Abstract: The timing of moves in conventional games is deterministic. To better capture the uncertainty of many real world situations, we postulate a stochastic timing framework. The players get a revision opportunity at a pre-specified time (common to them) with some known probability (different across them). The probabilistic revisions resemble the Calvo (1983) timing widely used in macroeconomics, and by nesting the standard simultaneous move game and Stackelberg leadership they can serve as a “dynamic commitment” device. The analysis shows how the revision time and probabilities affect the outcomes in games with multiple and/or inefficient equilibria. Unsurprisingly, we show in the Battle of the sexes that commitment – low revision probability relative to the opponent – improves the player’s chances to uniquely achieve his preferred outcome (i.e. to dominate). What may, however, seem surprising is that the less committed (higher revision probability) player may dominate the game under some circumstances (for which we derive the necessary and sufficient conditions). This is in contrast to the intuition of Stackelberg leadership where the more committed player (leader) always does so. The paper then applies the framework to the strategic interaction between monetary and fiscal policies in the aftermath of the Global financial crisis. It is modelled as the Game of chicken in which a double-dip recession and deflation can occur when both policies postpone stimulatory measures – attempting to induce the other policy to carry them out. In order to link our theoretic results to the real world, we develop new indices of monetary and fiscal policy leadership (pre-commitment) and quantify them using institutional characteristics of high-income countries. This exercise shows that the danger of the undesirable deflationary scenario caused by a monetary–fiscal policy deadlock may be high in some major economies.

Keywords: timing of moves, revisions, Stackelberg leadership, Battle of the sexes, monetary–fiscal interactions

JEL Classification: C71, C73, E63
1 Introduction

Most real world interactions are strategic in nature and can thus be modelled as games. While many game theoretic aspects have been considered in the literature, the timing of moves is commonly deterministic. To allow for the players’ uncertainty we propose a simple quasi-stochastic timing framework. It extends the simultaneous moves and Stackelberg leadership settings by allowing for probabilistic revisions of moves.

Specifically, following an initial simultaneous move at time $t = 0$, each player $i$ can revise his action at common time $\tau \geq 0$ with some individual probability, $1 - \theta_i$. The revision time and probabilities are known to both players. This timing, summarized in Figure 1, is inspired by the Calvo (1983) timing scheme used frequently in macroeconomics to describe the behaviour of price setters and other economic agents.\(^1\) It is assumed that at time $\tau$ of their revision the players can observe the opponent’s initial play, but they cannot observe whether or not the opponent is also given a revision opportunity. We consider flow payoffs and derive subgame perfect equilibria.

Figure 1: The timing of moves featuring Calvo revisions, whereby the dashed line expresses their probabilistic nature

What is our motivation for postulating such timing framework? While the standard simultaneously repeated game is a sensible benchmark for analysis, its tractability may come at a cost of missing important features of some real

\(^1\) In Calvo’s framework, each agent faces an exogenously given probability, independent across periods, that they will be able to revise their existing action. While the context of our timing differs from Calvo’s, the time of the probabilistic revision is pre-determined, which implies a stochastic duration of actions in both frameworks.
world situations. This seems most apparent in games with multiple and/or inefficient equilibria, in which the literature has long tried to find ways to alleviate inefficiency and equilibrium selection problems. In addition to equilibrium refinements, many authors proposed a slight change in the rules of the game that may be realistic in certain contexts, e.g. Ambruš and Ishii (2012), Shaffer (2004), or Farrell (1987).

This trend included altering the timing of moves. However, the existing literature on asynchronous games has not fully explored how infrequent or probabilistic timing, which can act as a player’s commitment, may ensure uniqueness and efficiency. For example, in the alternating move game by Maskin and Tirole (1988) and Lagunoff and Matsui (1997), the commitment periods are the same across the players, in Wen (2002), they are multiples of each other. In Takahashi and Wen (2003) and Yoon (2001), the timing of moves lacks a consistent time pattern, so commitment effects cannot be fully studied. Based on this, Cho and Matsui (2005) argue that: “[a]lthough the alternating move games capture the essence of asynchronous decision making, we need to investigate a more general form of such processes...”.

Our framework offers a step in this direction. In doing so, it nests the simultaneous move game and the Stackelberg leadership games while departing as little as possible from these standard setups. This is in the sense of keeping the revision time $\tau$ deterministic and common across the players. The novel heterogeneity in the game regards the players’ revision probabilities. The fact that the revisions may not occur with certainty attempts to incorporate uncertainty present in many real world situations.2

In a sense, the framework offers a dynamic concept of commitment, which extends the static commitment of Stackelberg leadership. It is apparent that

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2 Specifically, the random revision element may express technological factors, e.g. the probability that firms will be able to convert their R&D investment into a new invention allowing them more frequent production rounds. Alternatively, the revision probability may express physical or environmental constraints, e.g. different weather conditions in various parts of the country affecting the farmers’ relative ability to supply to the market. Macroeconomic factors can also be captured by the revision probabilities, for example, a recession in one country reduces the probability (relative to a competitor in a well-performing country) that local firms will be able to launch a new marketing campaign. Stochastic revisions may also represent political and legal developments that can never be predicted with certainty, but affect the ability of economic agents to make decisions at will. Section 5 will compare the analysis with alternative timing frameworks we have examined. One is a fully-stochastic setup from Basov, Libich, and Stehlík (2013) in which the revision of one player can arrive at any time $\tau \in [0, 1]$ (but the other player cannot revise or can only revise prior to that). Another is a fully-deterministic setup of Libich and Stehlík (2010) in which each player $i$ moves with a constant frequency – every $\tau \in \mathbb{N}$ periods.
suitable applications of the framework include coordination games such as the Battle of the sexes, Pure coordination, and Stag hunt, anti-coordination games such as the Game of chicken, and the Time-inconsistency game, in all of which commitment through Stackelberg leadership alters the set of equilibria compared to the simultaneous move game.

Our main example demonstrating the framework is the Battle of the sexes game. This is because it contains both a coordination problem (how to avoid the inefficient mixed Nash equilibrium) and a conflict (which player’s preferred pure Nash equilibrium will be selected). As neither conventional nor evolutionary game theory provides a tool to select between the game’s two pure strategy Nash equilibria, our aim is to offer a possible mechanism.

1.1 Theoretic results

Our analysis examines how equilibrium outcomes depend on the revision time and probabilities, as well as on the players’ normal-form payoffs. In particular, in Theorem 1, we derive the necessary and sufficient conditions under which each player $i$ ‘dominates’ the game, and uniquely achieves his preferred payoff throughout the whole game – for all $t \in [0,1]$. This occurs if and only if: (i) his revision probability is sufficiently low, $\theta_i > \theta_j$ (i.e. he is sufficiently strongly committed) and (ii) the opponent $j$’s revision probability is sufficiently high, $\theta_j < \theta_j(\tau_i)$. For the latter, it is necessary that the revision time occurs sufficiently early in the game, $\tau < \tau_i$.

