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Strategic Monetary–Fiscal Interactions in a Downturn*

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Highly diverse responses of monetary and fiscal policies have been observed around the world in the post global financial crisis period of 2010–2014. While some countries implemented various mixes of monetary and/or fiscal stimuli, others have seen austerity. Our paper explores whether the strategic interaction between the central bank and government can shed some light on this diversity, and what lessons about the institutional design of the two policies can be learnt from it. This is done by mapping a reduced-form New Keynesian model into a generalised game-theoretic framework with deterministic and stochastic revisions of policy actions. Our focus is on the short-term policy interaction regarding stabilisation of an adverse shock (rather than long-term issues related to fiscal sustainability and unpleasant monetarist arithmetic). Particular attention is paid to the effect of institutional and structural features such as inflation targeting, monetary and fiscal implementation lags, and the policies' leadership.

I Introduction

The aftermath of the global financial crisis has seen a variety of monetary and fiscal policy mixes across the globe. Ranging from fiscal stimulus to austerity measures to quantitative easing, policy-makers in governments and central banks have used a number of different economic recipes. In an attempt to understand this plurality and provide novel insights and policy recommendations, this paper examines monetary–fiscal interactions following a major adverse shock.

Our focus is on the *strategic* aspect of the monetary/fiscal responses to the shock. This is because the literature is scarce on this point, with most papers assuming that the two policies are able and willing to perfectly coordinate their actions. The 2010–2014 period has, however, shown us that this is not necessarily the case. For example, while central banks have attempted to lower long-term yields via quantitative easing, governments have tended to issue long-term rather than short-term bonds, and thus sabotage the central banks' stimulatory efforts.[1]

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[1] For instance, The Economist (2011) reported that between mid-November 2010 and the end of March 2011 'America's Treasury has issued some $589 billion in extra long-term debt, of which the Fed has bought $514 billion'. From early 2009 until March 2010 the UK Treasury issued £ 247 billion ($396 billion) of extra long-term gilts, of which the Bank of England bought £ 199 billion. *The Economist* concludes: 'In effect, [quantitative easing] in both countries has been undermined by debt-management policy'.

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To keep the analysis as transparent as possible, we incorporate fiscal policy into the familiar Clarida *et al.* (1999) New Keynesian model. In order to highlight the strategic considerations, this reduced-form model is then mapped into a 2×2 game-theoretic representation, and the resulting policy Game of Chicken is analysed via novel game-theoretic methods. Specifically, we examine two frameworks in which the timing of the moves is more general. One features deterministic and the other stochastic revisions of actions, and hence in both the Stackelberg leadership concept is transformed form static to dynamic.

Monetary and fiscal policies are postulated as partial substitute demand-side stabilisation tools – both of them can stimulate the economy following an adverse shock. It is therefore fairly uncontroversial that the two policies may face a coordination problem in terms of which policy should respond to each particular economic disturbance. Our analysis, however, shows that the policies may face an outright conflict in the form of the Game of Chicken. Perhaps surprisingly, this can happen even in the most favourable scenario in which: the government and the central bank share the same targets for inflation and output; the shared output target is at the potential level (i.e. there is no time-inconsistency problem *à la* Kydland and Prescott (1977) or Barro and Gordon (1983)); the shocks only come from the demand side of the economy; and there exists no uncertainty about the structure of the economy nor about the shocks (that can be perfectly observed by both policy-makers and private agents in real time).

What drives the policy conflict if none of the standard culprits apply? For a monetary–fiscal policy conflict regarding the occurrence of shock stabilisation, it suffices that the policies are not fully credible (i.e. expectations are not perfectly anchored), and the central bank places a different weight on inflation versus output stabilisation than the government. This is because in such a case each institution prefers to stabilise the shocks by itself to apply its own weights between inflation and output volatility.

(i) Monetary–Fiscal Conflict

As a consequence, we may observe three distinct types of short-term policy conflict or miscoordination. Let us stress that this paper examines the short-term perspective of policy interactions. A possible long-term conflict between monetary and fiscal policies related to fiscal sustainability and the unpleasant monetary arithmetic is studied in Libich and Stehlík (2012). The link between the short-run and long-run perspective is explored in Libich *et al.* (2012), but only at the game-theoretic level without an underlying macroeconomic model, which makes it impossible to link the results back to the structural and policy parameters as we attempt here.

As the first type of policy conflict, each institution may respond strongly to the shock in attempt to discourage the other institution from responding. Such a strategic tug of war may lead to the joint response being excessive. It may overheat the economy and possibly plant seeds for future imbalances or bubbles – as many argue was the case in the United States during 2001–2005. As a second type of post-shock conflict, each institution may delay a response to the shock in anticipation that the other institution will respond and provide the required stimulus. Such policy deadlock may send the economy into a deep contraction and possibly a deflationary spiral. In a third type of short-term conflict the economy may fall into a mixed Nash equilibrium with randomisation between policies, for example between fiscal stimulus and austerity. Such regime switching results in excessively high volatility of both inflation and output.[2]

All three conflict/miscoordination scenarios are costly for society and policy-makers. In our game-theoretic analysis they are shown to be inferior to the two pure Nash equilibria in which the policies coordinate their actions, and only one of them responds to the adverse shock to stabilise the economy.

(ii) Credibility and Explicit Coordination

Our analysis has several policy implications. First, it shows the positive role of policy credibility. It ensures that the expectations of private agents are well anchored, which in turn improves the policy stabilisation trade-off. The analysis thus warns of a vicious circle associated with lack of credibility: the more likely private agents find inferior macro outcomes due to policy conflict, the less likely expectations are anchored, and this in turn increases the likelihood of inferior out-

[2] Davig and Leeper (2011) show that the monetary–fiscal policy regime in the US changed fairly frequently – 15 times – between 1950 and 2007.

comes and so on. One way to alleviate the problem under some circumstances may be to legislate an explicit (but not necessarily strict) inflation target. As it tends to improve credibility outcomes and anchor expectations (see, for example, Gürkaynak *et al.*, 2010), it may be useful in avoiding such a vicious circle.

Second, the analysis highlights the importance of coordination between the central bank and the government, and their joint communication with the public. The challenge in improving policy coordination, however, is that it is often interpreted by the markets as compromising central bank independence (for a discussion, see Libich *et al.*, 2011). Explicit inflation targeting may again be useful here, and play a positive role in this communication. The transparency and accountability associated with the regime help the public understand the short-term policy actions and how they fit with the long-term goals of both policies. In addition, a formal legislated procedure guiding monetary–fiscal coordination in the aftermath of a major adverse shock may help reduce uncertainty and improve macroeconomic outcomes.

(iii) Deterministic and Stochastic Revisions

The final and key contribution of this paper is to apply two game-theoretic frameworks (postulated in Libich & Nguyen, 2013) and formally explore channels that can alleviate the above conflict and coordination problems. The frameworks allow a more general timing of moves in the Game than the standard simultaneous move and Stackelberg leadership set-ups. Specifically, they feature deterministic and stochastic revisions of the players' actions. In the deterministic setting each policy-maker i can revise his action with some delay τ_i, but the revision opportunity arrives with certainty. Such revisions can be interpreted as the policies' implementation lags. In the stochastic revisions setting the revision opportunity occurs without delay, but only with some probability $1 - \theta_i$. This can be interpreted as the degree of the policies' leadership (precommitment).

The aim of our extended timing is to identify circumstances under which conflict between monetary and fiscal policies can be avoided. We show two channels, one in each timing set-up, that act as implicit coordination devices. In game-theoretic terms, they eliminate multiple equilibria and uniquely ensure a Pareto efficient equilibrium. It is the central bank's preferred outcome in a monetary dominance region or the government's preferred outcome in a fiscal dominance region.

In the stochastic timing framework this happens if the degrees of monetary and fiscal policy leadership, that is, the revision probabilities, differ sufficiently across the two policies. This is because one policy is strongly committed (has a low revision probability) and thus has sufficient leverage over the other policy in inducing compliance and cooperation. By increasing the degree of central bank leadership, an explicit inflation target may be useful in this respect. Intuitively, the fact that it is legislated gives the central bank ammunition in the Game of Chicken against the government. It may thus contribute to an improvement of both monetary outcomes and fiscal policy outcomes, empirical evidence for which is reported in Franta *et al.* (2012).

Another conflict-avoiding channel identified by our deterministic set-up relates to the length of monetary and fiscal policy implementation lags. These must be neither sufficiently similar nor too different in order to escape multiplicity of equilibria. Intuitively, this guarantees – for both the central bank and government – that the cost of potential conflict is offset by a sufficiently long-lasting gain from subsequent policy coordination.

