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On the stressful interaction of monetary and fiscal targets

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ABSTRACT

In this paper, we study an asymmetric strategic and dynamic interaction between two policy-makers, the Central Bank and the Government, during periods of fiscal stress induced by the imperative of delivering the targeted debt levels. The Central Bank determines the monetary policy and the government controls fiscal policy. Strategies are driven by inflation, public debt, and government transfer payments to households. We show that the combination of monetary expansion and fiscal contraction cannot be a Nash equilibrium and is therefore not evolutionarily stable. Yet, regimes in which both players run either expansionary or contractionary policies can be maintained both as global and local attractors. In addition, the interaction is also able to sustain an asymmetric global equilibrium in which the Central Bank uses a contractionary policy while the government opts for an expansionary fiscal policy. We provide the conditions for each of these scenarios and show that these are in line with empirical results.

1. Introduction

Fiscal and monetary policies are essential tools for creating a stable economic growth framework due to their significant influence on economic outcomes such as aggregate demand, price level, employment level, and short-run growth rates. Conversely, macroeconomic variables, such as inflation, output, exchange rates, debt, and consumer confidence impact the results of these policies. As a result, fiscal and monetary policies are closely linked and mutually affect each other. For example, increased government spending can boost aggregate demand and raise inflation above the central bank's target. Consequently, authorities should ideally coordinate their actions and decisions to benefit all decision makers (Bianchi, 2012).

Stabilizing a country's economy can therefore be challenging, especially given the asymmetric objectives and preferences of the Central Bank and the Government (Nguyen & Hoang, 2020; Stawska et al., 2022), and even more so in an environment of stress caused by inflation and public debt. Consequently, conflicting interests require coordination of monetary and fiscal policies and can curtail their efficiency. The greater the discrepancy in policy preference between the Central Bank and the Government, the less favorable the policy (Foresti, 2018).

Although the interaction between fiscal and monetary policies is well documented, we still lack an understanding of the role of various macroeconomic factors, especially the dynamic strategic implementation of fiscal and monetary policy in a context of conflict and coordination. This paper studies the strategic interaction between the Central Bank and the Government subject to economic stress and inflation, public debt, and government transfer payments to households. The government wishes to stabilize

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debt levels while keeping its political promise to increase the amount of disposable income for households. On the other hand, the Central Bank can lend a helping hand by inflating the debt level, but this would violate its inflation target.[1]

We study the evolutionary dynamics of fiscal and monetary policies in times of fiscal stress triggered by the projected over-target debt levels due to a government's excessive promised transfer. The adaptation of the well-known model of Leeper and Walker (2011) into an evolutionary game-theoretic framework allows us to analyze the impact of various factors on the evolutionary dynamics of fiscal and monetary interactions. We demonstrate that one of four different evolutionarily stable regimes can occur and show that the type of regime depends on how two conditions are met, each linked to the time preferences of the Central Bank and the Government, respectively. We further illustrate that the combination of monetary expansion and fiscal contraction does not constitute an evolutionarily stable state. Since both authorities care about their own policy targets (price stability and meeting political promises) as well as maintaining the debt target, each player will opt for the former should the other player's strategy address the latter. Therefore, an expansionary monetary policy is not a locally efficient response to a contractionary fiscal policy, and vice versa.

Our paper is part of a growing literature on the interaction between monetary policy and fiscal policy and their effects on socioeconomic activities, since the seminal contributions of Sargent and Wallace (1984) and Leeper (1991).[2] These foundational studies asserted that without a fiscal commitment to adjusting primary surplus and stabilizing public debt, monetary authorities cannot effectively control inflation. Following these influential papers, numerous studies have explored the conflict between fiscal and monetary objectives — government spending versus central bank inflation control and attempted to empirically estimate changes in the fiscal and monetary policy mix (see, for instance, Adam & Billi, 2008; Bassetto, 2002; Benhabib & Eusepi, 2005; Bilbiie et al., 2024; Branch et al., 2008; Davig & Leeper, 2011; Dixit & Lambertini, 2001; Gordon & Leeper, 2006; Kirsanova et al., 2009; Lambertini, 2006; Nordhaus, 1994; Saulo et al., 2013; Stojanovikj & Petrevski, 2024; Tabellini, 1985; Woodford, 1994, and for empirical studies on the US, see Bianchi, 2012; Cochrane, 2001; Davig & Leeper, 2011; Sims, 2011; Sims & Zha, 2006 and on the EU countries Stawska et al., 2022).[3]

Despite the extensive literature on fiscal and monetary interactions, few studies addressed the impact of fiscal stress on the policy mix. Leeper and Walker (2011) use a simple inter-temporal model to examine the impact of fiscal stress caused by an aging population. They find that unresolved fiscal gaps due to increased government spending on old-age benefits raise the risk of violating the fiscal limits, potentially undermining central bank control over inflation as taxes and spending can no longer adjust to stabilize debt. Libich et al. (2015) consider the stress of a short-term contractionary gap caused by the 2007–2009 financial crisis and a long-term fiscal gap caused by excessive promised transfers and show that the policy interactions are influenced by the extent of policy leadership, business cycle uncertainty, and the specific preferences of the Central Bank and the Government over their targets. Nguyen and Hoang (2020) adapt the Leeper and Walker (2011) model into a game theoretic framework to examine the strategic dimensions of monetary and fiscal interactions under fiscal stress caused by an aging population and demonstrate that the commitment to targets (such as inflation and government transfers) is critical to shaping policy interactions (Canzoneri et al., 2010; De Grauwe & Foresti, 2023; Leith & Wren-Lewis, 2000; Miao & Su, 2024). However, Dennis (2007, 2010) show how rational expectations and discretionary monetary policy can lead to more efficient policy choices. Afonso et al. (2019) present evidence that when a government accumulates excessive public debt, the Central Bank often takes the dominant role in addressing the stress created by fiscal authorities.

Other relevant literature uses game theory to analyze the strategic interaction between fiscal and monetary policy. However, most literature using a game-theoretic approach relies on a non-cooperative game setting in which monetary and fiscal authorities typically make decisions independently and the Nash equilibrium of the game is represented by a specific combination of monetary and fiscal policies (see Adam & Billi, 2008; Bassetto, 2002; Blackburn & Christensen, 1989; Blinder, 1982; Branch et al., 2008; Kirsanova et al., 2009; Nordhaus, 1994; Semmler & Haider, 2018; Walsh, 2001). Yet, studies have raised concerns that in such simultaneous move settings the Nash equilibria are sub-optimal Nash (Debelle & Fischer, 1994; Dixit & Lambertini, 2003). In particular, Debelle and Fischer (1994) and Dixit and Lambertini (2001) concluded that Stackelberg leadership leads to better solutions. The former argue that the Central Bank should commit to a specific inflation target to ensure a lower inflation rate. The latter showed that the resulting policy mix of the game is mainly influenced by the credibility of the decision-makers and that fiscal stress can undermine the effectiveness of Central Bank policies and lead to unstable prices.[4]

Dixit and Lambertini (2001) study the positive role of leadership in a non-cooperative game leading to synergies between both authorities, and van Aarle et al. (2002) show under which conditions policy coordination can occur in a non-cooperative game. Chortareas and Mavrodimitrakis (2017) study the strategic advantages of a first-mover in a three-stage game. Similarly to this literature, in this paper, we show that policy coordination can also occur in an evolutionary setting with repeated interactions

[1] Given the high inflation and increasing public debt levels after the COVID-19 pandemic, a better understanding of the underlying tensions and strategic elements is highly topical (see, for instance, Gregory, 2022). These tensions test the limits of the constellations of monetary and fiscal policies that ensure macroeconomic and financial stability and curtail political tensions.

[2] The importance of understanding the interaction between fiscal (F) and monetary (M) policy dates back to the studies of Cooper and Fischer (1974), Friedman (1948), Mundell (1962), Tinbergen (1954).

[3] Other literature has studied strategic policy interactions under different settings, such as inflation pressure (Libich, 2011), post-2008 financial crisis conditions featuring short-term stagnation risks and long-term high inflation due to fiscal imbalances (Libich et al., 2015), recession-induced stimulus needs (Libich & Nguyen, 2015), asset purchase programs (Wang, 2018).

[4] Other studies, such as Fialho and Portugal (2005), Saulo et al. (2013), Tanner and Ramos (2003) also supported the result that Stackelberg leadership of the Central Bank causes less social loss. However, monetary leadership does not always ensure a social optimum.

and without a clear first- and second-mover. Cardoso-Costa and Lewis (2017) obtain a result similar to ours that inflation can be used as a strategic instrument by the monetary authority if debt levels are high. In addition, some literature studies the interaction between fiscal and monetary policies under stochastic timing, including Chortareas and Mavrodimitrakis (2017), Libich (2009, 2011), Libich and Nguyen (2015), Libich et al. (2015), Nguyen and Hoang (2020). Foresti (2018) offers a broader overview on the game theoretic approaches.[5]

This paper contributes to this literature by analyzing the strategic interaction between a Government and a Central Bank in a context of fiscal stress. Our framework is specifically designed to capture the policy game that emerges under conditions of high public debt, where the risk of "fiscal dominance" – the subordination of monetary policy to fiscal needs – becomes a first-order concern for both authorities. We are not modeling the conduct of policy during "normal times", but rather the challenging episodes where debt sustainability concerns can create significant strategic tension and potentially lead to suboptimal outcomes.