The analysis shows how the players’ normal-form costs of mis-coordination and conflict, as well as the victory gain from securing their preferred outcome (relative to coordinating on the opponent’s preferred outcome), affect the size of the two dominance regions. For example, a higher $\frac{\text{victory gain}}{\text{conflict cost}}$ ratio of player $i$ decreases the thresholds $\theta_j(\tau_i)$ and $\tau_i$ and, thus, makes player $i$’s dominance region larger.

While these results are intuitive, what may seem surprising is that there exist circumstances under which the less committed player – the one with a higher revision probability – dominates the game. This contrasts the Stackelberg leadership case, in which the more committed player always dominates. Intuitively, each player’s $\frac{\text{victory gain}}{\text{conflict cost}}$ ratio can partially substitute the player’s commitment in getting an upper hand in the Battle of the sexes. Therefore, if the less committed player has a lot to gain and little to lose from the conflict (relative to the opponent), he may be willing to go ahead with it. Such credible threat then makes the more committed opponent coordinate from the start.
1.2 Application

The paper then considers a real world example. It postulates strategic monetary–fiscal policy interactions in the post-Global financial crisis era (the reader can think of the 2010–2013 period) as the Game of chicken between the central bank and the government. An economy hit by an adverse shock is assumed to require a stimulus from either policy. But there is a conflict between the policies. Both would prefer the other policy to stimulate the economy – not to jeopardize the pursuit of its remaining objectives and post-recovery options. Furthermore, there is also a coordination problem for two reasons. First, a joint policy response may be excessive, and overheat the economy creating future imbalances. Second, randomizing by playing the mixed strategy, Nash equilibrium leads to inferior payoffs for both policymakers.

The values of $\theta_M$ and $\theta_F$ can thus be interpreted as the degrees of monetary and fiscal leadership, which are influenced by the political realities and institutional design of the two policies. The analysis shows that if the values of $\theta_M$ and $\theta_F$ are too close to each other then neither policy dominates – neither has sufficient leverage over the other policy. We may, therefore, observe a psychological tug-of-war (a waiting game) whereby both policies postpone stimulatory measures in attempt to induce the other policy to carry them out. Such policy conflict leads to an avoidable recession and possibly deflation – with dire consequences for the wellbeing of individuals.

The paper concludes by mapping high-income countries to the equilibrium regions derived in the theoretic analysis. To do so, we develop new indices of monetary and fiscal policy leadership based on 12 related empirical measures in the existing literature. This exercise attempts to roughly predict the countries’ chances of the undesirable contractionary/deflationary scenario caused by a monetary–fiscal policy deadlock. The data seem to suggest that in a number of countries (including some in the Eurozone), the probability may be non-trivial.

2 Timing of moves

The game starts with a simultaneous move of both players $M$ (male) and $F$ (female) at time $t = 0$. Then, at a pre-determined time $\tau \in [0, 1]$, the players may

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3 For example, the central bank may prefer to avoid additional rounds of quantitative easing for fear of a difficult “exit strategy”. Similarly, the government may be reluctant to engage in additional fiscal packages to avoid debt problems.
or may not get a revision opportunity as in Calvo (1983). Specifically, with exogenous probabilities $\theta_M \in [0,1]$ and $\theta_F \in [0,1]$ – known to both players – they are unable to revise at time $\tau$. The payoffs accruing continuously over time and the game ends at time $t = 1$.

We assume that at time $\tau$ the players observe the opponent’s initial action, but they cannot observe the move of nature (the “Calvo fairy”) regarding the opponent’s revision opportunity. We will denote the initial simultaneous moves with subscript 1 ($M_1$ and $F_1$), and the possible revisions with subscript 2 ($M_2$ and $F_2$), see Figure 1 for a graphical depiction. We will denote the best response as $b(.)$. For example, $F_2^S = b(M_1^S)$ expresses that in her revision $S$ is $F$’s static best response to $M$’s initial $S$ move. An asterisk will denote optimal play, i.e. $F_2^* = b(M_1^*)$ expresses that $F$’s optimal revision is the static best response to $M$’s initial move.

We will demonstrate the framework using the following version of the Battle of the sexes game

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where

$$\min\{d, w\} > 1.$$  

Nevertheless, for the reader to be able to better follow the effects of the off-diagonal payoffs in the proofs, we will provide each initial incentive compatibility condition for the following general Battle of the sexes game where

4 Let us note five related issues. First, it is apparent that our setup nests the standard simultaneous move game and the Stackelberg leadership game as special cases. Specifically, the former is represented, for all $\tau$, by $\theta_i = \theta_j = 1$, whereas the latter by $\tau = 0, \theta_i = 0, \theta_j = 1$. Second, we consider the case of a common $\tau$ to keep it closer to the standard setting and to only focus on one type of heterogeneity (regarding $\theta$s). It is, however, easy to show that the intuition of the $\tau_M \neq \tau_F$ case is analogous. Third, the timing can be endogenized. Libich and Stehlik (2011) do so in a different timing framework, for an alternative avenue, see Leshem and Tabbach (2012). Fourth, we do not examine a repeated version of this game, since the effects of repetition in improving coordination are widely known. This is both under standard and asynchronous timing, see Mailath and Samuelson (2006) or Wen (2002). Fifth and similarly, the players’ discounting has the standard effects and is, therefore, disregarded for parsimony.
In order to show the wide applicability of the framework to many classes of games, we will below examine another coordination game, namely the Stag hunt, and in the macroeconomic application section also an anti-coordination game, namely the Game of chicken.

Before we proceed, let us provide further motivation for the use of stochastic revisions in these classes of games (over and above the examples in the Introduction). In justifying the framework one can start from the standard rationale for (simultaneously) repeated games, in which $\theta_M = \theta_F = 0$. And then think of the departure in terms of higher $\theta_i$’s as expressing uncertainty about possible constraints on the part of the players. For example in the conventional narrative of the Battle of the sexes, the female, upon arriving at the opera house and not finding her partner there, may be able to catch a taxi or public transport to get to the soccer stadium for the $(1 - \tau)$ part of the game. Her revision probability $1 - \theta_F$ thus embodies uncertainty regarding transport availability between the venues.

## 3 Results

### 3.1 Battle of the sexes

Being an extension of the simultaneous move and the Stackelberg leadership games, it is natural that we obtain the three equilibrium regions occurring in these standard setups. The results are graphically summarized in Figure 2 depicting the $\theta_M \times \theta_F \times \tau$ space and formalized as follows:

**Theorem 1.** Consider the Battle of the sexes game in eqs [1]–[4] with Calvo revision probabilities $1 - \theta_i$ and $1 - \theta_j$ at time $\tau$. The game features:

(i) a multiple equilibria region; and

(ii) up to two dominance regions in each of which the unique equilibrium payoff coincides with the respective Stackelberg one. Specifically, player $i$’s
dominance region obtains if and only if \( \theta_i > \theta_j \) and \( \theta_j < \theta_i(\tau) \), whereby a necessary condition for the latter is \( \tau < \tau_i \).