(iv) Conservative Central Banker

We also assess the Rogoff (1985) recommendation of appointing a conservative central banker who is strict(er) on inflation than the government.[3]

We show that in the standard simultaneous move framework the appointment of a strict(er) central banker lacks traction and does not by itself achieve policy coordination. In fact, it makes things worse by deepening the policy differences and conflict. Nevertheless, we then show that in *combination* with one of the above cooperation channels this appointment may still

[3] From our modelling as well as real-world experience it is apparent that strict and explicit inflation targeting are two distinct features of monetary policy regimes. As demonstrated in Libich (2011), real-world explicit inflation targets do not imply strict monetary policy (inflation 'nutters') because they are postulated as long-term objectives that need to be achieved on average over the business cycle. Similarly, strict monetary policy may be pursued without explicit numerical inflation targets.

be desirable by increasing the size of the monetary dominance equilibrium region in which policy conflict is avoided. Put differently, while not a prerequisite, strict(er) inflation targeting may under some circumstances enhance the effectiveness of explicit inflation targeting.

More broadly, our analysis hints at a possible explanation for the diverse monetary-fiscal policy actions observed during 2010–2014 around the globe. It shows that the outcomes of strategic policy interactions depend on a number of institutional and policy parameters, which are likely to differ across countries. Among these are the slope of the Phillips curve and IS curve, the inflation aversion of the central bank, the preferences of governments regarding output, the policies' implementation lags and the degree of their leadership. Put differently, one of the contributions of this paper is to show how a macro model can be linked to a game-theoretic framework, and some of its strategic aspects analysed using richer game-theoretic methods.

(v) Limitations

Let us acknowledge that our focus is on the dynamics at the game-theoretic level, and thus we have to suppress much of the dynamics at the macroeconomic level considered in existing models. Nevertheless, we believe that stripping the macroeconomic environment to the bare bones is justified since novel insights emerge that cannot be obtained from conventional macro set-ups. Furthermore, the micro-foundations of the Clarida *et al.* (1999) model are well known (see Woodford, 2003).

II Model

(i) Economy

We postulate the simplest possible set-up from which some lessons about policy interactions in the aftermath of the global financial crisis can be drawn. The Clarida *et al.* (1999) model features an IS curve and a Phillips curve, and we incorporate fiscal policy in the former:

$$x_t = -\varphi[i_t - E_t\pi_{t+1}] + E_t x_{t+1} + \gamma e_t + g_t, \quad (1)$$

$$\pi_t = \lambda x_t + E_t\pi_{t+1} + u_t. \quad (2)$$

The parameters φ,γ,λ are positive, x is the output gap, π is the inflation rate, i is the nominal interest rate set by the central bank, and e denotes government expenditure net of taxes. Specifically, $e > 0$, $e = 0$, and $e < 0$ represent a budget deficit, balanced budget, and budget surplus, respectively.[4] The terms g_t and u_t are demand and cost-push shocks respectively that are independent and identically distributed random variables with zero means for simplicity. For the same reason we consider the case of no discounting (both private agents and the two policy-makers).[5]

(ii) Preferences

The period objective functions of the monetary (M) and fiscal (F) policy-makers are standard:

$$U_i = -\left(\pi_t - \pi^T\right)^2 - \alpha_i\left(x_t - x_i^T\right)^2, \quad (3)$$

where $i \in \{M,F\}$, x^T and π^T are the output gap target and the inflation target respectively, and α is the weight on output relative to inflation stabilisation (the inverse of central bank conservatism).

Let us reiterate that our analysis will focus solely on strategic policy interactions regarding short-term stabilisation problems – long-term interactions featuring fiscal sustainability and the unpleasant monetary arithmetic are examined in Libich and Stehlík (2012). Therefore, we will consider the case assumed in Clarida *et al.* (1999), namely,

$$x_F^T = x_M^T = 0. \quad (4)$$

[4] Intuitively, the e term results from the feature of New Keynesian models (adopted here as an implicit assumption) that output equals private consumption plus government consumption, which is financed via lump-sum taxes (possibly in combination with public debt). In models of this type, government spending tends to have a positive impact on output and inflation in the short term regardless of the monetary–fiscal regime (see, for example, Davig & Leeper, 2011). These authors further show that the size of the fiscal multiplier may be different in the Ricardian regime (active monetary and passive fiscal policy) and the non-Ricardian regime (passive monetary and active fiscal policy). The specific micro assumptions regarding Ricardian equivalence also have a quantitative effect on the outcome of policy actions. Nevertheless, given our focus on the game-theoretic analysis of the short-term policy interaction, and its qualitative rather than quantitative insights, we do not model these issues explicitly in this paper.

[5] This will not play a role as we are interested in short-term outcomes rather than long-term outcomes. Furthermore, the effect of discounting, namely that it deepens coordination problems, is well documented.

Assuming the policy-makers' output targets to be at the potential level serves to highlight the fact that any conflict between the policies is due neither to their disagreement over the inflation or output target levels, nor to the time-inconsistency problem of Kydland and Prescott (1977). Put differently, the policy-makers do not have a temptation to boost output through surprise inflation, contrary to the 1980s literature using a Lucas supply relationship. We will throughout focus on the relevant case

$$\alpha_F \geq \alpha_M \geq 0, \tag{5}$$

in which the central banker may (or may not) be conservative in the Rogoff (1985) sense ($\alpha_F > \alpha_M$) and he may (or may not) be strict on inflation ($\alpha_M = 0$).

(iii) Steady-State Outcomes

Using (2)–(4), we get the conventional optimality condition for both policy-makers under discretion,

$$x_t = -\frac{\lambda}{\alpha_i}\left(\pi_t - \pi^T\right). \tag{6}$$

There is consensus between the policy-makers about the steady-state levels (denoted by a 'bar') – both inflation and output are preferred to be on target:

$$\bar{\pi} = \pi^T \quad \text{and} \quad \bar{x} = 0. \tag{7}$$

Therefore, expectations by the public regarding these long-term levels are also on target:

$$\bar{E}_t \pi_{t+1} = \pi^T \quad \text{and} \quad \bar{E}_t x_{t+1} = 0. \tag{8}$$

In the absence of a shock the setting of both policies is therefore, using (7)–(8) with (1)–(2), at the neutral levels

$$\bar{\imath} = \pi^T \quad \text{and} \quad \bar{e} = 0. \tag{9}$$

(iv) Demand Shock

Consider an adverse demand shock of size ε at the start of period $t + 1$, namely,

$$g_{t+1} = -\varepsilon.$$

Equations (1)–(2) imply that if

$$\varepsilon > \frac{\pi^T}{\lambda} \tag{10}$$

the shock is large enough to potentially lead to deflation. This is in the case of no response in policy and expectations, that is, if (8)–(9) hold. We will assume such a sizable shock – that equation (10) holds – albeit purely for terminology purposes; none of our qualitative results hinges on this assumption.

To focus on strategic interactions between the central bank and the government, we will abstract from uncertainty and incomplete information. In particular, we will assume that both policy-makers and private agents can perfectly anticipate the shock at the end of period t.

III Game-Theoretic Representation

Since the monetary and fiscal authorities have different preferences over output and inflation stabilisation, their desired responses to an adverse demand shock may not be fully aligned. Therefore, the policy-makers need to consider the other policy's response when making their decisions. In other words, they need to act strategically.

In order to explore strategic monetary–fiscal interactions, we will map the macro model into a 2×2 game-theoretic representation following the approach of Backus and Driffill (1985). This will enable us to examine the effect of changes in structural and policy parameters on the payoffs and strategic policy outcomes, which was generally not the case in the literature and our earlier work. Let us, however, acknowledge up-front the limitations of this approach, which also apply to Backus and Driffill (1985) and other papers (e.g. Cho & Matsui, 2005) attempting to analyse macro models via game-theoretic methods.

First, the continuous action spaces of i and e are reduced to two actions – each policy chooses from stimulus (denoted S) and no stimulus (denoted N).[6] This truncation of the action space may, if the results are not interpreted carefully, overstate the extent of policy conflict. Second, in line with the S and N policy options, we depict

[6] We use these labels rather than Leeper's (1991) active/passive policy terminology to avoid confusion. This is because the latter tends to be associated with the medium- to long-term setting of the policies. In particular, it relates to the government's intertemporal budget constraint – with the passive policy stance ensuring that the budget constraint is satisfied over the long term. In contrast, our paper focuses on short-term policy responses and interactions, which is why we prefer to label the policy actions as 'stimulus' and 'no stimulus'.

two possibilities in terms of expectations, anchored and unanchored. These are first used to endogenously derive the S and N policy actions, but in the subsequent game-theoretic analysis expectations are treated as given by the policy-makers, implying they may not be fully in unison in some policy regimes.[7] This, however, enables us to separate the effect of the game-theoretic dynamics from the usual macroeconomic dynamics, and see what is driving the results. Furthermore, framing the problem as a two-player rather than a three-player Game (i.e. not including the public as another strategic player) is designed to make the strategic interactions between monetary and fiscal policies as transparent as possible. Third, by focusing on short-term stabilisation issues and sidelining long-term fiscal sustainability issues (explored in Libich & Stehlík, 2012), the paper by itself does not offer a full account of policy interactions. It is effectively a snapshot of the policy interaction at some point in time.