We model this interaction as an evolutionary game. We show that the combination of monetary expansion and fiscal contraction cannot be a Nash equilibrium and is therefore not evolutionarily stable. However, our analysis reveals the existence of four distinct policy regimes, characterized by different combinations of policy stances. We find that cooperative outcomes, where both players run either expansionary or contractionary policies, can be stable equilibria. Furthermore, we identify conditions under which a "conflict" equilibrium can emerge, where the Central Bank pursues a contractionary policy while the government opts for an expansionary one.

The replicator dynamics, which govern the interaction between the Central Bank and the Government, model both players as myopic decision-makers. While this dynamic setup precludes backwards induction and more sophisticated conditional strategies, such an evolutionary process better captures the less far-sighted but more reactive way monetary and fiscal policies are adopted and implemented. In addition, the evolutionary dynamics of this approach replicate the bounded rationality of players and eliminate outcomes that are implausible in the given context.[6] Our assumptions align with other literature in the behavioral macroeconomics literature, which assumes myopic agents.[7] In addition, by modeling the interaction as an infinitely repeated game in which both players repeatedly and incrementally react to each other, we avoid problems linked to backward induction and the sequence of interaction (i.e., needing to clarify which authority moves first) in a Stackelberg game.

The remainder of the paper proceeds as follows. The following Section 2 studies the objective functions of each of the two players subject to the strategy profile, while Section 3 presents the evolutionary dynamics of the game by analyzing the dynamic replicator system. Section 4 discusses the main results, and Section 5 concludes the paper.

2. The static model

We first focus on the constraints faced by a representative government. While households are not an active player in the game we develop, their actions determine the government's budget constraint. Assume that in each period t, a representative intertemporal utility-maximizing household is endowed with goods x_t, and chooses a level of consumption c_t, and an investment in bonds B_t, which are defined in real terms as $b_t = B_t/P_t$, given price level P_t. The household maximizes its utility present value with a discount factor $\beta \in (0,1)$:

$$E_0 \sum_{t=0} \beta^t u(c_t), \tag{1}$$

subject to a budget constraint,

$$c_t + b_t = x_t + (\alpha_t T_t - \tau_t) + R_{t-1} \frac{b_{t-1}}{\pi_t} \tag{2}$$

given the inflation rate as the gross increase in price level $\pi_t = \frac{P_t}{P_{t-1}}$. The left side of Eq. (2) defines the total amount of household expenses, i.e. the household spends its disposable income on consumption c_t and investment bonds b_t. The right side of Eq. (2) defines how such spending is financed, i.e. through the gross nominal return R_{t-1} of the previous investment in bonds, the period's endowment x_t, and the net transfers received from the government. The latter is the difference between the transfers received $\alpha_t T_t$ and the taxes τ_t paid by the household. Since the government needs to stabilize its debt, it determines transfers and taxes based on its budget constraint. To meet the constraint and stabilize its debt, the government may decide not to offer households the entire previously promised transfer T_t in period t, but only a fraction defined by $\alpha \in (0,1]$. We can then define an expansionary transfer policy by $\alpha_t = 1$, and a contractionary transfer policy by $0 < \alpha_t < 1$ describing a case in which the government reneges on its promise.

[5] Given the criticism of static games and the limitations of a Stackelberg setting, it is surprising that considerably less attention has been paid to evolutionary interactions between fiscal and monetary authorities. To our knowledge, only Zhu and Zhang (2022) explore the evolutionary aspect of policy interactions. However, their study focuses on the interactions between the central government, the local government, and companies in formulating a stable strategy in the context of resource-based cities.

[6] We will further elaborate the evolutionary setting on Section 3 and also show that this approach determines those states as evolutionarily stable that are also strict Nash equilibria and therefore, would have been chosen under more stringent rationality assumptions.

[7] Benchimol and Bounader (2023) study optimal monetary policy with heterogeneously myopic households and firms, De Grauwe (2011) develops a model in which agents use heuristics to forecast future output and inflation (see also De Grauwe & Ji, 2019 for a broader exposition).

Note that the government is not interested in maintaining its real debt b_t but in keeping the debt-to-GDP ratio $d_t = \frac{B_t}{GDP_t}$ close to a target ratio $\bar{d} = \frac{\bar{B}_t}{GDP_t}$. Therefore, the government chooses a fiscal policy (F) that determines the lump sum tax subject to the following rule:

$$\tau_t = \tau^* + \gamma \left(d_t - \bar{d} \right) \tag{3}$$

where τ^* is the given long-run (steady-state) tax. If $1 + \gamma = 1/\beta = 1 + r$, the government's response to a deviation of the debt level from the target ratio leads to an adequate change in the tax paid by the household. Given the household's budget constraint in (2) and denoting real GDP $Y_t = \frac{GPD_t}{P_t}$, and g_t the real GDP growth rate, the government's budget constraint is defined accordingly as[8]:

$$d_t + \frac{\tau_t}{Y_t} = \alpha_t \frac{T_t}{Y_t} + \frac{R_{t-1} d_{t-1}}{\pi_t g_t} \tag{4}$$

For simplicity, we assume that tax, transfer, and growth rate are constant. Also, debt in previous period is at its target level $\bar{d}$, and interest rate is at its long-run rate R. We further consider that the tax-to-GDP ratio is $\tau = \tau^*/Y$, and the transfer-to-GDP ratio (see Bassett et al., 1999) is $\tilde{T} = T/Y$, leading to the simplified budget constraint:

$$d_t + \tau = \alpha_t \tilde{T} + \frac{R\bar{d}}{\pi_t g} \tag{5}$$

Therefore, the transfer rate can increase if the government is willing to incur a higher debt ratio, applies a higher long-term tax, faces a higher inflation, or households have a higher discount rate. Consequently, transfers decrease if the government is subject to a high existing/target debt ratio. Note that if the government initially promises a large transfer by setting $\alpha = 1$ and

$$\bar{d} + \tau < \tilde{T} + \frac{R\bar{d}}{\bar{\pi} g} \tag{6}$$

the government either has to reduce the transfer $\left(\alpha_t < 1\right)$ or the central bank has to inflate the debt $\left(\pi_t > \bar{\pi}\right)$ to keep the debt at the target level.

For its part, the representative Central Bank decides which monetary policy action (MP) to adopt considering the inflation target $\bar{\pi}$ and using a feedback rule for the interest rate (Taylor-type rule), i.e. it fixes the nominal interest rate, while maintaining the usual mandate of price stability. Then,

$$R_t = R^* + \sigma \left(\pi_t - \bar{\pi} \right), \tag{7}$$

where $\bar{\pi}$ is the inflation target and σ is the strength of the policy reaction to deviations of inflation from the target. Parameter R^* is the nominal interest rate that results from target inflation and the natural real interest rate, denoted by $\bar{r}$, i.e. $R^* = (1 + \bar{r})\bar{\pi}$. Hence, in each period the nominal interest rate is subject to an inflation gap given by the right side of (7). If inflation exceeds the target rate, the Central Bank will increase the gross nominal interest rate beyond the target rate.

2.1. Discussion of Key modeling assumptions

It is important to note the institutional separation of instruments in our model. The government's tool is the fiscal transfer (T), and the central bank's tool is inflation (π). This is a standard and realistic representation of the primary division of policy tools in modern economies. While monetary policy has distributional consequences (e.g., via the "inflation tax"), direct fiscal transfers to households are the exclusive domain of the government. Our formulation respects this institutional reality. However, it is important to acknowledge that central banks, even while officially targeting inflation, will intervene to ensure financial stability or prevent market collapse (see, De Grauwe, 2013; Altavilla et al., 2016; Acharya et al., 2019; Court of Justice of the European Union, 2015).[9]

Moreover, to maintain analytical tractability and isolate the core strategic mechanisms of the policy game, we consider several simplifying assumptions. Here, we justify these choices and argue for the conceptual robustness of our results: We assume that the growth rate of the economy, g, is exogenous. This is a simplification that allows us to derive closed-form solutions for the

[8] Here, we ignore public expenditure, which we acknowledge is a critical element for fiscal policy and bears political impact. However, we claim that in the context of our simple model, adding public spending will not alter the results we obtain. Note that in our simple mode, we do not endogenize the real GDP growth rate and can thus ignore differences in the multiplier effect. Therefore, changes to public spending and household transfers are equivalent for a government in this simplified context.