**Proof.** The nature of the result is straightforward. In the standard Stackelberg cases in which \(|\theta_i - \theta_j| = 1\) and \(\tau = 0\), there are unique equilibria by dominance. Then, from the continuity of \(\theta_M, \theta_F,\) and \(\tau\), it follows that these equilibria apply to nearby parameters as well, and upper-hemicontinuity implies they are still unique.

We will throughout the proof focus on the case \(\theta_M > \theta_F\) and derive conditions for the more committed (lower revision probability) player M’s “victory outcome” \((M_1^S M_2^S F_1^S F_2^S)\) to uniquely obtain on the equilibrium path. The conditions for the opposite case \(\theta_M < \theta_F\) are symmetric and also reported below. Let us start with a roadmap of the proof. In the first step, it will explain the intuition and the mechanics of the proof. In the second step, it will derive sufficient conditions for M’s dominance region by backwards induction. In the third step, it will show that the derived conditions are in fact necessary and sufficient.

**Step 1, the intuition.** To uniquely ensure M’s preferred outcome on the equilibrium path, one has to derive conditions that eliminate the remaining Nash equilibria of the simultaneous game – those featuring the O action. For this, it is required that M finds it optimal to play S – in both its initial move and in its
revision – even if the opponent plays $F^0_1$. That is, neither $M^0_1$ nor $M^0_2$ is the static best response to $F^0_1$, formally $\{M^0_1, M^0_2\} \neq b(F^0_1)$. How will this be ensured? Intuitively, for $M$ to be willing to undergo a costly mis-coordination with $F$, he has to be sufficiently compensated (in expected value) by $F$’s subsequent switching from $F^0_1$ to $F^0_2$. This implies that three inter-related conditions will be necessary and sufficient for a player’s dominance region.

Specifically, solving backwards Condition A will require that the less committed (higher revision probability) player $F$ chooses in her revision to respond to $M$’s initial move rather than to his anticipated revision. Formally, $F^0_2 = b(M_1)$. This condition ensures that the more committed player can influence the opponent’s revision through his first move – induce her to cooperate from time $t$. Assuming Condition A holds, Condition B will then ensure that if $M$ opens with $S$, he finds it optimal to stick to $S$ in his revision even if he observes his opponent’s initial move to have been $O$. Formally, $M^0_2 \neq b(F^0_1)$. Condition C will then require that $M$ will indeed open with $S$. Intuitively, he must find it optimal to open with $S$ even if he knows with certainty that the opponent starts with $O$ and a low off-diagonal payoff will incur. Formally, $M^0_1 \neq b(F^0_1)$. If that is the case then the $F$ will not in fact start with $O$, she is induced to coordinate with $M$ from the beginning of the game.

Conditions A and C are clearly necessary – without them the more committed player will never have enough leverage over the opponent to make her cooperate, similar to the simultaneous move game. Condition B will be shown to also be necessary by considering the alternative in which $M$ follows $F$’s initial move, i.e. switches to $M^0_2$ if he observes $F^0_1$. Nevertheless, Condition B happens to be weaker than Condition C for all general parameter values in eq. [4].

In summary, if Conditions A and C hold then the less committed player $F$ knows she has no way to sway $M$ into cooperating on her preferred $O$ action. Her best option is then to cooperate with $M$ on his preferred $S$ action from the start to avoid off-diagonal payoffs. Therefore, both players open with the $S$ action and never revise.

**Step 2, the conditions.** Condition A: The higher revision probability player $F$ chooses in her revision to respond to $M$’s initial move rather than to his anticipated revision, $F^0_2 = b(M_1)$, if and only if $M$’s revision probability is sufficiently low. In particular, for $F^0_2$ to be the unique best response to $M^0_1$ it must hold that

$$\theta_M z + (1 - \theta_M) x > \theta_M y + (1 - \theta_M) w,$$

where the left-hand side reports $F$’s minimum payoff from playing $F^0_2$ in response to $M^0_1$, and the right-hand side reports $F$’s maximum payoff from playing $F^0_2$ in
response to $M_2^S$. Analogously, for $F_2^O$ to be the unique best response to $M_1^O$, it must hold that

$$\theta_M w + (1 - \theta_M) y > \theta_M x + (1 - \theta_M) z.$$  \[6\]

Note that since $w - x \geq z - y$ the condition in eq. [5] is always at least as strong as the condition in eq. [6]. Using the normalized payoffs in eqs [1] and [2] and rearranging eq. [5] yields the following threshold

$$\theta_M > \theta_M = \frac{w}{1+w}.$$  \[7\]

The condition in eq. [7] states that $M$’s revision must be sufficiently unlikely, or, put differently, $w$ must be sufficiently low. If it is satisfied, then $F_2$ is always the static best response to $M_1$ rather than $M_2$. Then, there are eight possible outcomes: (i) $\left(M_1^SM_2^F F_1^S F_2^F\right)$; (ii) $\left(M_1^O M_2^S F_1^F F_2^O\right)$; (iii) $\left(M_1^O M_2^O F_1^F F_2^O\right)$; (iv) $\left(M_1^O M_2^O F_1^O F_2^S\right)$; (v) $\left(M_1^S M_2^O F_1^O F_2^S\right)$; (vi) $\left(M_1^O M_2^S F_1^O F_2^O\right)$; (vii) $\left(M_1^O M_2^S F_1^S F_2^O\right)$; and (viii) $\left(M_1^O M_2^O F_1^O F_2^O\right)$.

Condition B: Assuming condition A holds and $M_2^S$ will be played, under what circumstances is $M$ willing to stick to the $S$ action even if he can observe that the opponent played $F_2^O$? This is not automatically guaranteed as $M$ knows that under $\theta_F > 0$ there is some probability $F$ will be unable to revise, so the initial mis-coordination may continue throughout the whole game. For $M_2^O \neq b(F_1^O)$, it is required that $M$’s expected continuation (i.e. post $r$) payoff from the “tug-of-war outcome” $\left(M_1^S M_2^S F_1^O F_2^S\right)$ must be strictly higher than his expected continuation payoff from the “mis-coordination outcome” $\left(M_1^O M_2^O F_1^O F_2^S\right)$. These are obviously averages weighted by $\theta_M$ and $\theta_F$:

$$\theta_FC + (1 - \theta_F)d > \theta_M[\theta_FC + (1 - \theta_F)d] + (1 - \theta_M)[\theta_Fa + (1 - \theta_F)b].$$  \[8\]


$$\theta_F < \frac{d}{1+d}.$$  \[9\]

Intuitively, for $M$ to stand firm and not switch from $S$ to $O$, $F$’s revision probability has to be sufficiently high. That is, $d$ must be above a certain threshold.