We hope, however, that despite these concessions to the modelling approach our analysis can still offer valuable insights regarding strategic short-term monetary–fiscal interactions, the policies' conflict and their coordination in the aftermath of a major adverse shock. Concessions such as these seem necessary to make progress in the analysis of strategic policy interaction as it cannot be captured in standard micro-founded set-ups.

(i) Expectations Scenarios

In the *anchored expectations* scenario, denoted A, stabilisation policy is credible, and agents expect a coordinated policy stimulus, that is, regimes $(i^{\mathrm{S}}, e^{\mathrm{N}})$ or $(i^{\mathrm{N}}, e^{\mathrm{S}})$. As such stimulus leads to the shock being perfectly stabilised, inflation and output remain on target and expectations thus do not respond to the shock. They remain anchored at the steady-state levels of inflation and output as per (8).

In the alternative *unanchored expectations* scenario, denoted U, agents expect the no-stimulus outcome $(i^{\mathrm{N}}, e^{\mathrm{N}})$ and hence anticipate reductions in inflation and output. This change in expectations effectively acts as a positive supply shock that alters the policy-makers' stabilisation trade-off (lowers the relevant short-term Phillips curve).[8]

(ii) Payoff Matrices

Obviously, the public's expectations will impact the effectiveness of the policy actions, and hence the policy-makers' payoffs. The Game can therefore be summarised as follows:

Anchored expectations:

		F	
		e^{N}	e^{S}
M	i^{N}	a', w'	b', x'
	i^{S}	c', y'	d', z'

Unanchored expectations: (11)

		F	
		e^{N}	e^{S}
M	i^{N}	a, w	b, x
	i^{S}	c, y	d, z

The $\{a, \ldots z'\}$ letters denote the policy-makers' payoffs from the eight different policy and expectations regimes.

(iii) Policy Actions

The way we truncate the model into a 2×2 game-theoretic representation is driven by our interest in situations such as the 2010–2014 period. On the one hand, in the aftermath of a major downturn it is often feared that without an additional policy stimulus the economy may experience a double-dip recession accompanied by deflation. On the other hand, a danger exists that a continued stimulus of both policies $(i^{\mathrm{S}}, e^{\mathrm{S}})$ *may* be excessive, overheat the economy, and plant seeds for future imbalances.[9]

[7] Specifically, when deriving the equilibrium outcomes of the macroeconomic model, private expectations do not 'foresee' our truncation into the eight possible regimes at the game-theoretic level.

[8] In conventional (dynamic stochastic general equilibrium type) models a common reason for unanchored beliefs is the multiplicity of equilibria, and the same intuition applies in our paper – at the game-theoretic level. Due to the policies' distinct preferences over inflation and output stabilisation, and their strategic interaction, each scenario will feature two pure-strategy Nash equilibria and hence a coordination problem or policy conflict, which can in principle give rise to unanchored expectations. Let us also mention that we have analysed the case in which agents expect a double stimulus $(i^{\mathrm{S}}, e^{\mathrm{S}})$, but as it does not provide additional insights it is not reported here.

[9] As an example, it is now a widely held view that the joint policy response to the NASDAQ bust in the US during 2001–2005 was 'too much for too long', and that this partly fueled the subsequent housing/stock market bubble (see Taylor & Ryan, 2010). Naturally, there are real-world situations with little ambiguity about the need for large joint stimuli of both policies (e.g. the 2008–2009 period). But there is no short-term policy conflict in such a scenario, which is why it is not examined in this paper.

In selecting the S and N policy options we follow the intuitive approach of Backus and Driffill (1985). The no-stimulus policy levels i^{N} and e^{N} are set at the long-run values $\bar{\imath}$ and $\bar{e}$ in (9), for both expectations scenarios. In selecting the stimulus levels i^{S} and e^{S} we choose values that are the solutions of each policy-maker's optimisation problem: (i) assuming no response from the other policy; and (ii) taking private expectations as given. Formally, we define

$$i^{\mathrm{S}} = \arg\max\{U_M | e^{\mathrm{N}}, E_t x_{t+1}, E_t \pi_{t+1}\} \quad \text{and} \quad e^{\mathrm{S}} = \arg\max\{U_F | i^{\mathrm{N}}, E_t x_{t+1}, E_t \pi_{t+1}\}. \tag{12}$$

Using (2) and (6) then yields the optimal combinations of inflation and output chosen by the policy-makers,

$$\pi_i^{\mathrm{S}} = \frac{\lambda^2 \pi^T + \alpha_i E_t \pi_{t+1}}{\alpha_i + \lambda^2} \quad \text{and} \quad x_i^{\mathrm{S}} = \frac{-\lambda(E_t \pi_{t+1} - \pi^T)}{\alpha_i + \lambda^2}. \tag{13}$$

We will now study the Game under each expectations scenario.

IV Outcomes under Anchored Expectations

Let us derive the output and inflation outcomes in the four policy regimes, assuming that expectations are anchored at the long-term level. Put differently, agents believe the shock will be perfectly stabilised and thus do not alter their expectations, which are at the level in (9). In the monetary stimulus case, $i_{\mathrm{A}}^{\mathrm{S}}$, the interest rate is lowered to close the output gap assuming the government does not respond, $e_{\mathrm{A}}^{\mathrm{N}} = 0$. Analogously, in the fiscal stimulus case, $e_{\mathrm{A}}^{\mathrm{S}}$, the government runs a budget deficit to close the output gap assuming the central bank does not react to the shock, $i_{\mathrm{A}}^{\mathrm{N}} = \pi^T$. Using this information in (1) and (13) yields the exact levels of the two policy instruments if performing a stimulus:

$$i_{\mathrm{A}}^{\mathrm{S}} = \pi^T - \frac{\varepsilon}{\varphi} \quad \text{and} \quad e_{\mathrm{A}}^{\mathrm{S}} = \frac{\varepsilon}{\gamma}. \tag{14}$$

This means lowering the interest rate below the neutral level and increasing government spending. By combining (1)–(2) with (8) and the policy levels $\{i^{\mathrm{N}}, i^{\mathrm{S}}, e^{\mathrm{N}}, e^{\mathrm{S}}\}$ from (9) and (14), we obtain the following output and inflation outcomes:

(15)

		F: e^{N}	F: e^{S}
M	i^{N}	Contraction/Deflation $x = -\varepsilon,\ \pi = \pi^T - \lambda\varepsilon$	Optimal recovery $x = 0,\ \pi = \pi^T$
	i^{S}	Optimal recovery $x = 0,\ \pi = \pi^T$	Overheating $x = \varepsilon,\ \pi = \pi^T + \lambda\varepsilon$

The two regimes featuring one policy's stimulus, $(i_{\mathrm{A}}^{\mathrm{S}}, e_{\mathrm{A}}^{\mathrm{N}})$ and $(i_{\mathrm{A}}^{\mathrm{N}}, e_{\mathrm{A}}^{\mathrm{S}})$, lead to the optimal outcomes. In both the shock is perfectly stabilised – by monetary and fiscal policy, respectively. This is , however, not the case in the remaining regimes. In the $(i_{\mathrm{A}}^{\mathrm{N}}, e_{\mathrm{A}}^{\mathrm{N}})$ regime we have an avoidable contraction accompanied by deflation since neither policy provides the required stimulus. In contrast, in the $(i_{\mathrm{A}}^{\mathrm{S}}, e_{\mathrm{A}}^{\mathrm{S}})$ regime we observe a positive output gap and inflation above the target due to an excessive uncoordinated stimulus of both policies. Combining (15) with the policy objectives in (3)–(4) yields the following payoff matrix:

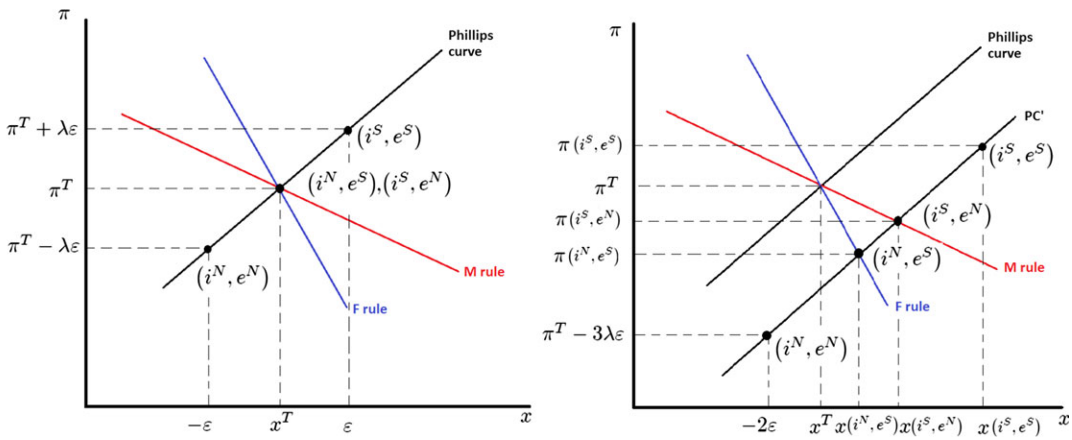
(16)

