is not the case, then there will be additional SPNEs, also featuring the H and/or h levels.

This result nests the special case in which the timing of the Revision is the same for an individual player across all r-period dynamic games, i.e., $F_n^m(t) = F_n(t)$, $\forall m$. In that case the r-period dynamic game is a *dynamic stage game*, and the whole game is a *repeated dynamic game*. Intuitively, if the dynamic stage game has a unique SPNE, then we know that the effective minimax values (the infima of the players' subgame-perfect equilibrium payoffs (Wen, 1994) are the payoffs that obtain from

that SPNE. If this unique SPNE is Pareto-efficient, 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.[29]

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.[30]

The players may then face a trade-off: a greater commitment may achieve their preferred 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 policy interaction, if there is no cost involved in long-term committing, then the central bank will choose an r level such that its commitment is (well) above the threshold. If, however, committing is sufficiently costly, then the central bank may not commit.

This is demonstrated in Libich and Stehlik (2011) 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 and the frequency with which agents update expectations, and also of the potential short-run costs due to stabilization inflexibility, and of the benefit of better-anchored expectations.

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 institutional 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 players' moves (both deterministic and stochastic), as well as an arbitrary combinations of probability distributions. For illustration we complement the results for a general setting by depicting several realistic scenarios – namely,

---

[29] The result is consistent with the body of literature showing that the Folk Theorem may not apply in some asynchronous games; see, e.g., Takahashi and Wen (2003).

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

uniform, normal, and binomial distributions, the last being in line with the timing in Calvo (1983).

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 free-riding 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 for governments to set excessive policies, and hence it improves the policy coordination and outcomes of both policies.

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 in that the global financial crisis of 2007–2009 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 has commonly answered in the negative; e.g., Bernanke and Gertler, 2001).

All settings, however, also show that if $\mathcal{M}$ commitment is insufficient, then $\mathcal{F}$ accesses may spill over and cause undesirable $\mathcal{M}$ outcomes with excessive inflation. In such a situation significant macroeconomic imbalances may build up over time with adverse consequences. In order to better understand how much $\mathcal{M}$ commitment is required to avoid such situations, we show the threshold degree to be an increasing function of: (i) the $\mathcal{F}$ 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 last 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, the UK, Canada, and Australia) than in those with a rather independent central bank (such as the U.S., Germany, and Switzerland).

An important insight that can be modelled formally in our framework is the free-riding problem in a monetary union. By running excessive $\mathcal{F}$ policy an individual member country imposes a negative externality on the rest of the union in the form of higher average interest rates. If this externality is not internalized, each member country has an extra incentive to be spend excessively. It can be argued that this reasoning can be applied to the current debt crisis of Greece and some other EMU members.

Our findings are related to several existing literatures, both game-theoretic and macroeconomic. First, our framework extends the work on asynchronous games by

Cho and Matsui (2005), Wen (2002), Lagunoff and Matsui (1997), and Maskin and Tirole (1988), and provides some insights into equilibrium selection.

Second, our $\mathcal{M}$ 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, i.e., how the short-term (interest-rate) policy instrument should be adjusted in response to shocks. In fact, our commitment does not even restrict *how* medium-term decisions about the policy stance should be made; it only puts a constraint on *how frequently* 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 over the business cycle, it does *not* require the central bank to become more conservative (strict) in achieving it, and does not compromise its flexibility in stabilizing the real economy in response to shocks (as in Rogoff, 1985).

It should be noted that explicit inflation targets in almost all industrial countries have indeed been specified in such a medium–long-run fashion; see, e.g., Mishkin and Schmidt-Hebbel (2001). As Svensson (2009, p. 4) 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." Obviously, 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.

Third, Schaumburg and Tambalotti (2007) also examine the gains from $\mathcal{M}$ commitment, which they call quasi commitment, as it lies somewhere between discretion and timeless perspective commitment. Similarly to our paper, the authors find that a stronger commitment leads to an improvement in $\mathcal{M}$ policy credibility and outcomes.[31] In addition to examining a very different type of $\mathcal{M}$ commitment from ours, their analysis 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.

Fourth, 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. In particular, explicit inflation targets have been shown to reduce the nominal interest rate (and hence inflation) and its volatility to a larger extent than is seen in non-IT countries (e.g., Siklos, 2004; Neumann and Von Hagen, 2002), without an increase in output volatility (e.g., Corbo, Landerretche, and Schmidt-Hebbel, 2001; Arestis, Caporale, and Cipollini, 2002; Fatas, Mihov, and Rose, 2004).