Condition C: Assuming eqs [7] and [9] hold, move backwards to $M$’s initial move. To ensure the $M$ dominance region, it must hold that $M$’s payoff from the “tug-of-war outcome” $\left(M_1^S M_2^S F_1^O F_2^S\right)$ is strictly higher than his payoff from the “surrendering outcome” $\left(M_1^O M_2^O F_1^O F_2^O\right)$. In such case, we have $M_1^O \neq b(F_1^O)$, i.e. it is incentive compatible for $M$ to open with $M_1^S$ even if he knows with certainty that an avoidable conflict would initially occur due to the opponent playing $F_1^O$. The incentive comes from the fact that playing $M_1^S$ induces the opponent’s switching to
$F^S_2$ – if given a revision opportunity. As the probability of $F$’s revision is sufficiently high due to eq. [9], the implied victory gain will more than compensate $M$ for the costly pre-revision conflict. The following condition ensures that

$$\tau c + (1 - \tau) [\theta_F c + (1 - \theta_F) d] > a.$$  

[10]


$$\theta_F < \bar{\theta}_F = 1 - \frac{1}{(1 - \tau)d},$$  

[11]

which can be easily shown to be a stronger condition than eq. [9] for all general parameter values in eq. [4]. For the threshold $\bar{\theta}_F$ to exist in the plausible range of $[0, 1]$, it is necessary that $\tau$ be sufficiently low, namely

$$\tau < \tau_M = 1 - \frac{1}{d}.$$  

[12]

In summary, we have shown that for the $M$ dominance region it is sufficient that eqs [7], [11], and [12] be satisfied. By symmetry, the $F$ dominance region obtains if the following three conditions hold:

$$\theta_F > \bar{\theta}_F = \frac{d}{1 + d},$$  

[13]

$$\theta_M < \bar{\theta}_M = 1 - \frac{1}{(1 - \tau)w},$$  

[14]

$$\tau < \tau_F = 1 - \frac{1}{w}.$$  

[15]

**Step 3, necessity vs sufficiency.** The above discussion showed that there exists conditions ensuring the lower revision probability player’s dominance region. Let us now demonstrate that the derived conditions are also necessary, not just sufficient. We will do so by asking whether an alternative scenario may achieve the dominance region, i.e. eliminate the Nash equilibria featuring the $O$ action. Consider an “Imitating scenario”, which differs from the above scenario in that Condition B in eq. [9] is not satisfied. Player $M$ would not stick to his initial move $S$, but in his revision he would follow $F$’s initial play, $M^*_2 = b(F_1)$. Assuming that Condition A in eq. [7] holds, this would happen if the inequality in eq. [9] is reversed:

$$d < \frac{\theta_F}{1 - \theta_F}.$$  

[16]
In such case, we could in principle still obtain a dominance region by making two changes. First, we would have to include an additional condition, \( F_1^O \neq b(M_1^S) \). Such condition would ensure \( F \)'s greater willingness to cooperate, and thus compensate the lack of \( M \)'s resolve to fight. Second, to reflect the imitating behaviour of player \( M \) in his revision, Condition C above would be modified into

\[
\tau_c + (1 - \tau)[\theta_M \theta_F c + \theta_M (1 - \theta_F) d + (1 - \theta_M) \theta_F a + (1 - \theta_M)(1 - \theta_F)b] > a. \tag{17}
\]


\[
d > \frac{1 - \tau}{\theta_M(1 - \theta_F)}. \tag{18}
\]

It is straightforward to check that the conditions in eqs [16] and [18] can never hold jointly; it follows from \( d > 1 \) and \( \frac{1}{1 - \tau} > 1 \) that there are no \( d \) values satisfying both inequalities. Hence, the Imitating scenario cannot deliver the dominance region – Appendix A shows this for the general payoffs in eq. [4]. Noting that there is no other scenario capable of achieving the dominance region, i.e. eliminating the \( O \) action from the set of equilibrium outcomes, completes the proof.

Intuitively, for a dominance region to obtain the players’ revision probabilities must be sufficiently different from each other – as apparent in Figure 2. The fact that a stronger pre-commitment (higher \( \theta_i \)) increases player \( i \)'s chances of reaching its dominance region is not surprising. Similarly the opponent’s stronger commitment reduces these chances. In each case, it is because the revision probabilities change the expected payoff from conflict and/or mis-coordination – even for fixed normal-form conflict/mis-coordination costs. As a consequence, the players’ willingness to undergo a conflict evolves with both \( \theta_M \) and \( \theta_F \), as well as with \( \tau \).

Theorem 1 further implies that as \( \tau \) increases the dominance regions are gradually reduced and, once the \( \bar{r}_i \) thresholds are reached, eliminated altogether. Let us also note that the \( d \) payoff increases the \( \bar{\theta}_F \) and \( \theta_F \) thresholds in eqs [11] and [13], i.e. it increases the size of the \( M \) dominance region and decreases the size of the \( F \) dominance region. We can, thus, conclude that a higher \( d \) improves \( M \)'s chances to achieve his preferred outcome. This is analogously true for the payoff \( w \) and its effect on player \( F \). In order to obtain additional insights, the following proposition reports the effects of the payoffs on the dominance regions for the general game.

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5 The respective condition is \( w < \frac{\theta_M(1 - \theta_F)}{(1 - \theta_M)\theta_F} \).
Proposition 1. Consider the Battle of the sexes game in eqs [3] and [4] with Calvo revision probabilities $1 - \theta_i$ and $1 - \theta_j$ at time $\tau$. The size of each player’s dominance region is:

(i) increasing in his victory gain ($d - a$ for $M$ and $w - z$ for $F$), as well as in the opponent’s coordination gain ($z - y$ and $a - c$, respectively); and

(ii) decreasing in his conflict cost ($d - c$ for $M$ and $w - y$ for $F$), as well as in the opponent’s mis-coordination cost ($w - x$ and $d - b$ respectively).

Proof. Building on the proof of Theorem 1, the conditions in eqs [5] and [10] for the $M$ dominance region can be rearranged into

$$\theta_M > \bar{\theta}_M = \frac{w - x}{z - y} + \frac{w - x}{w - x},$$

where $F$’s coordination gain, $F$’s mis-coordination cost

$$\theta_F < \bar{\theta}_F = 1 - \frac{(d - c) - (d - a)}{(1 - \tau)(d - c)}.$$  \[19\]

By symmetry, the $F$ dominance region obtains iff

$$\theta_F > \bar{\theta}_F = \frac{d - b}{a - c} + \frac{d - b}{d - b},$$

where $M$’s coordination gain, $M$’s mis-coordination cost

$$\theta_M < \bar{\theta}_M = 1 - \frac{(w - y) - (w - z)}{(1 - \tau)(w - y)}.$$  \[22\]

This, by inspection, completes the proof. \(\Box\)

The effects of changes in the costs and gains are graphically depicted in Figure 3.6 While the result is intuitive, what may seems surprising is that a higher conflict cost of either player increases (rather than decreases) the