[9] Such literature demonstrates that: (i) The ECB's official justification for the OMT was to "safeguard an appropriate monetary policy transmission and the singleness of the monetary policy" (as stated in its official press release). (ii) In practice, this meant stopping the sovereign debt panic that was threatening to tear the Eurozone apart. (iii) The mere announcement of a credible backstop (the OMT) was enough to calm markets, proving the crisis was driven by a panic that the central bank was uniquely positioned to stop. (iv) This provides a real-world, high-stakes example of a central bank expanding its toolkit to include financial stability and crisis prevention, even when these actions are not part of its narrow, primary mandate. This is precisely the "stressful interaction" of this paper's models. Specifically, De Grauwe (2013) argues that the Eurozone was inherently fragile because its member states issued debt in a currency they could not control, making them vulnerable to self-fulfilling liquidity crises (i.e., market panics). The OMT, in this view, was the ECB finally stepping into the role of a "lender of last resort" for sovereigns, a function necessary to stabilize a monetary union. This directly supports the idea of a central bank acting to prevent a collapse that its primary mandate does not explicitly cover. Altavilla et al. (2016) show that the announcement of OMT alone – the program was never actually used – was enough to dramatically lower sovereign bond yields in stressed countries like Italy and Spain. Hence, the central bank's credible commitment to intervene was sufficient to stop the panic, confirming its powerful role in ensuring financial stability.

stability of the different policy regimes. A formal robustness check with endogenous growth, where government spending might affect productivity, is a valuable extension but would add significant complexity. However, we argue that our core results are conceptually robust as we show in Appendix B. The fundamental strategic tension in our model arises from how fiscal transfers (T) and inflation (π) directly affect the government budget constraint and, consequently, the loss functions of the two players. As long as the fundamental mechanics of the budget constraint are preserved – i.e., as long as higher inflation still erodes the real value of debt, and higher transfers still increase it – the signs of the partial derivatives that determine the strategic incentives will not change. While the quantitative boundaries of the stability regions would shift, the existence of the four qualitatively different strategic regimes we identify is structurally robust.

Notice that our central bank loss function does not include an output gap term, a staple of standard Taylor-type rules. This is a deliberate choice to focus the analysis on periods of fiscal stress. The literature on fiscal dominance (e.g., Sargent & Wallace, 1981) shows that when debt sustainability is at risk, the debt-inflation trade-off can become the dominant concern for the monetary authority, potentially superseding its focus on stabilizing the business cycle. Our model is designed to be an exploration of exactly these kinds of episodes, where the strategic game over debt and inflation becomes the primary driver of policy outcomes.

For simplicity, we assume that both policymakers can single-handedly deliver the debt target ratio. The two pure strategies of the representative central bank are given by:

1. **Contractionary Monetary Policy — CM**: Strategy CM implies that the central bank equates the inflation level to the target inflation, $\pi_t = \bar{\pi}_t$.
2. **Expansionary Monetary Policy — EM**: Strategy EM implies that the central bank put their main objective aside, i.e. it does not follow the monetary rule (7), and raises inflation rate to a level exceeding target inflation, $\pi_t^E > \bar{\pi}_t$. In other words, it inflates the debt, if the government lives up to its promised transfers $\left(\alpha_t = 1\right)$.
   We have,

$$\begin{aligned} \bar{d} + \tau &= \tilde{T} + \frac{R\bar{d}}{\pi_t^E g} \\ \pi_t^E &= \frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right) g} > \bar{\pi} \end{aligned} \tag{8}$$

We can further define the two pure strategies of the representative government as:

1. **Expansionary fiscal policy — EF**: Strategy EF means the government transfers the promised amount at $\alpha_t = 1$.
2. **Contractionary Fiscal Policy — CF**: Strategy CF implies that the government reduces the transfer ($\alpha_t^C < 1$) to keep debt at the target ratio, assuming the central bank does not choose to take actions $\left(\pi_t = \bar{\pi}\right)$.
   We have,

$$\bar{d} + \tau = \alpha_t^C \tilde{T} + \frac{R\bar{d}}{\bar{\pi} g} \tag{9}$$

   and solving for α_t^C,

$$\alpha_t^C = \frac{\bar{d} + \tau - \frac{R\bar{d}}{\bar{\pi} g}}{T} \tag{10}$$

   We can see that the government only needs to reduce transfers, (i.e. $\alpha_t^C < 1$) if the promised transfers T are high (i.e. the government overpromised) or the tax rate, the target inflation and the growth rate are low. More specifically, since the actual transfer can range between 0 and the full amount, we have $0 < \alpha_t^C < 1$ for which it must hold:

$$\begin{aligned} &\text{For } g > R/\pi : \ \frac{\bar{\pi} g \tau}{R - \bar{\pi} g} < \bar{d} < \frac{\bar{\pi} g(\tilde{T} - \tau)}{\bar{\pi} g - R} \\ &\text{For } g < R/\pi : \ \frac{\bar{\pi} g(\tilde{T} - \tau)}{\bar{\pi} g - R} < \bar{d} < \frac{\bar{\pi} g \tau}{R - \bar{\pi} g} \end{aligned} \tag{11}$$

Notice that the first part of the inequalities always holds as long as the target ratio $\bar{d}$ is strictly positive. We can see that α_t^C increases in τ, $\bar{\pi}$ and g and decreases in R.

Given the previously obtained values for each of the four pure strategies, we have the following results for each of the four possible pure strategy profiles:

1. Contractionary monetary policy and contractionary fiscal policy — pure strategy profile (CM, CF):

$$\pi_t = \bar{\pi}, \ \ \alpha_t = \alpha_t^C, \ \ d_t = \bar{d} \tag{12}$$

   In the (CM, CF) profile, the central bank prioritizes achieving the inflation target while the government stabilizes debt by cutting public transfer. Consequently, the economy exhibits a stable inflation rate and stable real debt.
2. Contractionary monetary policy and expansionary fiscal policy — pure strategy profile (CM, EF):

$$\pi_t = \bar{\pi}, \ \ \alpha_t = 1 \tag{13}$$

and thus,

$$d_t + \tau = \tilde{T} + \frac{R\bar{d}}{\bar{\pi}g} \tag{14}$$

causing a temporary deficit at the steady-state tax

$$d_t = \tilde{T} + \frac{R\bar{d}}{\bar{\pi}g} - \tau > \bar{d} \tag{15}$$

In (CM, EF), both policymakers commit to their primary targets, i.e. inflation for the central bank and promised transfers for the government. Therefore, under this profile, both inflation and government transfers are stable. However, since no party is responsible for managing debt, public debt ratio exceeds its target.

3. Expansionary monetary policy and contractionary fiscal policy — pure strategy profile (EM, CF):

$$\pi_t = \pi_t^E, \quad \alpha_t = \alpha_t^C \tag{16}$$

and thus

$$d_t + \tau = \alpha_t^C \tilde{T} + \frac{R\bar{d}}{\pi_t^E g} \tag{17}$$

leading to a temporary surplus

$$d_t = \bar{d}\left(2 - \frac{R}{\bar{\pi}g}\right) + \tau - \tilde{T} < \bar{d} \tag{18}$$

In (EM, CF), both policymakers set aside their primary objectives and try to reduce the level of debt. The joint efforts from both authorities would be excessive, resulting in a decrease in public debt below the target level at the cost of an increased inflation rate. We will see that since each policymaker hopes that the other addresses the debt issue, this strategy profile is unlikely to hold in the long run.

4. Expansionary monetary policy and expansionary fiscal policy — pure strategy profile (EM, EF):

$$\pi_t = \pi_t^E, \quad \alpha_t = 1, \quad d_t = \bar{d} \tag{19}$$

In (EM, EF), the government fulfills its promise by providing the full amount of public transfers, while the central bank manages the public debt by allowing the price level to increase. Under this profile, stable real debt is met with increased inflation.

2.2. On the objective functions

Let the objective function be given by $u_i(s_i, s_j)$ for player $i \in \{C, G\}$, with C being the central bank and G the government, using strategy s_i against another player $j \in \{C, G\}$ with $i \neq j$, who is using strategy s_j. We therefore assume that a value (which we call *payoff* in line with the game theoretic literature) of the function increases if a player achieves an outcome that is more in line with their mandate or objective. Since the payoffs depend on the strategies of both players, a player's objective function is also their reaction function. Consequently, the monetary authority chooses a response that best achieves its mandate based on its preferences and subject to the action of the government.