---

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

In terms of the disciplining effect of $\mathcal{M}$ commitment on $\mathcal{F}$ policy, the results of Franta, Libich, and Stehlik (2012) confirm the above findings. Using a novel empirical framework that combines time-varying-parameter VARs with sign restrictions, the paper shows two things about the countries that implemented a long-term commitment to an explicit inflation target (such as Australia, Canada, or the U.K.). First, they stopped accommodating debt-financed government spending shocks after adoption of the regime, and in fact started offsetting these shocks by raising interest rates. Second and subsequently, they improved their $\mathcal{F}$ outcomes since adoption. These findings are in contrast to comparable nontargeters (such as the United States, Japan, or Switzerland), in which the degree of accommodation of fiscal shocks has been increasing over time, and $\mathcal{F}$ outcomes have been unchanged or deteriorating.

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 a sustained improvement in the long-term stance of $\mathcal{F}$ policy. In doing so, the issue of causality versus 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.

Appendix: EMU Data

We use the data from Eurostat to create our variables S, θ, and w for each member country n reported in Table A1. The way these are created is described in the main

Table A1
EMU Data

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 (nonweighted)	0.067	−1.75	0.5
Average (weighted)		−2.4	0.62

text.[32] 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 carried out to nine decimal places.

References

Adam, K., and R. Billi (2008), "Monetary Conservatism and Fiscal Policy," *Journal of Monetary Economics*, 55(8), 1376–1388.

Alesina, A., and G. Tabellini (1987), "Rules and Discretion with Noncoordinated Monetary and Fiscal Policies," *Economic Inquiry*, 25(4), 619–630.

Arestis, P., G. M. Caporale, and A. Cipollini (2002), "Does Inflation Targeting Affect the Trade-Off between Output Gap and Inflation Variability?" *The Manchester School*, 70, 528–545.

Artis, M. J., and B. Winkler (1998), "The Stability Pact: Trading Off Flexibility for Credibility?" in: A. Hughes Hallett, M. Hutchison, and S. E. H. Jensen (eds.), *Fiscal Aspects of European Monetary Integration*, Cambridge University Press, Cambridge (MA), pp. 157–188.

Barnett, R. (2001), "Inflation, Taxes, and the Coordination of Monetary and Fiscal Policy by Use of a Game of Chicken," *Canadian Journal of Economics*, 34, 82–99.

Basov, S., J. Libich, and P. Stehlik (2009), "Stochastic Timing and Equilibrium Selection," Mimeo, La Trobe University, Melbourne.

Benhabib, J., and S. Eusepi (2005), "The Design of Monetary and Fiscal Policy: A Global Perspective," *Journal of Economic Theory*, 123(1), 40–73.

Bernanke, B. S. (2003), "Perspective on Inflation Targeting," Remarks at the Annual Washington Policy Conference of the National Association of Business Economists, Washington (DC), March 25.

— and M. Gertler (2001), "Should Central Banks Respond to Movements in Asset Prices?" *The American Economic Review*, 91(2), 253–257.

Bhaskar, V. (2002), "On Endogenously Staggered Prices," *The Review of Economic Studies*, 69, 97–116.

Bhattacharya, J., and J. H. Haslag (1999), "Monetary Policy Arithmetic: Some Recent Contributions," *Federal Reserve Bank of Dallas Economic and Financial Policy Review*, 1999 (Q III), 26–36.

Blake, A. P., and M. Weale (1998), "Costs of Separating Budgetary Policy from Control of Inflation: A Neglected Aspect of Central Bank Independence," *Oxford Economic Papers*, 50(3), 449–467.

Blanchard, O. J. (2008), "The State of Macro," NBER Working Paper 14259.

Branch, W. A., T. Davig, and B. McGough (2008), "Monetary–Fiscal Policy Interactions under Implementable Monetary Policy Rules," *Journal of Money, Credit and Banking*, 40(5), 1095–1102.

Brash, D. (2010), "Monetary and Fiscal Policy: How an Agreed Inflation Target Affects Fiscal Policy," Speech at the Australian Conference of Economists, September, 27, available at www.donbrash.com/monetary-and-fiscal-policy-how-an-agreed-inflation-target-affects-fiscal-policy.

Calvo, G. A. (1983), "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 12, 383–398.