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6 It is apparent that the players’ discounting would have the conventional effects. A greater amount of impatience would make it harder for the more committed player to achieve his dominance region, as it would decrease the present value of his victory gain/conflict cost ratio.
unconditional probability of conflict in some sense. This is because it shrinks or fully eliminates the dominance regions in which conflict never occurs, and enlarges the multiplicity region in which conflict and mis-coordination may occur.\footnote{Fully examining the multiplicity region is beyond the scope of the paper. Let us just note that the “probability” of coordinating on one of the efficient outcomes may differ within this region. Consider for example the case of $\theta_M > \theta_F$. If $\theta_F \in (\theta_F, \theta_M)$, then $M$ knows that if he initially plays $S$ he will surely achieve his preferred coordinated regime $(S, S)$ after time $\tau$ provided $F$ gets a revision opportunity. If instead $\theta_F > \theta_M$, this is no longer the case, and hence $(S, O)$ may occur throughout the whole game even if $F$ does get a revision opportunity.}

Perhaps the most interesting aspect of the analysis is the finding that one of the dominance regions may extend across the $45^\circ$ line of the $\theta_M \times \theta_F$ space. For player $i$’s dominance region to do so it must hold that $\theta_i < \theta_j(\tau)$. The fact that the less committed player may have an upper hand in the game is in contrast to the intuition of Stackelberg leadership, in which the committed player (leader) always ensures his preferred outcome in the Battle of the sexes.

Figure 3: The equilibrium $\theta_M \times \theta_F$ space of the Battle of the sexes under Calvo revisions for some $\tau < \min\{\tau_M, \tau_F\}$. The arrows indicate the direction of changes due to increases in the players’ mis-coordination/conflict costs and coordination/victory gains.
Proposition 2. If there exists a sufficient asymmetry in the payoffs across the players then the less committed (higher revision probability) player may dominate the game. Specifically, if and only if:

$$w > w = \frac{1 + d}{1 - \tau}.$$  \[23\]

then there exist values $\theta_F < \theta_M$ that yield the F dominance region, whereas if and only if:

$$d > d = \frac{1 + w}{1 - \tau}.$$  \[24\]

then there exist values $\theta_M < \theta_F$ that yield the M dominance region.

Proof. Consider the case $\theta_F < \theta_M$. For the F dominance region to cross the 45° line of the $\theta_M \times \theta_F$ space it is required that $\theta_F < \theta_M(\tau)$. Using eqs [13] and [14] and rearranging yields eq. [23]. The opposite case in eq. [24] follows by symmetry. □

The threshold $w$ is increasing in $\tau$ and $d$. Intuitively, F's payoff $w$ from achieving her preferred outcome must be sufficiently high to compensate her for a longer conflict implied by a later revision time $\tau$. It must also offset higher $d$, which reduces M's willingness to coordinate with F. 8 This has implications for games under incomplete information in that a player may try to manipulate his opponent's beliefs about the exact values of his payoffs in order to improve the likelihood of his preferred outcome.

Example 1. Consider the following parameter values: $w = 5$, $d = 2$ and $\tau = \frac{1}{4}$. Such values yield the thresholds as follows: $\theta_M = \frac{5}{6}$, $\theta_F = \frac{11}{15}$, $\theta_F = \frac{2}{3}$ and $\theta_M = \frac{1}{2}$. Hence the game ends up in the F dominance region even if M is more committed, for instance if $\theta_M = 0.73 > 0.67 = \theta_F$.

8 In the general game, $w$ is further increasing in $z$ and $c$, whereas it is decreasing in $y, a, \text{ and } b$. This is because (i) higher $z$ and lower $y$ lead to a more costly conflict for F, and (ii) higher $c$ reduces M's benefit from coordination with the opponent (payoffs $a$ and $b$ increase this benefit and, therefore, have the opposite effect on $w$).
3.2 Stag hunt

The reader may ask whether our results are applicable to other classes of games. Let us show that the answer is affirmative using a different type of coordination game, namely the Stag hunt. In its general form, it can be presented as follows:

\[
\begin{array}{c|cc}
 & \text{Hare} & \text{Stag} \\
\hline
\text{Hare} & a, w & b, x \\
\text{Stag} & c, y & d, z
\end{array}
\]

where

\[d > a = b > c \quad \text{and} \quad z > w = y > x.\]

The normalized game is as follows:

\[
\begin{array}{c|cc}
 & \text{Hare} & \text{Stag} \\
\hline
\text{Hare} & 1, 1 & 1, 0 \\
\text{Stag} & 0, 1 & d, z
\end{array}
\]

where

\[\min\{d, z\} > 1.\]

The game has two pure strategy Nash equilibria: the payoff dominant (Stag, Stag) and the risk dominant (Hare, Hare). Our framework allows to select between them under some parameter values.

**Proposition 3.** Consider the Stag hunt game in eqs [25]–[28] with Calvo revision probabilities \(1 - \theta_i\) and \(1 - \theta_j\) at time \(t\). The necessary and sufficient conditions for the payoff dominant outcome to be the unique equilibrium are identical to those that achieve a dominance region of either player in the Battle of the sexes in Theorem 1 and Proposition 1. Specifically, this happens iff either eqs [19] and [20] or eqs [21] and [22] hold. In contrast, there exist no circumstances under which the risk dominant outcome is the unique equilibrium. \(\square\)

**Proof.** See Appendix B.
4 Application: strategic monetary–fiscal policy interactions

The Global financial crisis and the subsequent Great Recession showed that the borderline between monetary and fiscal policy is less obvious than most economists and policymakers had believed. In order to offer some insights, Libich, Nguyen, and Stehlík (2012) model strategic interactions between these policies in the aftermath of an adverse shock: the reader can think of the 2010–2013 period in the United States and the Eurozone.

4.1 The game

Let us depict here the scenario featuring the short-term perspective of stabilizing the shock. The post-shock economy is characterized by two main assumptions. First, economic conditions require a stimulus of either monetary or fiscal policy to avoid a (double-dip) recession and possibly even liquidity trap and deflation. Second, a joint policy response may, however, be excessive and cause future costly imbalances. This situation can be summarized as follows:

<table>
<thead>
<tr>
<th>Fiscal policy (government)</th>
<th>Monetary policy (central bank)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-stimulus</td>
<td>Stimulus</td>
</tr>
<tr>
<td></td>
<td>Stimulus</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No-stimulus</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9 The companion scenario of the incomplete information game in Libich, Nguyen, and Stehlík (2012) features the long-term sustainability perspective and the threat of an unpleasant monetarist arithmetic. We do not cover it here, as it has been studied extensively since Sargent and Wallace (1981).