While the central bank's mandate is not linked to fiscal sustainability, it still has an interest in sustaining a low debt-to-GDP ratio. Since higher interest rates entail increased debt servicing costs, central banks are faced with a trade-off between maintaining price levels and ensuring government solvency. Svensson (2017) shows that a tighter monetary policy to control the level of debt leads to an increase in the debt-to-GDP ratio. Tightening monetary policy more than necessary for inflation stabilization will raise real household debt and dampen nominal GDP, increasing the debt-to-GDP ratio. In addition, as central banks consider financial stability more imperative, avoiding high debt ratios becomes an objective (Bertsch et al., 2025; Checherita-Westphal et al., 2024, see also Cawley & Finnegan, 2019; Fouejieu et al., 2019). Consequently, central banks are less willing to run a tighter monetary policy if high debt ratios threaten economic or financial stability.[10]

Similarly, the government follows a strategy which according to its preferences, helps it to achieve its political objectives, which balance public debt against meeting political promises, given the economic environment and the central bank's strategy. Consistent with the intuition of Leeper (1991), Leeper and Walker (2011), Sargent and Wallace (1981), and Sims (1994), by allowing for

[10] In this paper, we consider the case in which fiscal and monetary policies are set during economic stress and which requires authorities to set temporary targets for the debt-to-GDP ratio and inflation. The central bank's utility function in (20) therefore defines its reaction in response to a changing economic environment causing and caused by higher public debt. In addition, the temporary targets define the amount of the debt-to-GDP ratio that is incompatible with future fiscal adjustments and the amount of inflation the central bank must forgo to stabilize it. Under fiscal orthodoxy, the central bank is fully committed to responding robustly to inflation deviations from its fixed target with the nominal interest rate of a one-period bond. Here, however, the central bank faces a situation in which the fiscal adjustment required to stabilize the high debt stock is too costly for the economy and decides to resort to inflation to correct the large fiscal imbalance. This parameterization corresponds to a combination of passive monetary and non-Ricardian fiscal policies. It is worth noting that, in this case, the central bank abandons the objective of stabilizing inflation to support the objective of correcting the fiscal imbalance (see also Libich & Nguyen, 2015; Libich et al., 2015; Nguyen & Hoang, 2020 for similar assumptions). Note that we do not exclude the standard case, which is simply obtained by setting ϕ_M to a low value leading to a violation of condition (33), thus leading to regime two or regime four.

preemption of public debt dynamics (Goodfriend, 2011; Svensson, 2017; Zhao, 2023), we define the central bank's monetary policy objective/reaction function $u_C(s_C, s_G)$ as[11]:

$$u_C(s_C, s_G) = -\phi_M \left(d_t - \bar{d}\right)^2 - \delta_M \left(\pi_t - \bar{\pi}\right)^2 \tag{20}$$

where ϕ_M is the weight of the central bank's policy on the gap between the actual and the target debt-to-GDP ratio. Parameter δ_M is the weight of the central bank's policy on the gap between the actual inflation and the inflation target level. The government's objective function $u_G(s_G, s_C)$ is defined equivalently as

$$u_G(s_G, s_C) = -\phi_F \left(d_t - \bar{d}\right)^2 - \varphi_F \left(1 - \alpha_t\right)^2 \tag{21}$$

where, similar to the central bank, ϕ_F is the weight of the government's policy on the gap between the actual and the target debt-to-GDP ratio, while φ_F is the weight of the government's policy on the transfers relative to the promised amount offered to households.

By setting in the results in (12)–(19) into the respective utility functions (20) and (21), we obtain the expected utilities of each player at the pure strategy profiles:

1. (CM, CF):

$$u_C(CM, CF) = 0 \tag{22}$$

$$u_G(CF, CM) = -\varphi_F \left(\frac{\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}}{\tilde{T}}\right)^2 \tag{23}$$

2. (CM, EF):

$$u_C(CM, EF) = -\phi_M \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}\right)^2 \tag{24}$$

$$u_G(EF, CM) = -\phi_F \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}\right)^2 \tag{25}$$

3. (EM, CF):

$$u_C(EM, CF) = -\phi_M \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}\right)^2 - \delta_M \left(\frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right) g} - \bar{\pi}\right)^2 \tag{26}$$

$$u_G(CF, EM) = -\phi_F \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}\right)^2 - \varphi_F \left(\frac{\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}}{\tilde{T}}\right)^2 \tag{27}$$

4. (EM, EF):

$$u_C(EM, EF) = -\delta_M \left(\frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right) g} - \bar{\pi}\right)^2 \tag{28}$$

$$u_G(EF, EM) = 0 \tag{29}$$

Note that if the central bank opts for a contractionary monetary policy and given Eqs. (23) and (25), the government achieves a higher utility by also choosing a contractionary policy if

$$\varphi_F \left(\frac{\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}}{\tilde{T}}\right)^2 < \phi_F \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}\right)^2 \tag{30}$$

which can be equivalently written as

$$\tilde{T}^2 > \frac{\varphi_F}{\phi_F} \tag{31}$$

That is, the government coordinates with the central bank on a contractionary policy if the size of the transfer-to-GDP ratio is sufficiently large, i.e. greater than the importance the government places on household transfers φ_F, relative to the importance it places on the gap between actual to target debt-to-GDP ratio ϕ_F. Put differently, the government will opt for a contractionary transfer policy if the importance the government places on household transfers φ_F is sufficiently low.

[11] Previous literature features similar assumptions as our framework. Accounting for the fact that the output gap is related to both inflation and debt-to-GDP ratio, would entail significantly more complex underlying dynamics, which are not easily tractable without providing additional significant insights. For example, Leeper and Walker (2011) indicate that when the economy hits its fiscal limits caused by unresolved public debt, monetary policy may lose its effectiveness in controlling inflation. Libich et al. (2015) infer that the central bank may have different foci over time, it may prioritize the underperforming economy in the short term and the inflationary consequences of public debt in the long term.

Given Eqs. (24) and (28), the central bank will choose an expansionary policy if the government is also running an expansionary policy if

$$\phi_M \left(\tilde{T} + \frac{R\bar{d}}{\bar{\pi}g} - \tau - \bar{d} \right)^2 > \delta_M \left(\frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right) g} - \bar{\pi} \right)^2 \tag{32}$$

which can be equivalently written as

$$\left(\frac{\bar{d} + \tau - \tilde{T}}{\bar{\pi}} \right)^2 > \frac{\delta_M}{\phi_M} \tag{33}$$

Given that we can write the numerator as $\left(\bar{d} - (\tilde{T} - \tau)\right)^2$, the central bank coordinates on an expansionary monetary policy if the promised size of the transfer-to-GDP ratio is sufficiently small and the target debt rate is high. Since the term is squared, condition (33) also holds if the debt target is small but the government has promised a substantial net transfer to households. More specifically, the squared difference between the target debt-ratio and the current government net payments at the target rate of inflation needs to be greater than the ratio of the weight the central bank places on avoiding a gap between actual and target inflation relative to the weight it places on avoiding a deviation from the target debt-to-GDP ratio. Consequently, the central bank will opt for an expansionary monetary policy to assure the targeted debt level if the importance the central bank places on target inflation is sufficiently low relative to the importance of stabilizing or reducing public debt, especially if the government is promising high net transfers or the country is suffering from high long-term debt which positively affects $\bar{d}$.

3. Evolutionary dynamics

So far, we have only considered the game in the context of the four pure strategy profiles. In addition, we have not discussed through which mechanism the central bank and the government will update their policies and reach an equilibrium. We define $x \in [0, 1]$ as the degree of the contractionary monetary policy of the central bank, and therefore, $(1 - x)$ as the degree to which the policy is expansionary. The central bank's policy set is then given by a spectrum in which its policy ranges from strongly expansionary ($x \approx 0$) to strongly contractionary ($x \approx 1$). Similarly, let $y \in [0, 1]$ indicate the degree to which the government's fiscal policy is contractionary and thus, $(1 - y)$ defines the degree to which it is expansionary.

Empirical evidence shows that central banks are forward-looking to varying but very limited degrees (see Brzoza-Brzezina et al., 2013). Similarly, governments lack a long-term perspective, often shorter than their legislative period (see Lodge & Wegrich, 2014; Ogami, 2024). Given the complexity of their economic environment, we assume that both players are not fully rational nor can they rely on perfect information. Instead, we assume that both are myopic and gradually adapt their mixed strategy as part of a dynamic game relying mostly on previous experience. Under most circumstances, each player evaluates whether a small change in the degree of the contraction of their policy helps to meet their target better given by their respective objective function. Consequently, each actor updates their policy given the other actor's current policy in an incremental manner. Since each player is at least partially and myopically forward-looking, we further assume that sometimes the government and the central bank update their policies based on idiosyncratic information and projections.

Under these assumptions, we can study the dynamics of this repeated interaction on the basis of replicator dynamics which account for the incompleteness of the players' information and their bounded rationality. Instead of an interaction between members of two larger societies, however, the replicators describe here an internal updating process.[12] An additional advantage of this approach is that the replicator dynamics represent a larger variety of learning processes in which individuals cannot rely on perfect information. For example, Börgers and Sarin (2000) show that the replicator dynamic illustrates reinforcement learning if slight increases in the overall payoffs encourage strategy change. Similarly, replicator dynamics are equivalent to Q-learning without exploration (Kianercy & Galstyan, 2012).

On the other hand, the limited forward-looking behavior of both players will cause the latter to react to new distinct and individual information and projections. This behavior translates into deviations from existing strategy profiles which we will use for our stability analysis of the following dynamic system.[13] We will show that, in this case, the evolutionarily stable states are equivalent to the set of strict Nash equilibria in this game. Consequently, more stringent assumptions about the rationality of both players will lead to similar results.