		F: e^{N}	F: e^{S}
M	i^{N}	$a' = -\varepsilon^2(\lambda^2 + \alpha_M), w' = -\varepsilon^2(\lambda^2 + \alpha_F)$	$b' = 0, x' = 0$
	i^{S}	$c' = 0, y' = 0$	$d' = -\varepsilon^2(\lambda^2 + \alpha_M), z' = -\varepsilon^2(\lambda^2 + \alpha_F)$

The left-hand panel of Figure 1 summarises the outcomes using the Carlin and Soskice (2005) graphical framework. The monetary and fiscal rules are the optimal targeting type rules derived from the policies' objective functions. The different slopes depicted in the figure are for the Rogoff (1985) conservative central banker case $\alpha_M < \alpha_F$.

The payoff matrix in (16) shows that the policy-makers are indifferent between the two

FIGURE 1
The Four Policy Regimes for the $\alpha_M < \alpha_F$ Case under Anchored Expectations (Left) and Unanchored Expectations (Right)



pure Nash equilibria, (i_A^S, e_A^N) and (i_A^N, e_A^S). Both, however, find these equilibria superior to (i_A^N, e_A^N), which leads to deflation, and (i_A^S, e_A^S), which leads to overheating. The payoffs in (16) satisfy

$$b' = c' > a' = d' \quad \text{and} \quad x' = y' > w' = z',$$

and hence the Game has the structure of a coordination game *Choosing sides*. There are two efficient pure strategy Nash equilibria, neither of which Pareto-dominates the other. Conventional game-theoretic methods cannot choose between these two equilibria due to their symmetry. Therefore, the inefficient mixed strategy Nash equilibrium, in which the policies randomise between the regimes, is a possibility, and a reason for concern among the policy-makers. This is even more so in the unanchored expectations case explored in the next section.

V. Outcomes under Unanchored Expectations

In the unanchored expectations case the public expects neither policy to respond to the shock – in anticipation of the other policy's response. [10]

[10] In the real world the fact that private agents expect the policy-makers not to respond may be due to future considerations. For example, the government may be reluctant to increase spending due to concerns over fiscal sustainability, whereas the central bank may be reluctant to carry out quantitative easing for lack of an exit strategy and fear of inflationary consequences in the longer term.

Agents therefore believe the setting of both policies will remain at the (insufficiently stimulatory) neutral levels in (9), and predict the macroeconomic outcomes in (15) associated with the (i^N, e^N) policy regime. Specifically, agents expect a contraction accompanied by deflation:

$$E^U x = -\varepsilon \quad \text{and} \quad E^U \pi = \pi^T - \lambda\varepsilon. \tag{17}$$

Using (1), (13) and (17) yields the stimulatory levels of the interest rate and government spending:

$$i_U^S = -\frac{1}{\varphi}\left[2\varepsilon + \varphi(\lambda\varepsilon - \pi^T) + \lambda^2 \frac{\varepsilon}{\alpha_M + \lambda^2}\right] \quad \text{and}$$
$$e_U^S = \frac{1}{\gamma}\left(2\varepsilon + \lambda\varepsilon\varphi + \lambda^2 \frac{\varepsilon}{\alpha_F + \lambda^2}\right). \tag{18}$$

Taking these into account, we can derive the output and inflation outcomes in the four policy regimes:

Note that compared to (15), the single policy stimulus cases (i_U^S, e_U^N) and (i_U^N, e_U^S) no longer provide optimal recovery, since inflation and output are below and above their target levels, respectively. Applying (19) together with (3)–(4) yields the policy-makers' payoffs:

		F: e^{N}	F: e^{S}
M	i^{N}	Contraction/Deflation $x = -\varphi\lambda\varepsilon - 2\varepsilon,$ $\pi = \pi^T - \varphi\lambda^2\varepsilon - 3\lambda\varepsilon$	Sub-optimal recovery $x = \frac{\lambda^2\varepsilon}{\alpha_F+\lambda^2},$ $\pi = \pi^T - \frac{\alpha_F\lambda\varepsilon}{\alpha_F+\lambda^2}$
	i^{S}	Sub-optimal recovery $x = \frac{\lambda^2\varepsilon}{\alpha_M+\lambda^2},$ $\pi = \pi^T - \frac{\alpha_M\lambda\varepsilon}{\alpha_M+\lambda^2}$	Overheating $x = \varepsilon\left[2+\varphi\lambda+\lambda^2\left(\frac{1}{\alpha_M+\lambda^2}+\frac{1}{\alpha_F+\lambda^2}\right)\right],$ $\pi = \pi^T + \lambda\varepsilon\left[1+\varphi\lambda^2+\lambda^2\left(\frac{1}{\alpha_M+\lambda^2}+\frac{1}{\alpha_F+\lambda^2}\right)\right]$

(19)

		F: e^{N}	F: e^{S}
M	i^{N}	$a = -\varepsilon^2\left[\left(\varphi\lambda^2+3\lambda\right)^2+\alpha_M\left(\varphi\lambda+2\right)^2\right],$ $w = -\varepsilon^2\left[\left(\varphi\lambda^2+3\lambda\right)^2+\alpha_F\left(\varphi\lambda+2\right)^2\right]$	$b = -\left(\frac{\lambda\varepsilon}{\alpha_F+\lambda^2}\right)^2\left(\alpha_F^2+\alpha_M\lambda^2\right),$ $x = -\left(\frac{\lambda\varepsilon}{\alpha_F+\lambda^2}\right)^2\left(\alpha_F^2+\alpha_F\lambda^2\right)$
	i^{S}	$c = -\left(\frac{\lambda\varepsilon}{\alpha_M+\lambda^2}\right)^2\left(\alpha_M^2+\alpha_M\lambda^2\right),$ $y = -\left(\frac{\lambda\varepsilon}{\alpha_M+\lambda^2}\right)^2\left(\alpha_M^2+\alpha_F\lambda^2\right)$	$d = -(\lambda\varepsilon)^2\left[1+\varphi\lambda^2+\lambda^2\left(\frac{1}{\alpha_M+\lambda^2}+\frac{1}{\alpha_F+\lambda^2}\right)\right]^2 -\alpha_M\varepsilon^2\left[2+\varphi\lambda+\lambda^2\left(\frac{1}{\alpha_M+\lambda^2}+\frac{1}{\alpha_F+\lambda^2}\right)\right]^2,$ $z = -(\lambda\varepsilon)^2\left[1+\varphi\lambda^2+\lambda^2\left(\frac{1}{\alpha_M+\lambda^2}+\frac{1}{\alpha_F+\lambda^2}\right)\right]^2 -\alpha_F\varepsilon^2\left[2+\varphi\lambda+\lambda^2\left(\frac{1}{\alpha_M+\lambda^2}+\frac{1}{\alpha_F+\lambda^2}\right)\right]^2$

(20)

The right-hand panel of Figure 1 graphically summarises the outcomes, showing the following result.

Remark 1. *In the unanchored expectations case, the demand shock cannot be perfectly stabilised even if it is perfectly anticipated by both policy-makers and the public.*

Intuitively, when agents believe there will be no policy stimulus, output and inflation are expected to decrease. This change in expectations will bring down the negotiated nominal wage and shift the Phillips curve downward (i.e. it effectively constitutes a positive aggregate supply shock). As a consequence, the inflation rate is decreased further. In responding to the shock both policy-makers thus choose a positive output gap to increase the inflation closer to its target. The above outcomes can be summarised from a game-theoretic perspective as follows.

Proposition 1. *Unlike in the anchored expectations case, in which monetary and fiscal policies only face a coordination problem regarding the stabilisation of the adverse shock, in the unanchored expectations case the policies also face a conflict. Specifically, for all* $\alpha_M < \alpha_F$ *their interaction has a structure of the Game of Chicken in which each policy-maker prefers a different pure strategy Nash equilibrium.*

Proof. It is straightforward to verify, comparing the payoffs across the four regimes in (20), that in the unanchored case the following two scenarios can occur:

Scenario	Pure Nash	Mixed Nash	Coordination problem	Equilib. policy conflict	Parameter range
Game of chicken	$(i^{\mathrm{N}}, e^{\mathrm{S}})$ $(i^{\mathrm{S}}, e^{\mathrm{N}})$	yes	yes	yes	$\alpha_M < \alpha_F$
Choosing sides	$(i^{\mathrm{N}}, e^{\mathrm{S}})$ $(i^{\mathrm{S}}, e^{\mathrm{N}})$	yes	yes	no	$\alpha_M = \alpha_F$

(21)

For all $\alpha_M < \alpha_F$, the payoffs in (20) satisfy

$$c > b > \max\{a, d\} \quad and \quad x > y > \max\{w, z\}, \tag{22}$$

which constitutes a variant of the Game of Chicken.