10 This incorporates the experience of the post-Nasdaq bubble, whereby it is commonly accepted that “The Fed’s decision to hold interest rates too low for too long from 2002 to 2004 exacerbated the formation of the housing bubble”, see Taylor and Ryan (2010). Rajan (2011) and many others voice similar concerns about the policy actions during the Great Recession.
where the payoffs satisfy the constraints in eqs [1]–[4].\textsuperscript{11} To give a specific example, consider the normalized payoffs in eqs [1] and [2] with $d = w = 2$:

<table>
<thead>
<tr>
<th>Monetary policy (central bank)</th>
<th>Fiscal policy (government)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No-stimulus</td>
</tr>
<tr>
<td>Stimulus</td>
<td>1.2</td>
</tr>
<tr>
<td>No-stimulus</td>
<td>0.0</td>
</tr>
</tbody>
</table>

The central bank and the government are engaged in a Game of chicken. Intuitively, the policies are substitutes in dealing with the economic weakness, and each can close the contractionary gap by an appropriate stimulus. Nevertheless, each policy would like the other institution to carry out the required stimulus. This is not to jeopardize the pursuit of its other objectives, once the economy recovers. For example, the central bank may dislike additional stimulatory measures (such as quantitative easing) for fear of medium-term inflationary consequences, as was the case of the European Central Bank (ECB) since 2010. Similarly, the government may be reluctant to implement another round of fiscal stimulus due to concerns over fiscal sustainability, which seems to be the case in the United States and many European countries since 2010. This means that in the above game each institution prefers a different pure Nash equilibrium: the central bank prefers $(N, S)$, whereas the government prefers $(S, N)$. Both institutions would, however, like to cooperate on one of these to avoid the inferior mixed Nash equilibrium.

Before proceeding, it should be acknowledged that such a reduced form game representation is naturally not capable of fully capturing a dynamic macroeconomic environment, in which the normal-form game payoffs are likely endogenous to the strategies pursued by the policymakers. We, however, believe that this approach may still be helpful for building intuition and offering some policy insights regarding strategic policy interactions that are impossible to consider in a DSGE type model.

As the framework in Libich, Nguyen, and Stehlik (2012), only allows one policymaker to probabilistically revise its actions, it is worthwhile to re-examine the analysis under both players having Calvo revisions. In such setting, we can interpret $\theta_M$ and $\theta_F$ as the degrees of each policy’s leadership (pre-commitment). These are arguably determined by political economy factors and institutional

\textsuperscript{11} The $c \geq b$ and $y \geq x$ inequalities in eq. [4] may be reversed without affecting our conclusions.
design features, for example, whether the central bank is an explicit inflation targeter or what the long-term fiscal outlook is. In particular, if the fiscal gap (long-term budgetary shortfall) implied by the existing legislation and the demographic trend of ageing populations is large, then it will be more difficult for the government to provide additional fiscal stimulus to the economy. This is especially true in a downturn where the markets are more sensitive to the long-term fiscal projections and fear of a fiscal crisis can spread quickly (as some European countries experienced recently). Alternatively, the political realities (such as negotiations over the debt ceiling in the US in October 2013) may determine whether or not a fiscal stimulus can be implemented. Uncertainty arising from such channels is captured by our stochastic component $\theta_F$. Similarly, if the central bank has a legislated numerical inflation target, its ability to deviate from the target in the medium-term is arguably affected, and thus possibly also the probability and nature of its responses to adverse shocks summarized by $\theta_M$. This stochastic term can further express uncertainty regarding the logistic constraints on the central bank’s implementation of another round of quantitative easing.

4.2 Results

It is now apparent that the intuition of the game is analogous to the Battle of the sexes studied above. In fact, we have labeled the available actions in eq. [29] in a way such that the conditions for the three equilibrium regions are identical to the above.\footnote{Remark 1. The probability of a double-dip recession and deflation – regime $(N, N)$ caused by a psychological tug-of-war between monetary and fiscal policies – is minimized when the degrees of policy leadership $\theta_F$ and $\theta_M$ are sufficiently different from each other.}

The monetary dominance region with the central bank’s preferred outcome $(N, S)$ throughout the equilibrium path obtains iff eqs [7], [11], and [12] hold. Analogously, for the fiscal dominance region, the necessary and sufficient conditions are eqs [13]–[15].

In a nutshell, this is because then (and only then) one policy has sufficient power to induce the other policy to provide the needed stimulus. And this stimulus in turn leads to one of the dominance regions and an economic recovery. Such asymmetry in timing (and pre-commitment), therefore, resolves the coordination problem between

\footnote{Obviously, there are some differences between the two games (in addition to one falling in the coordination and the other anti-coordination class). While these differences may be relevant for some purposes, e.g. equilibrium stability, they do not play any role in our analysis.}
the policies. However, if \( \theta_M \) and \( \theta_F \) are insufficiently different, then we have the multiplicity region in which the policies may engage in a tug-of-war in the form of a waiting game. They both try to induce the other policy to respond to the economic weakness by postponing their response, which may lead to worsening of economic conditions and a deflationary spiral.

4.3 Policy discussion

The situation in the Eurozone during 2010–2013 seems to be an example of this \((N, N)\) regime. On the fiscal front, many European governments have engaged in short-term austerity measures (rather than conceptual long-term reforms that are required to address the inter-temporal budgetary problem). And they continue to do so despite the negative consequences of austerity actions on economic growth causing little or no improvement of the fiscal position. On the monetary front, the ECB has been reluctant to provide additional stimulus that the environment of soaring unemployment and declining inflation otherwise warrants. As the ECB President Mario Draghi argued in line with the intuition of our analysis: “It’s not our duty, it’s not in our mandate” to “fill the vacuum left by the lack of action by national governments…” [Bloomberg (2012)].

It can perhaps be conjectured that since \( \theta_M \) and \( \theta_F \) are not common knowledge in the real world, and/or may change over time, such behaviour by the ECB may be signalling: an attempt to credibly demonstrate a high level of pre-commitment \( \theta_M \). The aim may be to provide the bank with ammunition to withstand pressures to monetize government debt in the longer term, i.e. avoid the unpleasant monetarist arithmetic of Sargent and Wallace (1981). Similar reasoning may underlie the January 2012 statement by the Federal Open Market Committee in the United States in which the Fed committed to the 2% inflation level more explicitly.

In summary, our analysis can perhaps explain the diverse experiences observed around the globe during the 2010–2013 period. Even in countries with fairly comparable levels of development, current economic conditions, and future outlook, fiscal policies have ranged from large stimuli to severe austerity measures. Our analysis implies that institutional differences captured by our stochastic revisions may account for some of these differences.

4.4 Empirical assessment

In order to assess the likelihood of the \((N, N)\) outcome, Libich, Nguyen, and Stehlík (2012) use 12 existing measures in the literature to quantify indices of monetary and fiscal leadership for high-income countries. All capture constraints on the
government’s and central bank’s decisions that reduce their ability to choose (revise) their actions at will. This is how they map into the $\theta_M$ and $\theta_F$ variable in our timing framework. Appendix C has the details including a country ranking, whereas Figure 4 shows graphically the resulting $\theta_M \times \theta_F$ space. As its colour scheme indicates, it can be directly related to the equilibrium regions of Figure 3.