The dynamics of this game can be represented by the following replicator equations:

$$\dot{x} = (1 - x)x \left[\{y\, u_C(CM, CF) + (1 - y)u_C(CM, EF)\} - \{y\, u_C(EM, CF) + (1 - y)\, u_C(EM, EF)\} \right] \tag{34a}$$

$$\dot{y} = (1 - y)y \left[\{x\, u_G(CF, CM) + (1 - x)\, u_G(CF, EM)\} - \{x\, u_G(EF, CM) + (1 - x)\, u_G(EF, EM)\} \right] \tag{34b}$$

[12] Instead of a population of players in which each player chooses from a strategy set of pure behavioral rules, the government and central bank choose a mixed strategy where the weights do not illustrate mixed population state/profile but the degree of the contractionary policy. Strategy updating occurs in part as a deliberate or trial and error process in which an individual compares a newly realized payoff to earlier payoffs.

[13] For example, the central bank reacts to some new exogenous information and based on this, updates its strategy mix in an idiosyncratic manner.

Table 1
Summary of critical variables and their values chosen for the simulations in Fig. 1. Note that it is difficult to calibrate the correct quantitative values, but we have chosen plausible parameter values and are only interested in the qualitative results of our model in relation to the inequalities (31) and (33). The values for OECD countries are given in the last row. Note that transfer-to-GDP ratios very slightly exceed OECD values. However, the data range only includes social expenditures. For details, see https://www.oecd.org/en/data.html and https://www.imf.org/external/datamapper/datasets. For simplicity, we assumed that $\varphi_F = 1 - \phi_F$ and $\delta_M = 1 - \phi_M$ and thus the objective function is simply a convex combination of the two objectives.

Var	Meaning	Fig. 1(a)	Fig. 1(b)	Fig. 1(c)	Fig. 1(d)	OECD range
$\bar{\pi}$	target rate of inflation	1.03	1.02	1.02	1.02	1.01–1.03
g	GDP growth rate	1.04	1.04	1.04	1.04	1.01–1.04
R	long-run nominal interest rate	1.06	1.04	1.04	1.04	1.02–1.06
τ	tax-to-GDP ratio	0.4	0.4	0.3	0.2	0.25–0.46
$\tilde{T}$	transfer-to-GDP ratio	0.3	0.4	0.4	0.25	0.15–0.32
$\bar{d}$	target debt-to-GDP ratio	1.2	0.9	1.2	0.5	0.4–1.8
φ_F	Gov weight of transfer ratio	0.6	0.1	0.1	0.2	
ϕ_F	Gov weight of debt gap	0.4	0.9	0.9	0.8	
δ_M	CB weight of price stability	0.5	0.3	0.5	0.8	
ϕ_M	CB weight of debt gap	0.5	0.7	0.5	0.2	
Share of initial conditions going to:						
	(EM, EF)	1.0	0.0	0.515	0.0	
	(CM, CF)	0.0	1.0	0.485	0.0	
	(CM, EF)	0.0	0.0	0.0	1.0	
Inequality (31)				$\tilde{T}^2 > \varphi_F/\phi_F$		
Inequality (33)				$\left((\bar{d}+\tau-\tilde{T})/\bar{\pi}\right)^2 > \delta_M/\phi_M$		

Note that since the strategies of both players affect the utilities of each player, the strategies are coupled. According to system (34), the degree $x \in [0,1]$ increases if the expected payoff of a more contractionary monetary policy exceeds the expected payoff of a more expansionary monetary policy given the government's mixed strategy. Equivalently, degree $y \in [0,1]$ increases if a more contractionary fiscal policy grants a higher expected payoff than a more expansionary fiscal policy given the central bank's mixed strategy. Simplifying, we have:

$$\dot{x} = \frac{(1-x)x\left(R\bar{d} - \bar{\pi}g\left(\bar{d}+\tau-\tilde{T}\right)\right)^2\left((2y-1)\phi_M\left(\bar{d}+\tau-\tilde{T}\right)^2 + \bar{\pi}^2\delta_M\right)}{\bar{\pi}^2 g^2\left(\bar{d}+\tau-\tilde{T}\right)^2} \tag{35a}$$

$$\dot{y} = \frac{(1-y)y\left(R\bar{d} - \bar{\pi}g\left(\bar{d}+\tau-\tilde{T}\right)\right)^2\left((2x-1)\phi_F\tilde{T}^2 - \varphi_F\right)}{\bar{\pi}^2 g^2\tilde{T}^2} \tag{35b}$$

An equilibrium is then defined by those states in the state space in which $\dot{x} = \dot{y} = 0$. The corner solutions $(x,y) \in \{(0,0,),(0,1),(1,0),(1,1)\}$ constitute fixed points.[14] In addition, an interior equilibrium fixed point occurs if

$$(2y-1)\phi_M\left(\bar{d}+\tau-\tilde{T}\right)^2 + \bar{\pi}^2\delta_M = 0$$
$$\tilde{T}^2(2x-1)\phi_F - \varphi_F = 0$$

Solving both simultaneously, we obtain

$$x_0 = \frac{1}{2}\left(1 + \frac{\varphi_F}{\tilde{T}^2\phi_F}\right) \tag{36a}$$

$$y_0 = \frac{1}{2} - \frac{\bar{\pi}^2\delta_M}{2\phi_M\left(\bar{d}+\tau-\tilde{T}\right)^2} \tag{36b}$$

The existence of the interior fixed point then requires that inequalities (31) and (33) hold. To help the following discussion, we summarize the relevant parameters in Table 1.

We have the following observations:

[14] The dynamics can also be expressed in discrete replicator dynamics. The fixed points are identical, and the dynamics are the same in terms of global and local attractors. However, the stability conditions require a lower and upper bound and we therefore opt for a continuous representation for clarity of exposition. Furthermore, we can see that the system (35) is neutrally stable in the special case in which

$$\bar{d} = \frac{\bar{\pi}g(\tilde{T}-\tau)}{\bar{\pi}g - R}$$

at which the government either reduces the transfer rate to $\alpha = 0$ for $g < R/\pi$ or transfers the full promised amount to households for $g > R/\pi$ based on (19). We will ignore this special case.

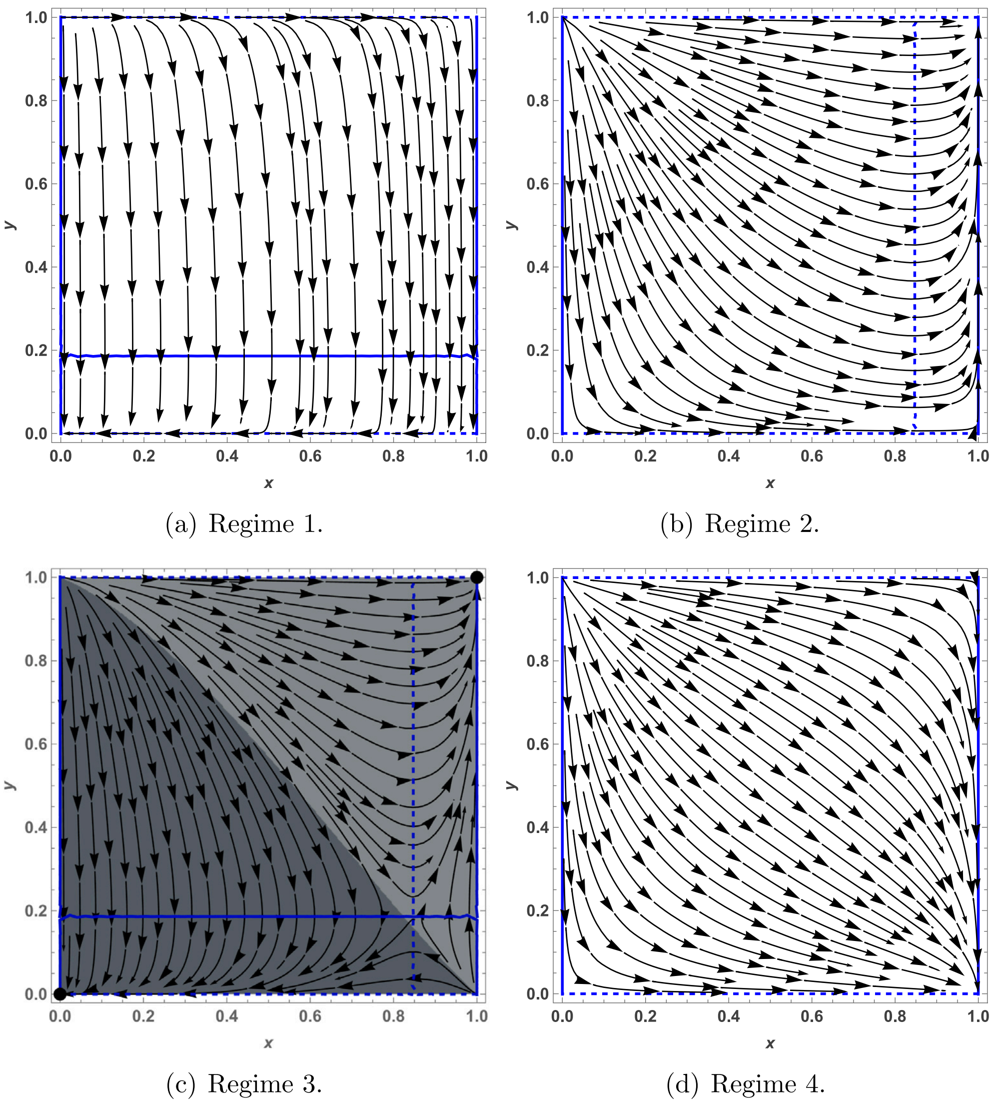


Fig. 1. The figure shows a stream plot for each of the four regimes in which the vectors indicate the direction of the dynamics. x determines the degree of the contractionary monetary policy, while y determines the degree of the fiscal policy. The blue curves represent the nullclines of the dynamical systems (solid for $\dot{x} = 0$ and dashed for $\dot{y} = 0$). Consequently, the direction of movement of the vectors shifts after a nullcline is crossed. Fixed states occur where a dotted and solid nullcline intersect. Shaded areas in Regime 3 indicate the basin of attraction for each of the two locally attracting equilibria. Parameters are given in Table 1.