Chadha, J. S., and C. Nolan (2007), "Optimal Simple Rules for the Conduct of Monetary and Fiscal Policy," *Journal of Macroeconomics*, 29(4), 665–689.

---

[32] 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*.

Cho, I., and A. Matsui (2005), "Time Consistency in Alternating Move Policy Games," *The Japanese Economic Review*, 56(3), 273–294.

Corbo, V., O. Landerretche, and K. Schmidt-Hebbel (2001), "Assessing Inflation Targeting after a Decade of World Experience," *International Journal of Finance and Economics*, 6, 343–368.

Debelle, G., and S. Fischer (1994), "How Independent Should a Central Bank Be?" in: J. C. Fuhrer (ed.), *Goals, Guidelines, and Constraints Facing Monetary Policymakers*, Conference Series No. 38, Federal Reserve Bank of Boston.

Dixit, A., and L. Lambertini (2001), "Monetary–Fiscal Policy Interactions and Commitment versus Discretion in a Monetary Union," *European Economic Review*, 45(4), 977–987.

— and — (2003), "Interactions of Commitment and Discretion in Monetary and Fiscal Policies," *The American Economic Review*, 93(5), 1522–1542.

Eggertsson, G. B., and M. Woodford (2006), "Optimal Monetary and Fiscal Policy in a Liquidity Trap," NBER International Seminar on Macroeconomics, 75–144.

Eusepi, S., and B. Preston (2008), "Stabilizing Expectations under Monetary and Fiscal Policy Coordination," NBER Working Paper 14391.

Fatas, A., I. Mihov, and A. K. Rose (2004), "Quantitative Goals for Monetary Policy," NBER Working Paper 10846.

Franta, M., J. Libich, and P. Stehlik (2012), "Tracking Monetary–Fiscal Interactions across Time and Space," Mimeo, La Trobe University, Melbourne.

Gali, J., and T. Monacelli (2005), "Optimal Fiscal Policy in a Monetary Union," Proceedings, Federal Reserve Bank of San Francisco.

Goodfriend, M. (2003), "Inflation Targeting in the United States?" NBER Working Paper 9981.

Hughes Hallett, A., and J. Libich (2007), "Fiscal–Monetary Interactions: The Effect of Fiscal Restraint and Public Monitoring on Central Bank Credibility," *Open Economies Review*, 18(5), 559–576.

—, —, and P. Stehlik (2009), "Rogoff Revisited: The Conservative Central Banker Proposition under Active Fiscal Policy," *Economics Letters*, 104(3), 140–143.

IMF (2009), "Fiscal Implications of the Global Economic and Financial Crisis," IMF Staff Position Note, SPN/09/13.

Jones, J. (2009), "Monetary and Fiscal Policy Interaction: The Consequences of Joining a Monetary Union," Mimeo, Furman University, Greenville (SC).

Kallenberg, O. (2002), *Foundations of Modern Probability Series: Probability and Its Applications*, 2nd edn., Springer, New York.

Kamada, Y., and M. Kandori (2009), "Revision Games," Harvard University, available at people.fas.harvard.edu/~ykamada/revision_games.pdf, accessed August 8, 2009.

Lagunoff, R., and A. Matsui (1997), "Asynchronous Choice in Repeated Coordination Games," *Econometrica*, 65, 1467–1477.

Leeper, E. M. (1991), "Equilibria under 'Active' and 'Passive' Monetary and Fiscal Policies," *Journal of Monetary Economics*, 27(1), 129–147.

— (2010), "Monetary Science, Fiscal Alchemy," Paper presented at Federal Reserve Bank of Kansas City's Jackson Hole Symposium, August 26–28.

Libich, J. (2008), "An Explicit Inflation Target as a Commitment Device," *Journal of Macroeconomics*, 30(1), 43–68.

—, A. Hughes Hallett, and P. Stehlik (2007), "Monetary and Fiscal Policy Interaction with Various Degrees and Types of Commitment," CEPR Discussion Paper 6586.

— and P. Stehlik (2011), "Endogenous Monetary Commitment," *Economics Letters*, 112, 103–106.

Maskin, E., and J. Tirole (1988), "A Theory of Dynamic Oligopoly, I: Overview and Quantity Competition with Large Fixed Costs," *Econometrica*, 56, 549–569.

Mishkin, F. S. (2004), "Why the Federal Reserve Should Adopt Inflation Targeting," *International Finance*, 7, 117–127.

— and K. Schmidt-Hebbel (2001), "One Decade of Inflation Targeting in the World: What Do we Know and What Do we Need to Know?" NBER Working Paper 8397.