The countries in the green top left corner (Japan and the United States) are likely to be in the fiscal dominance region featuring the $(S,N)$ regime, whereas the countries in the red bottom right corner (Australia and New Zealand) in the monetary dominance region featuring the $(N,S)$ regime. Both pairs of countries are thus likely to avoid the contractionary/deflationary outcome $(N,N)$, since the government/central bank has sufficient leverage over the other institution to induce the required stimulus. In particular, our analysis predicts that in Japan and the United States the central bank is likely to be the main stimulatory force, whereas in Australia and New Zealand it will be the government. This seems to largely correspond with what we observed during 2010–2013 in the real world.

However, the countries in the middle (in the yellow region along the 45° line such as France, Ireland, Spain, or Portugal) may fall into the multiplicity region. In this parameter region, any regime including the deflationary $(N,N)$ is possible in equilibrium.$^{13}$

---

13 While we have included the countries using/pegged to the Euro (indicated in blue), their monetary leadership values, and their position in the figure, should be interpreted with extreme
4.5 Robustness

Let us conclude by a robustness note. It should be acknowledged that the discrete \(2 \times 2\) action space in eq. [29] may overstate the extent of the policy conflict compared to a continuous specification in which the policies can share the stimulus between them in equilibrium.

To see this extend the game in eq. [29] by giving each policy another action: Half-stimulus. Further, use the specific payoffs from eq. [2] with the following values:

<table>
<thead>
<tr>
<th>M policy</th>
<th>F policy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No-stimulus</td>
</tr>
<tr>
<td>Stimulus</td>
<td>recovery</td>
</tr>
<tr>
<td>No-stimulus</td>
<td>deflation</td>
</tr>
<tr>
<td>Half-stimulus</td>
<td>under-stimulating</td>
</tr>
</tbody>
</table>

The game now features another pure strategy Nash equilibrium, the payoff of which is between that of the \((N,S)\) and \((S,N)\) outcomes for both players. This equilibrium can be selected by the focal point argument due to its symmetry. It remains to be seen whether monetary and fiscal policymakers around the globe will be able to coordinate on this outcome, or the other pure Nash equilibria, and thus avoid Pareto-inferior outcomes.

5 Summary and conclusions

This paper attempts to contribute to our understanding of Stackelberg games and equilibrium selection by postulating a framework with quasi-stochastic timing of moves. It nests the standard simultaneous move and Stackelberg leadership games as special cases and as such allows us to study a dynamic concept of commitment.

cautions. This is because they do not have an independent monetary policy, and thus the policy interaction is more complex. This is even more the case due to a free-riding problem in a monetary union, for details, see Libich, Nguyen, and Stehlík (2012).
The analysis shows how the players’ probabilities \( \theta_i \) of not being able to revise their actions (at pre-specified common time \( \tau \)) affect the outcomes in coordination and anti-coordination games.\(^{14}\) Specifically, we derive the necessary and sufficient conditions under which we can uniquely select an efficient outcome in the Battle of the sexes and Stag hunt games.

In order to demonstrate how our framework with quasi-stochastic timing can be applied to various economic situations, we use it to model the interactions between monetary and fiscal policies. We focus on the aftermath of a major adverse shock such as the 2008 financial crisis. The central bank and the government are engaged in a Game of chicken about which policy will respond to the shock. This can lead to a tug-of-war between them resulting in a costly recession and possible deflation.

Our analysis shows under what circumstances the policy conflict will be resolved and such undesirable outcomes avoided. We accompany this theoretical analysis by an empirical section in which the chances of avoiding the deflationary scenario are assessed for high-income countries. It is shown that the likelihood differs substantially across countries.

Let us relate our analysis to alternative timing frameworks we have examined elsewhere. In the fully-stochastic framework of Basov, Libich, and Stehlík (2013), the revision can arrive at any time \( \tau \in [0,1] \) during the game with an arbitrary probability distribution. The main drawback of such a general treatment is, however, that due to the analytical complexity the paper can only deal with the case in which the supports of the players’ revision distributions do not overlap, i.e. in which we can surely identify who revises first.

Such restriction implies \( 0 \leq \tau_i < \tau_j \) and essentially reduces the analysis to the case of only one player making a revision, \( 0 = \tau_i < \tau_j \). Therefore, the results of Basov, Libich, and Stehlík (2013) are fairly close to the intuition of the static Stackelberg leadership.\(^{15}\) Compared with the framework therein, the quasi-stochastic timing of the revisions in the presented paper is less general. But uncertainty about which player revises first (embedded by \( \tau_i = \tau_j \)), and about whether they are able to revise at all, provides novel insights into Stackelberg games and equilibrium selection.

\(^{14}\) It is apparent that our framework with stochastic timing is different from – but compatible with – the stochastic games by Shapley (1953).

\(^{15}\) The same is true of Libich and Stehlík (2012), which uses their special case of \( 0 = \tau_i < \tau_j \). The paper’s application is the long-term view of monetary–fiscal interactions, namely the sustainability of public finances and the likelihood of an unpleasant monetarist arithmetic of Sargent and Wallace (1981). The paper also formally studies policy interactions in a monetary union composed of independent fiscal authorities with differing sizes and revision probabilities and provides an empirical application to the Eurozone.
Our alternative framework in Libich and Stehlík (2010) considers a fully-deterministic timing of revisions. After a simultaneous initial move, each player moves with a constant frequency – every \( r_i \in \mathbb{N} \) periods. While this timing features more dynamics and asynchrony, the intuition of the findings is similar to the framework presented here. First, stronger commitment of the more committed player, higher \( r_i \) or \( \theta_i \), is an advantage in both setups, as it improves \( i \)'s chances to dominate in the game. Second, even the less committed player \( j \) may, under some special circumstances, achieve her dominance region. In both frameworks, this happens when \( j \)'s victory gain/tournament cost ratio is sufficiently high relative to \( i \)'s, and it, thus, offsets the relatively low degree of \( j \)'s commitment.\(^{16}\)

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Appendices

Appendix A: proof of necessity in Theorem 1 for general payoffs

Proof. Re-consider the Imitating scenario for general payoffs in eq. [4]. Rearrange eq. [8] to obtain the general form of eq. [9] and then reverse the inequality to obtain\(^{17}\)

\[
\theta_F > \frac{d - b}{a - c + d - b}.
\]

To reflect the imitating behaviour of player \( M \) in his revision, Condition C is altered to eq. [17], which yields, after rearranging, the general version of eq. [18]

\(^{16}\) Let us mention that both the fully-stochastic and fully-deterministic revision frameworks have some similarities to timing games developed by Simon and Stinchcombe (1989). In their framework, each player chooses the time(s) of his move from a finite set of options, implying that asynchronous timing and commitment can arise in such games (and can thus be used in various contexts, e.g. Monte 2010). For exploration of alternative timing structures and probability distributions using time scales calculus, see recent research in mathematics, e.g. Stehlík and Volek (2013).