Observation 1. *Inequality (31) implies that the square of the transfer ratio must exceed the ratio of the government's commitment to adhere to its fiscal promises over its preference for a balanced budget. It therefore holds if the government initially made significant promises. It fails to hold if a government cares more about re-election and short-term political survival than the long-term economic impact of overindebtedness (which it can pass on to a future government). The latter ratio strictly depends on the government's time preferences. Consequently, a government with a strong preference for current returns and subject to imminent political pressure needs to have promised more transfers for the inequality to hold. With a more farsighted government, the inequality also holds at lower promised transfer levels.*

Observation 2. *The left side of inequality (33) depends on the absolute difference between the target debt and the real net transfer to households relative to GDP. The right-hand side of condition (33) equals the ratio of the weight that the central bank places on price stability and the weight it puts on public debt. The ratio on the right-hand side will be larger if a central bank is more concerned about the immediate distortionary impact of price changes (and thus with current price stability) relative to its concern about the future implications of current additional borrowing. Assuming that the rate of inflation is positively correlated with the importance that a central bank places on curtailing further increases to the price level, (33) is violated if inflation is very high and holds if prices are stable.*

Consequently, both inequalities are more likely to be violated if both the government and the central bank have a strong preference for the present, i.e. political opportunism and survival for the government and price stability for the central bank. In addition, it is plausible to assume that a populist government is likely to care most about pleasing its constituents while putting little weight on the economic impact of its policies. A technocratic government, on the other hand, is more likely to show little political opportunism while caring most about curbing public debt. In the former case, condition (31) is likely violated while it is likely to hold in the latter case.

The left-hand side of inequality (33) is more likely to hold if the government is currently promising a small transfer to households, i.e. it has not over-promised, or it has deviated more repeatedly from a balanced budget in the past ($|\bar{d}|$ is large). More importantly, the inequality also holds for countries which have to service a high public debt.[15] In the following, we evaluate the stability of each of the fixed points. We obtain the following proposition.

Proposition 1. *The equilibrium* $(0,1)$ *is generally unstable. Furthermore, if conditions* (31) *and* (33) *are met and, therefore, the interior fixed point exists and is unstable, the fixed points* $(0,0)$ *and* $(1,1)$ *are local attractors while* $(1,0)$ *is an unstable fixed point. In the absence of the interior equilibrium, the fixed point* $(1,0)$ *can be sustained as a global attractor.*

Proof. Let $a = \bar{d} + \tau - T$. For the replicator dynamic system (35), we obtain the following eigenvalues of the Jacobian of the system at each of the fixed points:

$$(x=0, y=0): \ \lambda_{00} = \frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \left(\bar{\pi}^2\delta_M - a^2\phi_M\right)}{\bar{\pi}^2 a^2 g^2}, \ \lambda_1 = -\frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \left(\tilde{T}^2\phi_F + \varphi_F\right)}{\bar{\pi}^2 g^2 \tilde{T}^2} \tag{37a}$$

$$(x=0, y=1): \ \lambda_{01} = \frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \left(\bar{\pi}^2\delta_M + a^2\phi_M\right)}{\bar{\pi}^2 a^2 g^2}, \ -\lambda_1 = \frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \left(\tilde{T}^2\phi_F + \varphi_F\right)}{\bar{\pi}^2 g^2 \tilde{T}^2} \tag{37b}$$

$$(x=1, y=0): \ \lambda_{10} = \frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \left(-\bar{\pi}^2\delta_M + a^2\phi_M\right)}{\bar{\pi}^2 a^2 g^2}, \ \lambda_2 = \frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \left(\tilde{T}^2\phi_F - \varphi_F\right)}{\bar{\pi}^2 g^2 \tilde{T}^2} \tag{37c}$$

$$(x=1, y=1): \ \lambda_{11} = \frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \left(-\bar{\pi}^2\delta_M - a^2\phi_M\right)}{\bar{\pi}^2 a^2 g^2}, \ -\lambda_2 = -\frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \left(\tilde{T}^2\phi_F - \varphi_F\right)}{\bar{\pi}^2 g^2 \tilde{T}^2} \tag{37d}$$

Since all parameters, except for a, are strictly positive, equilibrium $(0,1)$ is unstable. Furthermore, we see that the denominator of all eigenvalues as well as the first multiplier in the numerator are strictly positive. The sign of each eigenvalue is defined by the sign of the second multiplier and therefore determined by conditions (31) and (33). Therefore, we refer to our earlier discussion of the two inequalities for an economic interpretation of the eigenvalues. If both conditions are met and therefore, the interior fixed point exists, fixed points $(0,0)$ and $(1,1)$ have negative eigenvalues while $(1,0)$ is an unstable fixed point. If neither condition holds and thus in the absence of the interior equilibrium, fixed point $(1,0)$ is stable.

The eigenvalues for the interior fixed point are given by:

$$(x=x_0, y=y_0): \ \lambda_{xy1} = -\frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \sqrt{a^4\phi_M^2 - \bar{\pi}^4\delta_M^2}\sqrt{\tilde{T}^4\phi_F^2 - \varphi_F^2}}{2\bar{\pi}^2 a^2 g^2 \tilde{T}^2 \sqrt{\phi_F}\sqrt{\phi_M}}, \tag{38a}$$

$$\lambda_{xy2} = \frac{\left(R\bar{d} - \bar{\pi}ag\right)^2 \sqrt{a^4\phi_M^2 - \bar{\pi}^4\delta_M^2}\sqrt{\tilde{T}^4\phi_F^2 - \varphi_F^2}}{2\bar{\pi}^2 a^2 g^2 \tilde{T}^2 \sqrt{\phi_F}\sqrt{\phi_M}} \tag{38b}$$

We can thus easily see that the interior fixed point is unstable. □

We therefore obtain the following possible regimes:

1. In regime one, inequality (31) is violated but (33) holds: (EM, EF) is the global attractor.
2. In regime two, inequality (31) holds but (33) is violated: (CM, CF) is the global attractor.
3. In regime three, both conditions (31) and (33) hold: (EM, EF) and (CM, CF) are local attractors with their basins of attraction separated by the interior equilibrium at (x_0, y_0).
4. In regime four, both conditions (31) and (33) are violated: (CM, EF) is the global attractor.

Note that the global and local attractors are also strict Nash equilibria in a non-cooperative game.[16] Looking at conditions (31) and (33), we can see that the transfer rate takes on a critical role in both conditions.

[15] Note further that given the budget constraint in (5) and assuming that the debt ratio is currently at the target level and the government is paying its promised transfers, we can substitute the left-hand side by $\left(R\bar{d}/\pi_t g\right)^2$. Therefore, the inequality also holds for highly indebted countries, and can explain why these countries run an expansionary fiscal and monetary policy.

[16] Since $u_C(CM, CF) = 0 > u_C(EM, CF)$ and $u_G = (EF, EM) = 0 > u_G(CF, EM)$, the strategy profile $\{EM, CF\}$ is not a Nash equilibrium for any strictly positive parameter values. If condition (31) is violated, EF is a strictly dominant strategy for the government. If condition (33) is violated, CM is a strictly dominant strategy for the central bank. Given (38), the interior equilibrium is unstable. While it is a mixed strategy Nash equilibrium, it is not strict.