Intuitively, in this Game of Chicken each policy-maker prefers to carry out the stimulus themselves to apply their preferred stabilisation weights: the central bank prefers the (i^S, e^N) regime whereas the government prefers the (i^N, e^S) regime.[11] To give a numerical example, under $\alpha_M = 0.5$, $\alpha_F = \lambda = \varphi = \varepsilon = 1$, the payoff matrix in (20) becomes, rounding the payoffs to one decimal place:

		F	
		e^N	e^S
M	i^N	Contraction/Deflation $-20.5, -25$	Sub-optimal recovery $\mathbf{-0.4}, \mathbf{-0.5}$
	i^S	Sub-optimal recovery $\mathbf{-0.3}, \mathbf{-0.6}$	Overheating $-18.7, -27.4$

(23)

Similarly to the choosing sides Game, conventional game-theoretic methods are unable to select between the two pure strategy Nash equilibria in the Game of Chicken. However, the policy-makers' disagreement about the desirable equilibrium further increases the probability of conflict and of randomising between the regimes, both of which are costly.[12]

[11] The alternative scenario in which each policy-maker prefers the *other* policy to carry out the required stimulus may also be relevant under some circumstances (see Libich *et al.*, 2012).

[12] New Keynesian models typically (implicitly) assume that the Ricardian regime with active monetary policy and passive fiscal policy is optimal. This, however, relates to the longer-term perspective, that is, it applies on average in the absence of a cyclical deviation. In contrast, in the aftermath of a major shock when the zero lower bound on interest rates is binding even many standard models imply room for short-term stimulatory policy (see, for example, the discussion regarding its effectiveness in Blanchard & Leigh, 2013). Naturally, the optimality of monetary versus fiscal policy stimulus from the social welfare perspective depends on a range of structural and policy variables, for example on how the fiscal stimulus is financed, whether the zero lower bound on interest rates is binding and the availability of unconventional policy measures (active management of the maturity structure of public debt by the government or quantitative easing by the central bank). Due to the focus on the game-theoretic analysis of strategic policy interactions, such underlying welfare analysis is not conducted in this paper.

In the rest of the paper we explore game-theoretic devices – with an institutional design interpretation – through which such inefficient outcomes can be avoided.

VI Solutions to Conflict/Coordination Problems

(i) Conservative Central Banker

Let us first revisit the case for appointing a central banker more concerned about inflation, as suggested by Rogoff (1985).

Remark 2. *Under the standard simultaneous timing of policy actions, a more conservative (stricter) central banker by itself does not solve the coordination problem between monetary and fiscal policy. In fact it may make coordination harder by moving the policies from the choosing sides scenario to the Game of Chicken.*

Below we will investigate ways of resolving these problems, by which we mean circumstances that deliver a unique and Pareto-efficient subGame perfect Nash equilibrium in the Game of Chicken (i.e. we will focus on the unanchored expectations scenario). To do so let us generalise the timing of the Game by allowing for deterministic or stochastic revisions of policy actions based on the approach of Libich and Nguyen (2013). Such revisions will enable us to examine various institutional design features such as strength of policy leadership and length of implementation lags. It will be apparent that the recommendation of Rogoff (1985) may still be warranted if central bank conservativeness is combined with another institutional mechanism.[13]

(ii) Timing Assumptions

Consider the following simple extension of the Stackelberg leadership concept from static to dynamic, along the lines of Calvo (1983). At the start of the Game, at time $t = 0$, the two policies move simultaneously, selecting i and e. Then, at

[13] An alternative approach is the contribution by Debortoli and Nunes (2010) featuring the concept of 'loose commitment'. The authors study probabilistic commitment in the spirit of Calvo in an explicit dynamic macroeconomic model, but due to the complexity they can only capture one strategic player, not two. For exploration of alternative timing structures and probability distributions using time scales calculus, see recent research in mathematics, such as Stehlík and Volek (2013).

predetermined times $\tau_M \in [0,1]$ and $\tau_F \in [0,1]$, each policy has exactly one revision opportunity with probability $1-\theta_M$ and $1-\theta_F$ respectively, whereby naturally $\theta_i \in [0,1]$.

We denote the players' initial move by subscript 1 and the revision by 2. We will assume that, at the time of revision, each player can observe all *past* actions of his opponent (including his initial action if his revision happens in $\tau = 0$). Furthermore, we assume that payoffs accrue continuously over time. This means that they will be affected by the timing of revisions, namely by the (expected) length of time spent in each policy regime.

We will focus on the one-shot version of the Game. This is because we want to capture the short-term nature of the policy interaction, and because the effect of repetition and reputation building in enhancing coordination is well established, (see Mailath & Samuelson, 2006). It may be noted that our revisions frameworks resemble the Calvo (1983) timing widely used in macroeconomics describing the behaviour of price setters. However, while in Calvo's timing the deterministic and stochastic components are combined, we separate them and examine deterministic and stochastic revisions in turn.

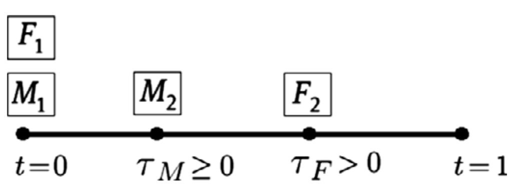
(iii) Deterministic Revisions

We will first explore the deterministic case where

$$\tau_M \neq \tau_F \quad \text{and} \quad \theta_M = \theta_F = 0. \tag{24}$$

The player with the lower (higher) τ will be called the *faster* (*slower*) *reviser*, respectively. In this scenario the revision times τ_M and τ_F can be roughly interpreted as the length of the policies' implementation lags (see Figure 2 for a graphical depiction). Implementation lags generally differ across the two policies. Monetary policy has a shorter implementation lag than fiscal policy, but its transmission mechanism is usually longer so their relative length is an empirical issue. For this reason we do not put any constraints on the relative values of τ_M and τ_F, that is, we obtain the results for any combination of these revision times from the interval [0,1].

FIGURE 2
The Timing of Moves with Deterministic Revisions, in the Case of $\tau_M < \tau_F$



We aim to derive circumstances under which the faster reviser dominates the Game and the unique subGame perfect equilibrium payoff coincides with his Stackelberg payoff.

Proposition 2. *Under deterministic revisions, the policy conflict and multiplicity of equilibria are resolved if and only if the implementation lags of monetary and fiscal policies are neither too similar nor too different. Formally, the Game of Chicken has a unique efficient outcome if and only if player* k *'s implementation lags are $\tau_k \in (\underline{\tau_k}, \overline{\tau_k})$, where $\underline{\tau_k}$ and $\overline{\tau_k}$ are increasing in opponent* j*'s implementation lag τ_j.*

Proof. Let us provide the proof for the parameter range $\tau_M < \tau_F$, that is, the central bank is the faster reviser. We will derive conditions for the faster reviser M's 'victory outcome' $(i_1^S i_2^S e_1^N e_2^N)$ to uniquely obtain on the equilibrium path. The alternative case $\tau_M > \tau_F$ will then follow by symmetry.

Solving by backwards induction, player F will at his revision τ_F play the best response to M_2. To uniquely ensure M's preferred outcome on the equilibrium path, one has to eliminate the other Nash equilibrium of the simultaneous Game, $(i_1^N i_2^N e_1^S e_2^S)$. Therefore it is required that M finds it optimal to play i^S, in both his initial and revision moves, even if player F plays e_1^S.