\(^{17}\) Note that this is simply Condition A for the opponent, player \( F \).
The conditions in eqs [32] and [33] can never hold jointly. To see this, realize that the former condition implies the denominator of the latter condition to be positive. But because the numerator of eq. [33] is negative for all general parameters in eq. [4], there are no $\theta_M$ values satisfying both eqs [32] and [33]. In other words, without Condition B, Conditions A and C cannot both hold.

To see the necessity of Condition B in a different way, consider the following counter-example. Take the case of eq. [9] holding with equality. In such case, both $M_2^O$ and $M_2^S$ are best responses to $F_1^O$. This modifies Condition C, as it decreases the minimum payoff $M$ can get from playing $M_1^S$. In particular, Condition C is altered from eq. [10] to

$$rc + (1 - \tau)c > a,$$

which can never be satisfied. Intuitively, as there may be no reward to the more committed player $M$ from trying to induce the opponent to cooperate, he may not go ahead with the conflict. Therefore, the $(M_1^OM_2^OF_1^OF_2^O)$ outcome still appears in the set of equilibria.

**Appendix B: proof of Proposition 3**

**Proof.** Building on the proof of Theorem 1, it is apparent that the general Conditions A, B, and C are, for the general payoffs in eqs [3] and [4], identical to the Battle of the sexes.\(^{18}\) Using those for the case $\theta_M > \theta_F$ with the normalized payoffs in eqs [27] and [28] yields Condition A as:

$$\theta_M > \theta_M = \min \left\{ 1 - \frac{1}{z}, 1 - \frac{1}{z} \right\}, \quad [35]$$

Condition B as:

$$\theta_F < 1 - \frac{1}{d},$$

and Condition C as:

$$\theta_F < \theta_F = 1 - \frac{1}{(1 - \tau)d}, \quad [36]$$

\(^{18}\) This is naturally the case for the Pure coordination game as well.
which is again stronger than Condition B for all considered parameter values. Revisiting the Imitating scenario in Step 3 of the proof of Theorem 1, condition [17] still applies, and the analogs of conditions [16] and [18] are

\[ d < \frac{1}{1 - \theta_F} \quad \text{and} \quad d > \frac{\frac{1}{1 - \theta_M} - (1 - \theta_M)}{\theta_M(1 - \theta_F)}. \]

It is straightforward to see that these two conditions cannot hold jointly (and Appendix A implies the same for the general payoffs). By symmetry, for the case \( \theta_M > \theta_F \), we obtain

\[ \theta_F > \theta_F = \min \left\{ \frac{1}{d}, 1 - \frac{1}{d} \right\}, \tag{37} \]

\[ \theta_M < \theta_M = 1 - \frac{1}{(1 - \tau)}z. \tag{38} \]

In summary, in the normalized game, the payoff dominant outcome becomes the unique equilibrium iff either eqs [35] and [36] or eqs [37] and [38] hold. \( \square \)

**Appendix C: monetary and fiscal leadership in high-income countries**

There exist no comprehensive indices of monetary and fiscal leadership in the literature. Libich, Nguyen, and Stehlík (2012), therefore, develop a measure of these variables based on related established indices, averaging over a number of them for maximum robustness. As explained in the main text, they capture constraints on the players’ actions that reduce their ability to revise their strategies freely and flexibly.

Table 1 summarizes the eight measures of fiscal leadership that enter our overall index with equal weights. Measures \( M1 \) and \( M2 \) reflect past fiscal outcomes; measures \( M3-M7 \) are based on the projected future fiscal outcomes implied by the existing tax and expenditure legislation. Measure \( M8 \) describes fiscal governance, which is their important determinant. Intuitively, if a large fiscal gap (inter-temporal imbalance) exists, then the government is more constrained in its actions, i.e. it has a lower probability of revision.

Table 2 summarizes the four measures of monetary leadership that enter our overall index with equal weights. They all relate to the transparency with which
inflation goals are specified in the central banking legislation/statutes, and the accountability of the bank for achieving these. Arguably, a numerical inflation target the central bank is accountable for makes the bank pre-committed and gives it more ammunition against the government.

Table 3 reports the data from the papers of Tables 1 and 2 (for the 25 countries for which at least 5 out of the 8 fiscal measures have been provided). Our ranking of countries is fairly robust to alternative weighting of the underlying measures. Iceland and Hungary are two non-Eurozone exceptions whereby some of their post-2008 developments may not be fully captured.

A more important exception is the Eurozone. Caution should be exercised when interpreting the monetary leadership data of countries using (or pegged
to) the Euro, as they do not possess an independent monetary policy. Our measure combines the values for the ECB (where available, namely measures $M_1$ and $M_2$), and values for the individual countries ($M_4$). For these countries, we have excluded measure $M_3$ since it reflected the fixed exchange rates within the Eurozone just prior to its inception.

To adjust for different units of the underlying measures we normalize all values on the $[0,1]$ interval. As some of the measures do not have a natural lower and/or upper bound, we assign the polar values 0 and 1 to the minimum and maximum appearing in our sample of 25 countries. Table 4 reports the resulting scores, as well as their ratio and country ranking.
Table 4: Our fiscal and monetary leadership indices, their ratios, and the countries’ ranks

<table>
<thead>
<tr>
<th>Country</th>
<th>Code</th>
<th>$F$ rigidity</th>
<th>$M$ commitment</th>
<th>$M$ commitment to $F$ rigidity scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Score</td>
<td>Rank</td>
<td>Score</td>
<td>Rank</td>
</tr>
<tr>
<td>Australia</td>
<td>AUS</td>
<td>0.19</td>
<td>24</td>
<td>0.93</td>
</tr>
<tr>
<td>Canada</td>
<td>CAN</td>
<td>0.35</td>
<td>16</td>
<td>0.91</td>
</tr>
<tr>
<td>Hungary</td>
<td>HUN</td>
<td>0.63</td>
<td>7</td>
<td>0.52</td>
</tr>
<tr>
<td>Iceland</td>
<td>ISL</td>
<td>0.70</td>
<td>5</td>
<td>0.71</td>
</tr>
<tr>
<td>Japan</td>
<td>JAP</td>
<td>0.89</td>
<td>1</td>
<td>0.41</td>
</tr>
<tr>
<td>Korea</td>
<td>KOR</td>
<td>0.31</td>
<td>19</td>
<td>0.79</td>
</tr>
<tr>
<td>New Zealand</td>
<td>NZL</td>
<td>0.21</td>
<td>21</td>
<td>0.92</td>
</tr>
<tr>
<td>Norway</td>
<td>NOR</td>
<td>0.18</td>
<td>25</td>
<td>0.47</td>
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<tr>
<td>Poland</td>
<td>POL</td>
<td>0.49</td>
<td>11</td>
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<td>Sweden</td>
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<td>0.21</td>
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<td>UK</td>
<td>GBR</td>
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<td>14</td>
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<td>USA</td>
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<td>8</td>
<td>0.31</td>
</tr>
<tr>
<td>Austria</td>
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