Corollary 1. *If a high promised transfer rate is met with a high inflation target, tax rate, or target debt-to-GDP ratio, it encourages a contractionary equilibrium (regime 2). The same occurs if the monetary authority has a strong focus on price stability while the government has little obligation to meet its political promise. The expansionary equilibrium (regime 1) occurs in the inverse cases. A strong focus on price stability combined with a strict commitment to the promised transfer rate, on the other hand, leads to a contractionary monetary policy and expansionary fiscal policy equilibrium (regime 4). Since the transfer rate is part of both conditions, the latter equilibrium is maintained if this rate is low and the target-debt ratio is also small. If the target debt-ratio and the promised transfer rate are high relative to the tax rate and are not offset by the inflation target, a regime with two local attractors occurs. In addition, a higher transfer rate moves the separatrix (36) closer to the center of the state space, making the contractionary and expansionary equilibrium roughly equally likely.*

We can further show that

Proposition 2. *The interior equilibrium constitutes an inefficient policy mix, since both policymakers can better satisfy their objectives at the pure strategy profiles (CF, CM) and (EM, EF).*

Proof. We calculate the value of the objective functions of both the central bank and the government at (x_0, y_0), which is

$$u_{C,0} = x_0 y_0 u_C(CM, CF) + y_0(1 - x_0) u_C(EM, CF) + (1 - y_0) x_0 u_C(CM, EF) + (1 - y_0)(1 - x_0) u_C(EM, EF) \tag{39a}$$

$$u_{G,0} = x_0 y_0 u_G(CF, CM) + y_0(1 - x_0) u_G(CF, EM) + (1 - y_0) x_0 u_G(EF, CM) + (1 - y_0)(1 - x_0) u_G(EF, EM) \tag{39b}$$

The differences are then given by

$$u_{C,0} - u_C(CM, CF) = -\frac{\left(R\bar{d} - \bar{\pi} g\left(\bar{d} + \tau - \tilde{T}\right)\right)^2 \left(\phi_M\left(\bar{d} + \tau - \tilde{T}\right)^2 + \bar{\pi}^2 \delta_M\right)}{2\bar{\pi}^2 g^2 \left(\bar{d} + \tau - \tilde{T}\right)^2}$$

$$u_{C,0} - u_C(EM, EF) = \frac{\left(R\bar{d} - \bar{\pi} g\left(\bar{d} + \tau - \tilde{T}\right)\right)^2 \left(\bar{\pi}^2 \delta_M - \phi_M\left(\bar{d} + \tau - \tilde{T}\right)^2\right)}{2\bar{\pi}^2 g^2 \left(\bar{d} + \tau - \tilde{T}\right)^2}$$

$$u_{G,0} - u_G(CF, CM) = -\frac{\left(\tilde{T}^2 \phi_F - \varphi_F\right)\left(R\bar{d} - \bar{\pi} g\left(\bar{d} + \tau - \tilde{T}\right)\right)^2}{2\bar{\pi}^2 g^2 \tilde{T}^2}$$

$$u_{G,0} - u_G(EF, EM) = -\frac{\left(\tilde{T}^2 \phi_F + \varphi_F\right)\left(R\bar{d} - \bar{\pi} g\left(\bar{d} + \tau - \tilde{T}\right)\right)^2}{2\bar{\pi}^2 g^2 \tilde{T}^2}$$

we can see that the differences are strictly negative given that conditions (31) and (33) must hold for the existence of the interior fixed point. □

Given the eigenvalues in (38), we can see that the interior equilibrium constitutes a saddle point which is evolutionarily unstable. To see this, note that given the mixed strategy profile defined by (36), any strategy mix of the central bank is a best response to the government choosing a contractionary degree of y_0. Similarly, any strategy mix of the government is a best response to the central bank choosing a contractionary degree of x_0.[17] However, once one of the players changes strategy, it is no longer a best response for the other player to keep the initial strategy mix.[18] Consequently, in a dynamic setting, the central bank and the government will not insist on choosing the inefficient strategy mix defined by (36).

4. Interpretation of results and policy implications

The phase portraits of the evolutionary dynamics of each of the four possible regimes of policy interaction are presented in Fig. 1. We have three regimes in which (EM, EF), (CM, CF), and (CM, EF) are global attractors, shown respectively in Figs. 1(a), (b), and (d). Fig. 1(c) illustrates regime three with (EM, EF) and (CM, CF) being local attractors with their basins of attraction separated by the interior equilibrium. Our earlier discussion demonstrates that our four distinct regimes depend on whether neither, one, or both of the two conditions of (31) and (33) are satisfied. Each condition pertains to the macroeconomic conditions and the preferences of the involved authorities, namely the government's preference for honoring its fiscal commitments over achieving a balanced budget, and the central bank's preference for price stability over the long-term effects of new government borrowing.

Our results are aligned with previous empirical studies where distinct policy regimes are observed in various countries or across different historical episodes within a country. Libich et al. (2015) classified several high-income countries into three regions, namely

[17] We can see this in Fig. 1(c): The nullcline where $\dot{x} = 0$ is horizontal and therefore a change of x given y_0 does not lead to a further change in x as the system moves along the solid blue line at which x does not change. Equivalently, the nullcline for $\dot{y} = 0$ is vertical and any change in y given x_0 does not lead to further change in y.

[18] Again this is made clear in Fig. 1(c): Except for the intersection of the nullclines, the vector going through any other point on one of the nullclines is pointing away from this point. The only strategy combination leading back to the interior fixed point is given by the stable manifold which is situated at the border between the lighter and darker shaded area, i.e. the border between the basins of attraction of the two local attractors.

monetary dominance, fiscal dominance, and regime-switching regions, based on the degree of fiscal and monetary leaderships. The empirical results indicate that countries like Australia and New Zealand with strong monetary leaderships, i.e. strong commitment to maintaining an inflation target, are likely to fall under a rule of monetary dominance (violating condition (33)). Australia's low debt ratio puts it into regime 2 where the interaction outcome is favorable for the central bank, while New Zealand has been switching between regime 2 and 4 in the past. In contrast, the U.S. which exhibits strong fiscal leadership, is likely to be placed in the fiscal dominance region, i.e. regimes one and four in our framework. Davig and Leeper (2011) show that the US was in regime one (in their paper it is (PM,AF)) during the period after the financial crisis where countries were under pressure of increasing expenditure to boost the economy. Libich et al. (2015) also suggest the US is in regime one during this period, while Australia and New Zealand were in regime two. Israel shows the same pattern. Similarly, Benchimol (2024) finds that an inflation targeting monetary policy rule is a better fit compared to nominal income targeting for Israel. This means the Israeli central bank has a strong preference for price stability; hence, regime two is expected to arise in Israel. Looking at the earlier period, Auerbach and Gorodnichenko (2011, 2012) measure the output responses to fiscal policy in the U.S. and document the variety of fiscal policies which prove effective during recessions. This result again can be matched with regime one in our framework, where both authorities pursue expansionary approaches during recessions (see also Fernández-Villaverde et al. 2015 for a study of the time-varying volatility in taxes and government spending in the United States).

Furthermore, our results show that the public debt ratio stabilizes only when one authority demonstrates a strong long-term preference for a balanced budget, while the other focuses on their immediate concerns. The two policymakers need to coordinate and assign the debt-stabilizing task to just one authority — for example, the central bank in regime one and the government in regime two. In regime one, the government has a strong current preference while the central bank is now less concerned with the inflation target, and consequently, both policymakers opt for an expansionary strategy. In regime two, the inverse holds and both government and central bank opt for a contractionary strategy.

Otherwise, regime three can occur, which constitutes a bridge between regime one and regime two. It features both equilibria (EM, EF) and (CM, CF) in the form of local attractors.[19] An interior equilibrium separates the basins of the other two pure Nash equilibria. Regime three, therefore, introduces the possibility of frequent regime switching. While the interior equilibrium is unstable, frequent switches in the policy strategy can lead to strategy profiles that temporarily impose states in the vicinity of the less favorable interior equilibrium (Proposition 2) causing inefficiency.

Notice that regime four follows intuitively from the discussion of conditions (31) and (33). This regime occurs when both the central bank and the government have a strong preference for the present and put relatively more weight on their current concerns, i.e. δ_M and φ_F are sufficiently high. In this case, the central bank will opt for a contractionary policy that ensures price stability, while the government will engage in an expansionary policy to meet its prior fiscal promises. In this case, the implications of current debt accumulation remain a future concern, because the objective functions of both authorities continue to feature the debt target.