Moving backwards, we now derive the condition for i_2^S to be the unique best response to e_1^S. Intuitively, for M to be willing to undergo a costly miscoordination with F at M's revision, he has to be sufficiently compensated (in expected value) by F's subsequent move e_2^N. We have:

$$\overbrace{d(\tau_F-\tau_M)}^{\text{conflict (overheating)}} + \overbrace{c(1-\tau_F)}^{M\text{'s victory}} > \overbrace{b(1-\tau_M)}^{F\text{'s victory}}, \tag{25}$$

where the first component on the left-hand side indicates M's conflict cost of playing i_2^{S} and the second component shows his victory gain after F switching to e_2^{N} as his best response to i_2^{S}. The right-hand side reports M's payoff when he plays i_2^{N} and subsequently F plays e_2^{S} at his revision. Equation (25) can be rearranged into

$$\tau_M > \underline{\tau_M} = \tau_F \left(\frac{\overbrace{c-d}^{M\text{'s conflict cost}}}{\underbrace{b-d}_{M\text{'s coordination gain}}} \right) - \frac{\overbrace{c-b}^{M\text{'s victory gain}}}{\underbrace{b-d}_{M\text{'s coordination gain}}}. \tag{26}$$

As the final step, assuming (26) holds, we know that M will always play i_2^{S} regardless of what F plays at his initial move. To ensure that F will always play e_1^{N}, which is consistent with M's victory outcome, one needs to derive the condition for e_1^{N} to be the unique best initial play for the government even if the central bank opens with i_1^{N}. This is if the inequality in (27) holds

$$\overbrace{w\tau_M}^{\text{policy conflict (deflation)}} + \overbrace{y(\tau_F - \tau_M)}^{M\text{'s victory}} > \overbrace{x\tau_M}^{F\text{'s victory}} + \overbrace{z(\tau_F - \tau_M)}^{\text{policy conflict (overheating)}} \tag{27}$$

where the left-hand side reports the expected payoff for F if he opens with e_1^{N} and the right-hand side shows his expected payoff for opening with e_1^{S}. Equation (27) can be rearranged into

$$\tau_M < \overline{\tau_M} = \tau_F \left(\frac{\overbrace{y-z}^{F\text{'s coordination gain}}}{\underbrace{x-w}_{F\text{'s miscoordination cost}} + \underbrace{y-z}_{F\text{'s coordination gain}}} \right). \tag{28}$$

Summing up, if both (26) and (28) are satisfied, that is, $\tau_M \in \left(\underline{\tau_M}(\tau_F), \overline{\tau_M}(\tau_F)\right)$, then player M will always start with i_1^{S} knowing that the opponent always starts with e_1^{N}. We therefore have the monetary dominance region in which $\left(i_1^{\mathrm{S}} i_2^{\mathrm{S}} e_1^{\mathrm{N}} e_2^{\mathrm{N}}\right)$ is the unique outcome on the equilibrium path. By symmetry, under the case $\tau_M > \tau_F$ the necessary and sufficient conditions for the fiscal dominance region are:

$$\tau_F > \underline{\tau_F} = \tau_M \left(\frac{\overbrace{x-z}^{F\text{'s conflict cost}}}{\underbrace{y-z}_{F\text{'s coordination gain}}} \right) - \frac{\overbrace{x-y}^{F\text{'s victory gain}}}{\underbrace{y-z}_{F\text{'s coordination gain}}}, \tag{29}$$

and

$$\tau_F < \overline{\tau_F} = \tau_M \left(\frac{\overbrace{b-d}^{M\text{'s coordination gain}}}{\underbrace{c-a}_{M\text{'s miscoordination cost}} + \underbrace{b-d}_{M\text{'s coordination gain}}} \right), \tag{30}$$

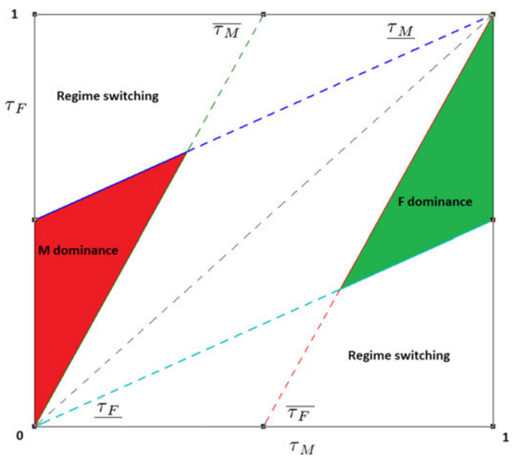
which completes the proof.

The findings are summarised in Figure 3, which shows the three equilibrium regions: monetary dominance, fiscal dominance and regime switching. The name of the latter region featuring multiple equilibria expresses the fact that within it we may observe randomising between regimes as part of the mixed strategy Nash equilibrium, or some form of switching between the three Nash equilibria.[14]

Note that the thresholds $\underline{\tau_M}$ and $\overline{\tau_M}$ are increasing in τ_F, and the thresholds $\underline{\tau_F}$ and $\overline{\tau_F}$ are increasing in τ_M. This implies that the policy implementation lags must by sufficiently – but not excessively – different from each other. Intuitively, sufficiently different revision times ensure that the deflationary policy conflict before

[14] Obviously, it is possible that even in this region the Game may end up in one of the two efficient pure strategy Nash equilibria, but the symmetry argument favours the mixed Nash equilibrium.

FIGURE 3
The Thresholds and Three Equilibrium Regions under Deterministic Revisions



the first revision would be sufficiently short, and hence not too costly for the *slower* reviser relative to his subsequent coordination gain. On the other hand, if the revision times are too different then the policy over-stimulatory conflict between revisions lasts too long and is therefore too costly for the *faster* reviser – relative to his subsequent victory gain.

Note that while each player acts as the leader exactly once in the Game, the second (i.e. faster) reviser's leadership is more effective in some sense. This is because he can take advantage of the fact that the slower reviser makes the last move of the Game and induce cooperation. For that reason there exist circumstances under which the dominance region of the faster reviser obtains, but it is never the case that the slower reviser has a dominance region.

Let us now revisit the Rogoff's (1985) suggestion of delegating monetary policy to a central bank stricter on inflation (with lower α_M), and examine its effect on the policy interaction and outcomes under revisions.

Proposition 3. *Consider the case $\tau_M < \tau_F$. Under deterministic revisions, an appointment of a more conservative (stricter) central banker leads to an enlargement of the monetary dominance region and shrinking of the regime-switching region.*

Proof. Using (20) and (26)–(28) under $\tau_M < \tau_F$ implies that

$$\frac{\partial \underline{\tau_M}}{\partial \alpha_M} > 0 \quad \text{and} \quad \frac{\partial \overline{\tau_M}}{\partial \alpha_M} < 0, \tag{31}$$

and completes the proof.

Proposition 3 suggests that a more conservative central banker reduces the (unconditional) probability of a policy conflict and miscoordination. This is because these undesirable outcomes cannot occur in the dominance regions, whereas they can occur in the regime-switching region; and because a lower α_M enlarges the range of parameters that lead to the former region. [15] Let us, however, recall Remark 2: this effect only occurs in the environment of revisions, it does not obtain in the standard simultaneous move setting.

(iv) Stochastic Revisions

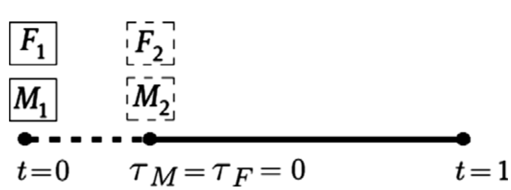
Now consider an alternative framework with probabilistic revisions whereby

$$\tau_M = \tau_F = 0 \quad \text{and} \quad \theta_M \neq \theta_F.$$

Figure 4 offers a graphical representation. The distinction of the previous set-up regarding slower and faster revisers no longer applies, as both players get their revision opportunity at the same time, if at all. Instead, the player with the lower (higher) θ will be called the *more-likely* (*less-likely*) reviser, respectively. It is assumed that at the time τ their revision opportunity arrives, the players cannot observe whether the opponent has also been granted a revision opportunity.

The probabilities that players are unable to revise their actions, θ, can be interpreted as the

FIGURE 4
The Timing of Moves with Stochastic Revisions; the Dashed Lines Express a Probabilistic Move



[15] Naturally, in the case $\tau_M < \tau_F$ considered there is no fiscal dominance region.

degrees of the policies' leadership. These are determined by various political economy and institutional factors. In terms of fiscal policy leadership, θ_F, it is arguably affected by legislation regarding government spending and taxation, the demographic trends of ageing populations affecting the size of the fiscal gap (unfunded liabilities), whether the country has an independent fiscal council and so on.

In terms of monetary leadership, θ_M, one of the important factors is whether the central bank has a legislated inflation target. The transparency of the regime's objectives and procedures, combined with more active communication to the public, enhances the central bank's ability to lead in the Game. Nevertheless, as will become apparent below, such explicit inflation targeting in no way implies, let alone requires, strict inflation targeting $\alpha_M = 0$ (for formal examination of this distinction, see Libich, 2011).