Neumann, M. J. M., and J. von Hagen (2002), "Does Inflation Targeting Matter?" *Federal Reserve Bank of St. Louis Review*, 84, 127–148.

Neyman, A., and S. Sorin (2003), *Stochastic Games and Applications*, Kluwer Academic Press, Boston (MA).

Nordhaus, W. (1994), "Policy Games: Coordination and Independence in Monetary and Fiscal Policies," *Brookings Papers on Economic Activity*, 1994(2), 139–216.

Orphanides, A., and J. C. Williams (2005), "Imperfect Knowledge, Inflation Expectations, and Monetary Policy," *Journal of Economic Dynamics & Control*, 29(11), 1807–1808.

Persson, M., T. Persson, and L. E. O. Svensson (2006), "Time Consistency of Fiscal and Monetary Policy: A Solution," *Econometrica*, 74(1), 193–212.

Petit, M. L. (1989), "Fiscal and Monetary Policy Co-Ordination: A Differential Game Approach," *Journal of Applied Econometrics*, 4(2), 161–179.

Resende, C., and N. Rebei (2008), "The Welfare Implications of Fiscal Dominance," Bank of Canada Working Paper 2008-28.

Rogoff, K. (1985), "The Optimal Degree of Commitment to an Intermediate Monetary Target," *The Quarterly Journal of Economics*, 100, 1169–1189.

Sargent, T. J., and N. Wallace (1981), "Some Unpleasant Monetarist Arithmetic," *Federal Reserve Bank of Minneapolis Quarterly Review*, 5, 1–17.

Schaumburg, E., and A. Tambalotti (2007), "An Investigation of the Gains from Commitment in Monetary Policy," *Journal of Monetary Economics*, 54(2), 302–324.

Shapley, L. S. (1953), "Stochastic Games," Proceedings of the National Academy of Science, 39, 1095–1100.

Siklos, P. L. (2004), "Central Bank Behavior, the Institutional Framework, and Policy Regimes: Inflation versus Noninflation Targeting Countries," *Contemporary Economic Policy*, 22, 331–343.

Sims, C. (1988), "Identifying Policy Effects," in: R. Bryant (ed.), *Empirical Macroeconomics for Interdependent Economies,* The Brookings Institution, Washington (DC), pp. 305–321.

— (1994), "A Simple Model for Study of the Determination of the Price Level and the Interaction of Monetary and Fiscal Policy," *Economic Theory*, 4(3), 381–399.

Svensson, L. (2009), "Transparency under Flexible Inflation Targeting: Experiences and Challenges," CEPR Discussion Paper 7213.

Takahashi, S., and Q. Wen (2003), "On Asynchronously Repeated Games," *Economics Letters*, 79, 239–245.

Tobin, J. (1982), "Money and Finance in the Macroeconomic Process," *Journal of Money, Credit and Banking*, 14(2), 171–204.

Van Aarle, B., J. Engwerda, and J. Plasmans (2002), "Monetary and Fiscal Policy Interaction in the EMU: A Dynamic Game Approach," *Annals of Operations Research*, 109(1–4), 229–264.

Wen, Q. (1994), "The Folk Theorem for Repeated Games with Complete Information," *Econometrica*, 62, 949–954.

— (2002), "Repeated Games with Asynchronous Moves," Department of Economics Vanderbilt University Working Paper 0204.

Woodford, M. (1994), "Monetary Policy and Price Level Determinacy in a Cash-in-Advance Economy," Economic Theory, 4(3), 345–380.

— (1995), "Price Level Determinacy without Control of a Monetary Aggregate," *Carnegie Rochester Conference Series on Public Policy*, 43, 1–46.

— (1999), "Commentary: How Should Monetary Policy be Conducted in an Era of Price Stability?" in: Federal Reserve Bank of Kansas (eds.), *New Challenges for Monetary Policy: A Symposium Sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming*, Kansas City, August 26–28, pp. 277–316.

Wyplosz, C. (1991), "Monetary Union and Fiscal Policy Discipline," CEPR Discussion Paper 488.

Jan Libich
School of Economics and Finance
La Trobe University
Bundoora 3086
Australia
E-mail:
j.libich@latrobe.edu.au

Petr Stehlik
Faculty of Applied Sciences
University of West Bohemia
Univerzitni 22
306 14 Plzen
Czech Republic
E-mail:
pstehlik@kma.zcu.cz