Proposition 4. *Under stochastic revisions, as under deterministic ones, we may have up to three equilibrium regions: monetary dominance, fiscal dominance, and regime switching. The dominance regions obtain if and only if the degrees of leadership are sufficiently different across the two policies.*

Proof. We will derive the necessary and sufficient conditions for the dominance regions in three steps, focusing on the case $\theta_M > \theta_F$ (the opposite case is again implied by symmetry). In step one, we derive conditions that guarantee the more-likely reviser F to find it optimal to respond to M's initial move rather than to his predicted revision.[16] This will be the case if M's revision probability is sufficiently low. In particular, for e_2^{N} to be the unique best response to i_1^{S}, it must hold that.

$$\overbrace{\theta_M y}^{M\text{'s victory}} + \overbrace{(1-\theta_M)w}^{\text{policy conflict (deflation)}} > \overbrace{\theta_M z}^{\text{policy conflict (overheating)}} + \overbrace{(1-\theta_M)x}^{F\text{'s victory}} \quad (32)$$

The left-hand side of (32) reports F's minimum possible payoff from playing e_2^{N} (i.e. the worst-case scenario whereby M's revision would lead to miscoordination and off-diagonal payoffs). The analogous condition for e_2^{S} to be the unique best response to i_1^{N} is

$$\overbrace{\theta_M x}^{F\text{'s victory}} + \overbrace{(1-\theta_M)z}^{\text{policy conflict (overheating)}} > \overbrace{\theta_M w}^{\text{policy conflict (deflation)}} + \overbrace{(1-\theta_M)y}^{M\text{'s victory}}. \quad (33)$$

The fact that $x - w \geq y - z$ implies that the condition in (32) is at least as strong as the condition in (33) for all parameter values considered. We can manipulate (32) to obtain a more informative form of the condition:

$$\theta_M > \underline{\theta_M} = \frac{\overbrace{x-w}^{F\text{'s miscoordination cost}}}{\underbrace{y-z}_{F\text{'s coordination gain}} + \underbrace{x-w}_{F\text{'s miscoordination cost}}}. \quad (34)$$

If (34) holds, that is, if M's revision occurs with a sufficiently low probability, then e_2 is the best response to i_1 and M ignores whatever F may do in i_2. This implies that eight outcomes remain possible on the equilibrium path, namely: (i) $(i_1^{\mathrm{S}} i_2^{\mathrm{S}} e_1^{\mathrm{N}} e_2^{\mathrm{N}})$; (ii) $(i_1^{\mathrm{N}} i_2^{\mathrm{N}} e_1^{\mathrm{S}} e_2^{\mathrm{S}})$; (iii) $(i_1^{\mathrm{S}} i_2^{\mathrm{S}} e_1^{\mathrm{S}} e_2^{\mathrm{N}})$; (iv) $(i_1^{\mathrm{S}} i_2^{\mathrm{N}} e_1^{\mathrm{S}} e_2^{\mathrm{N}})$; (v) $(i_1^{\mathrm{S}} i_2^{\mathrm{N}} e_1^{\mathrm{N}} e_2^{\mathrm{N}})$; (vi) $(i_1^{\mathrm{N}} i_2^{\mathrm{S}} e_1^{\mathrm{S}} e_2^{\mathrm{S}})$; (vii) $(i_1^{\mathrm{N}} i_2^{\mathrm{S}} e_1^{\mathrm{N}} e_2^{\mathrm{S}})$; and (viii) $(i_1^{\mathrm{N}} i_2^{\mathrm{N}} e_1^{\mathrm{N}} e_2^{\mathrm{S}})$.

[16] Recall that under $\tau_M = \tau_F$ a player cannot observe whether the opponent also has a revision opportunity.

In step two of the proof, we will consider the case of i_1^{S} and identify the circumstances under which M does *not* revise his initial play to i_2^{N} even if he can observe that F's initial move was e_1^{S}. Intuitively, it must be true that M's expected payoff from $\left(i_1^{\mathrm{S}} i_2^{\mathrm{S}} e_1^{\mathrm{S}} e_2^{\mathrm{N}}\right)$ is greater than his expected payoff from $\left(i_1^{\mathrm{S}} i_2^{\mathrm{N}} e_1^{\mathrm{S}} e_2^{\mathrm{N}}\right)$. This implies the inequality

$$\theta_F d + (1-\theta_F)c > \theta_M[\theta_F d + (1-\theta_F)c] + (1-\theta_M)[\theta_F b + (1-\theta_F)a], \quad (35)$$

which can be rearranged into

$$\theta_F < \frac{c-a}{b-d+c-a}. \quad (36)$$

As one would expect, F's revision probability has to be sufficiently high to compensate him for the cost of the initial conflict.

In step three of the proof, we will assume that (34) and (36) hold, and move backwards to M's starting move. The monetary dominance region with $\left(i_1^{\mathrm{S}} i_2^{\mathrm{S}} e_1^{\mathrm{N}} e_2^{\mathrm{N}}\right)$ uniquely on the equilibrium path requires that $\left(i_1^{\mathrm{S}} i_2^{\mathrm{S}} e_1^{\mathrm{S}} e_2^{\mathrm{N}}\right)$ generates a higher payoff to M than $\left(i_1^{\mathrm{N}} i_2^{\mathrm{N}} e_1^{\mathrm{S}} e_2^{\mathrm{S}}\right)$. This is because in such a case M is willing to undergo a costly pre-revision conflict knowing that his i_1^{S} induces F to switch from e_1^{S} to e_2^{N}. Such a scenario will sufficiently compensate him, given F's revision probability is high due to (36). It is ensured by the inequality

$$\overbrace{\theta_F d}^{\text{conflict (overheating)}} + \overbrace{(1-\theta_F)c}^{M\text{'s victory}} > \overbrace{b}^{F\text{'s victory}}, \quad (37)$$

and, after rearranging,

$$\theta_F < \overline{\theta_F} = \frac{\overbrace{c-b}^{M\text{'s victory gain}}}{\underbrace{c-d}_{M\text{'s conflict cost}}}. \quad (38)$$

This is a stronger condition than (36) for all parameter values considered. We can therefore conclude that for the monetary dominance region it is necessary and sufficient that (34) and (38) hold. Conditions for the fiscal dominance regions are symmetric, namely,

$$\theta_F > \underline{\theta_F} = \frac{\overbrace{c-a}^{M\text{'s miscoordination cost}}}{\underbrace{b-d}_{M\text{'s coordination gain}} + \underbrace{c-a}_{M\text{'s miscoordination cost}}}, \quad (39)$$

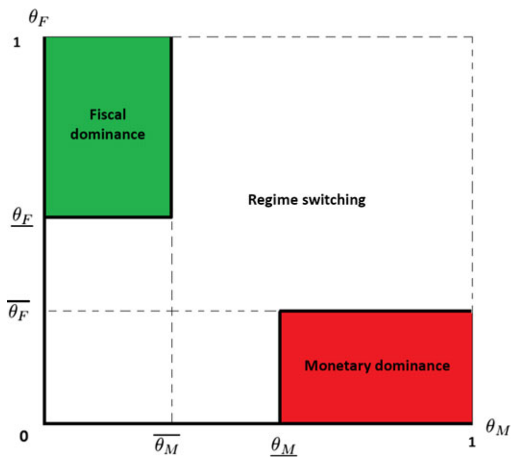
$$\theta_M < \overline{\theta_M} = \frac{\overbrace{x-y}^{F\text{'s victory gain}}}{\underbrace{x-z}_{F\text{'s conflict cost}}}, \quad (40)$$

which completes the proof.

In summary, the policies' payoffs – and willingness to undergo conflict or cooperate – evolves with both revision probabilities θ_M and θ_F even for fixed normal-form payoffs $\{a, \ldots, z'\}$. As shown in Figure 5, the dominance regions occur if and only if the degrees of leadership are sufficiently different across the policy-makers.

The fact that a stronger leadership improves a policy-maker's chances for dominance is intuitive. Equally intuitive is the fact that the oppo-

Figure 5
The Thresholds and Three Equilibrium Regions under Stochastic Revisions



nent's stronger leadership worsens these chances, because it is the *relative* strategic strength that matters. This cannot be shown in the standard Stackelberg leadership framework since only one player can be the leader.

Proposition 5. *Under stochastic revisions, the appointment of a more conservative (stricter) central banker enlarges the monetary dominance region, but it has an ambiguous effect on the size of the fiscal dominance region. For such an appointment to unambiguously shrink the regime-switching region and reduce the likelihood of policy conflict, the degree of monetary leadership must be sufficiently high.*

Proof. Under stochastic revisions, using (20) with (34) and (38)–(40) implies

$$\frac{\partial \underline{\theta_M}}{\partial \alpha_M} < 0, \quad \frac{\partial \overline{\theta_M}}{\partial \alpha_M} > 0, \quad \frac{\partial \overline{\theta_F}}{\alpha_M} > 0, \quad \text{and} \quad \frac{\partial \underline{\theta_F}}{\partial \alpha_M} \begin{cases} = 0 & \text{if } \alpha_M = \overline{\alpha_M}, \\ > 0 & \text{if } \alpha_M > \overline{\alpha_M}, \\ < 0 & \text{if } \alpha_M > \overline{\alpha_M}, \end{cases} \tag{41}$$

where $\overline{\alpha_M}$ is a highly non-linear function of λ,φ and α_F. This implies that a lower α_M increases the size of the monetary dominance region under all circumstances, but it may enlarge or shrink the other two regions. The effect of such an appointment on the probability of policy conflict thus cannot be unambiguously determined.

While deriving the necessary and sufficient condition is not possible due to the non-linearity of $\overline{\alpha_M}$, we can identify a sufficient condition. If the value of θ_M is sufficiently high, that is, greater than the threshold $\overline{\theta_M}$, then there is no fiscal dominance region. Therefore, the appointment of a more conservative central banker will surely lead to a reduction of the regime-switching region under such circumstances, and an improvement in the policy coordination prospects.

The threshold $\overline{\theta_M}$ is a decreasing function of the appointed conservative central banker's α_M, which implies an interesting insight. The more conservative the central banker to be appointed, the higher the degree of monetary leadership required to ensure that this appointment does not turn out to be counter-productive, and does not increase rather than decrease the probability of policy conflict.[17]

In summary, the policy implication is that the appointment of a conservative (stricter) central banker must be carefully considered, taking into account the existing institutional framework and the strategic policy interaction effects. Our analysis shows that implementation lags of monetary and fiscal policies, the degrees of their leadership, as well as other policy and structural parameters all play a role.[18]

Proposition 6. *Under both deterministic and stochastic revisions, changes in the slopes of the Phillips curve, λ, and IS curve, φ, have an ambiguous effect on the size of the two dominance regions (and thus the probability of policy conflict and miscoordination).*

Proof. It can be readily checked, using (20), that

$$\frac{\partial \overbrace{(c-d)}^{M\text{'s conflict cost}}}{\partial \lambda} > 0, \quad \frac{\partial \overbrace{(b-d)}^{M\text{'s coordination gain}}}{\partial \lambda} > 0, \quad \frac{\partial \overbrace{(c-a)}^{M\text{'s miscoordination cost}}}{\partial \lambda} > 0,$$

$$\text{and} \quad \frac{\partial \overbrace{(c-b)}^{M\text{'s victory gain}}}{\partial \lambda} \begin{cases} < 0 & \text{if } -\lambda^4 + \alpha_F \lambda^2 + 2\alpha_M \alpha_F < 0, \\ > 0 & \text{if } -\lambda^4 + \alpha_F \lambda^2 + 2\alpha_M \alpha_F > 0, \\ = 0 & \text{if } -\lambda^4 + \alpha_F \lambda^2 + 2\alpha_M \alpha_F = 0, \end{cases}$$

[17] Let us add that the probability of regime switching and excessive joint stimulus may differ not only across the three equilibrium regions, but also within the regime-switching region. Consider, for example, the case of $\theta_M > \underline{\theta_M}$. If $\theta_F \in (\overline{\theta_F}, \underline{\theta_F})$ the central bank knows that if it initially plays S it will surely achieve its preferred coordinated regime (i_2^S, e_2^N) after time τ – provided F gets a revision opportunity. If, however, $\theta_F > \underline{\theta_F}$ this is no longer the case.

[18] For important contributions on the effect of a conservative central banker, see also Blake and Kirsanova (2011) and Adam and Billi (2008).

and analogously for F's payoffs. In words, a higher λ increases both players' coordination gains, miscoordination costs, as well as conflict costs. Combining this with (34) and (38)–(40) implies that a change in λ in a certain direction may alter the eight relevant thresholds τ and θ in the same or opposite directions, and therefore the effect on the size of the dominance region cannot be determined in general.

Similarly, in relation to the slope of the IS curve, it can be shown, using (20), that

$$\frac{\partial(c-d)}{\partial\varphi} > 0, \quad \frac{\partial(b-d)}{\partial\varphi} > 0, \quad \frac{\partial(c-a)}{\partial\varphi} > 0, \quad \frac{\partial(c-b)}{\partial\varphi} = 0.$$

While in this case the $\overline{\theta_F}$ and $\overline{\theta_M}$ thresholds are unambiguously decreasing in φ, the sign of the effect of this IS slope parameter on the size of the dominance region is again ambiguous due to the remaining thresholds.

Intuitively, changes in λ and φ alter the players' incentives to coordinate/fight through several different channels, and the sign of the overall effect depends on the relative magnitude of these channels. It is interesting to note that even if monetary policy becomes more potent (φ and λ both increase) this will not help the central bank gain an upper hand in the Game of Chicken. Conversely, a higher potency of fiscal policy does not affect the size of the dominance regions (none of the eight thresholds), and hence cannot help the government in pressuring the central bank either. This suggests the following insight.

Remark 3. *What matters in the monetary–fiscal interaction is the leverage one policy has over the other policy through leadership and implementation lags, not so much the leverage it has over economic outcomes.*

VII Summary and Conclusions

This paper attempts to add *strategic* considerations into an investigation of monetary–fiscal policy interactions. This is because events in the aftermath of the global financial crisis have shown that strategic effects, missing in standard models of policy interactions, may play an important role.

Our analysis implies that the variety of monetary and fiscal policy mixes observed during 2010–2014 across the globe may possibly be caused by the existence of multiple equilibria in the Game of Chicken between the central bank and the government. These may, in turn, be due to differences in monetary and fiscal policy preferences, as well as due to country differences in various institutional factors such as the inflation-targeting regime, the degree of monetary and fiscal policy leadership and their implementation lags. Specifically, the paper maps the simple reduced-form New Keynesian model of Clarida *et al.* (1999) into a 2×2 game-theoretic representation, and examines monetary and fiscal policy responses to an adverse shock to output. It shows that there may be a coordination problem or even a conflict in terms of which policy should stabilise the shock. It may be that both policies delay the required stimulus in anticipation that the other policy will carry it out. Alternatively, it may be the opposite: each policy engages in a strong stimulus in order to discourage the other policy from doing so. Each policy attempts to apply its preferred weights between inflation and output variability, leading to a policy tug of war in the form of a Game of Chicken. This, however, results in an excessive overall stimulation of the economy and likely future imbalances. Finally, miscoordination or conflict may manifest as costly regime switching that increases the variability of both nominal and real variables.

What may be surprising is that policy conflict may occur even in the most favourable case in which: (i) there is no disagreement between the central bank and the government about the optimal targets for inflation and output (i.e. at the potential level); and (ii) the shock comes from the demand side of the economy (where it is perfectly observed by both policy-makers and private agents). What is less surprising is that the behaviour of inflation expectations – whether or not they are anchored – affects the likelihood of such a policy conflict.

To provide some policy recommendations, we examine the outcomes of the policy interaction in two game-theoretic frameworks with deterministic and stochastic revisions of policy actions, developed in Libich and Nguyen (2013). The analysis shows under what circumstances the policy conflict can be avoided, and efficient outcomes secured in equilibrium. Put differently, the analysis identifies circumstances under which the multiplicity of equilibria in the policy Game of Chicken are resolved and a unique efficient outcome exists.

The main policy lessons can be summarised as follows. First, miscoordination or outright conflict between monetary and fiscal policies regarding short-term stabilisation actions may be more likely than previously thought. Second, the possible occurrence of miscoordination and conflict depends on a number of structural and policy variables, including the relative length of policy implementation lags, leadership strength and the degree of conservativeness. Other structural parameters such as the slope of the Phillips and IS curves are found to be less important. Third, to avoid inferior macroeconomic outcomes the two policies need to coordinate their stabilisation actions, but such coordination tends to be problematic as it is perceived by the markets to be in breach of central bank independence. Finally, an institutional reform of the policies that alters the relative degree of their leadership in a downturn may help alleviate the policy conflict.

The analysis implies that legislating a formal procedure that guides the coordination of monetary and fiscal policy actions after a large shock could go a long way in reducing the likelihood of a policy conflict as well as uncertainty of economic agents. All of these insights have some relevance for the 2008 financial crisis, and (except for the third) they cannot be derived in conventional microfounded models in which strategic policy interaction is absent.

We acknowledge that in order to focus on game-theoretic insights about strategic short-term monetary–fiscal interactions, some concessions had to be made regarding the macroeconomic environment. Nevertheless, while these may have implications for the dynamics of longer-term policy outcomes, our main findings are largely independent of these simplifications. It is apparent that richer assumptions about the financing of fiscal stimulus or Ricardian equivalence would generally not alter the intuition of our results that monetary–fiscal policy conflict can occur in the unanchored expectations case (Proposition 1), and that the conflict can be resolved under a certain ‘coordination-enhancing’ combination of policy implementation lags (Proposition 2) or policy leadership degrees (Proposition 4). Our conclusions regarding the desirability of a conservative central banker (Propositions 3 and 5) are also likely to hold, albeit with set of relevant variables extended.

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