In sum, it is therefore ideal for one policymaker to focus on their main policy target — inflation for the central bank and public transfer for the government, and let the other authority take care of public debt. However, if the latter is unwilling to do so, one may want to execute the debt stabilizing policy oneself, i.e. by implementing monetary expansion or fiscal contraction. Hence, a lack of clarity about the commitment of each authority can create a dilemma between the central bank and the government about who will stabilize the debt leading to inefficient transitions between the expansionary and contractionary equilibria. Regime three is then similar to the regime-switching region reported in Libich et al. (2015) where neither of the two authorities satisfies the sufficient dominance condition to ensure policy coordination. Authorities who choose their policy less myopically than in our model will face a policy tug-of-war leading to multiple temporary policy mixes including the inferior interior fixed point that randomizes between different policy combinations. The corollary follows:

Corollary 2. *The public debt ratio is efficiently stabilized only in regimes one and two with a single global attractor, (EM, EF) and (CM, CF) respectively. In both regimes, one authority shows a strong farsighted preference for a balanced budget, while the other focuses on their current concerns — price stability for the central bank and political credibility for the government. In other words, to solve the debt stress, the two policymakers need to coordinate and assign the task of debt stabilization to only one authority, e.g. in regime one, to the central bank, and in regime two, to the government. In contrast, a less efficient outcome occurs if both players place a sufficiently strong weight on debt targeting.*

Both central bank and government are interested in avoiding a potential coordination problem arising in regime three and the resulting inefficiency. Conditions that cause inequality (31) or inequality (33) to be violated can help avert the coordination failure. This can be most efficiently achieved by policies that affect the weights in an opportune direction: A clear mandate of the central bank to keep prices stable and open communication that acts as a commitment device increases the central bank's focus on inflation control and thus δ_M. Similarly, a clear statement and a priori promise that the central bank will not inflate away an excessive debt acts as a similar commitment device to decrease ϕ_M. Such commitments are particularly important if fiscal rules or debt brakes result in an increase in the government's weight on debt gap ϕ_F and a decrease in the government's weight on transfer φ_F, since they force governments to prioritize debt control over transfer commitments and render condition (31) more likely. More broadly, public announcements and strong political pressure to abide by them act as coordination devices and help both policymakers to

[19] Corsetti et al. (2019) obtain a similar result with two equilibria – one characterized by underemployment, the other by increased inflation – however, in the context of small open economy with chronic deflation and deficient demand.

coordinate their policies to ensure settling on one of the two pure strategy equilibria (CM, CF) or (EM, EF) instead of being trapped in an inefficient policy mix.

On the government's side, strong political demands for social security benefits that increase transfers, especially if the political situation and government are fragile (such as in France, Italy, and Japan), increase pressure to promise high transfers and live up to these commitments increasing φ_F. If this is coupled with a history of high deficits and therefore little public demand to decrease debt, inequality (31) is violated. However, this comes with a caveat as we show further below. Since transfers are part of both inequalities, and while an increase in $\tilde{T}$ reduces the likelihood that (33) holds, we show further below that such an increase can have the negative effect of rendering both equilibria equally likely (i.e. leading to equal-sized basins of attraction) under reasonable parameter values.

We discuss this in the following, since the coordination game setting of regime three raises also the question of which of the two equilibria is more likely to occur. We can see in Fig. 1(c) that the size of the basin of attraction of each of the two local attractors (EM, EF) and (CM, CF) is defined by the stable manifold (where the lighter and darker gray areas meet) of the interior saddle point, which is given by Eqs. (36) and is situated at the intersection of the two nullclines (the solid and dashed lines). We assumed that both the central bank and the government make regular changes to their policies. As long as these changes are small, the strategy profile will remain in an equilibrium's basin of attraction and the strategies of both will converge back to the equilibrium. However, since each of the two players may react strongly to changes in the economic environment, new private information, and projections, they can find themselves at any point in the state space after significant economic shocks, after which their strategies will start to converge to the basin's local attractor. Consequently, the likelihood of (EM, EF) and (CM, CF) is given by the relative size of their respective basin of attraction. In Fig. 2, we illustrate the separatrix, i.e. the border between both basins of attraction and therefore their sizes in relation to the different weight that the government (Fig. 2a,b) and the central bank (Fig. 2c,d) may choose. For simplicity, we assume that $\varphi_F = 1 - \phi_F$ and $\delta_M = 1 - \phi_M$. Note that the stable manifold has to cross the interior equilibrium at (x_0, y_0) given in (36), and intercept the unstable fixed points $(0, 1)$ and $(1, 0)$ given (37b) and (37c), respectively. The first partial derivatives of (36) subject to inequalities (31) and (33) therefore provide us with the direction, in which the separatrix, which is forming the border between the two basins, is moving after a change in a parameter. The signs of the first partial derivative are then given by

$$\partial x_0/\partial \varphi_F > 0 \quad \text{and} \quad \partial x_0/\partial \phi_F\ ,\ \partial x_0/\partial T < 0$$

$$\partial y_0/\partial \phi_M > 0 \quad \text{and} \quad \partial y_0/\partial \delta_M\ ,\ \partial x_0/\partial \bar{\pi} < 0$$

The signs of partial derivatives of the remaining variables depend on the sign of $\left(\bar{d} - \tilde{T} + \tau\right)$ which is positive under general assumptions. We have

$$\partial y_0/\partial \tau \ = \ \partial x_0/\partial \bar{\pi} = \frac{\bar{\pi}^2 \delta_M}{\phi_M \left(\bar{d} - \tilde{T} + \tau\right)^3}$$

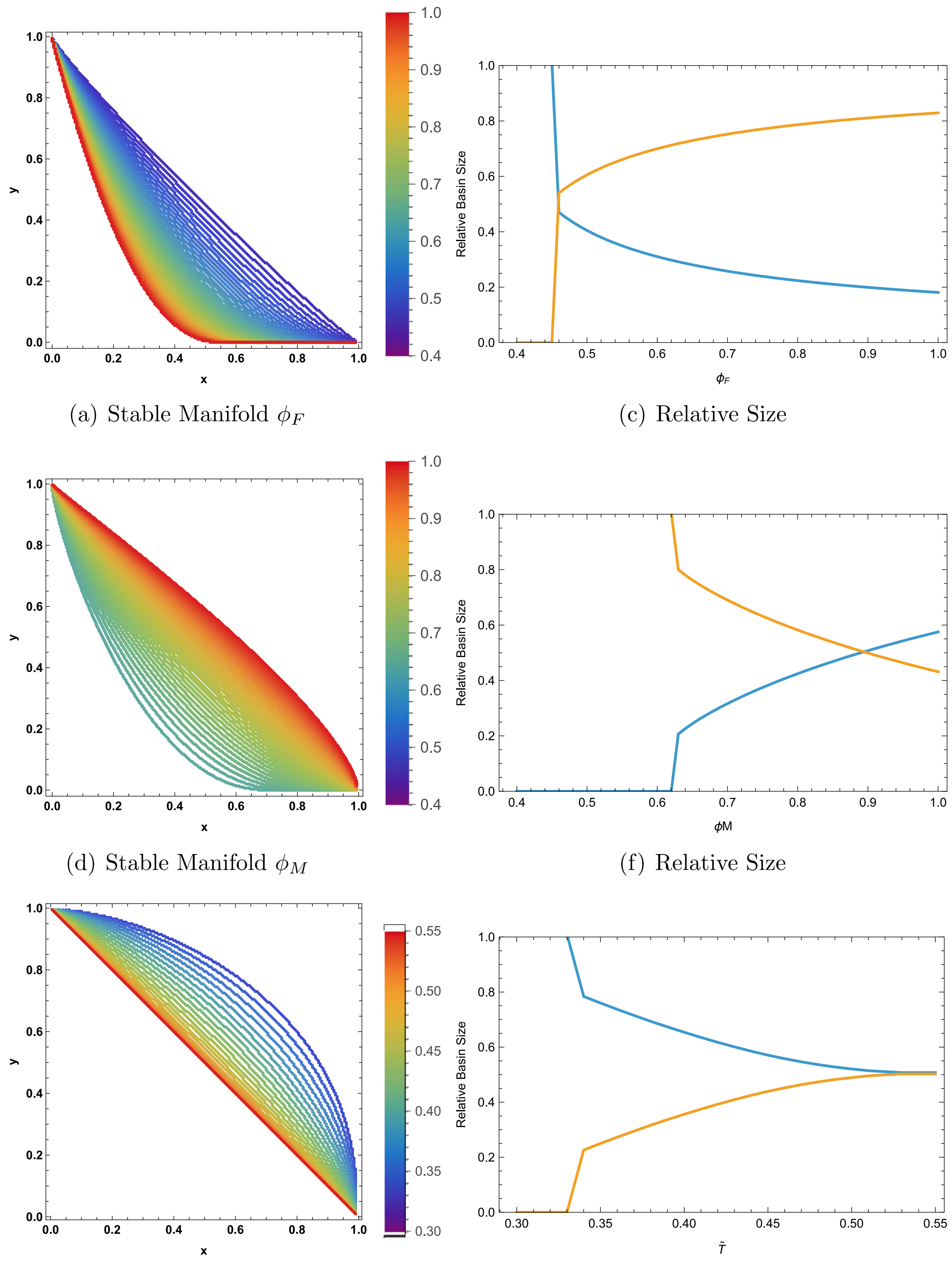
$$\partial y_0/\partial \tilde{T} \ = -\frac{\bar{\pi}^2 \delta_M}{\phi_M \left(\bar{d} - \tilde{T} + \tau\right)^3}$$

Fig. 2(a) shows that given the fixed weights in the central bank's objective function, the stable manifold bows inwards and this increases the basin of attraction of (CM, CF) as the government places more weight on minimizing the gap between the actual and target debt-to-GDP ratio. Consequently, as ϕ_F increases, the basin size and thus, the likelihood of (CM, CF) increases while the basin size of (EM, EF) and its likelihood decrease as illustrated in Fig. 2(b).

We observe the opposite situation if we hold the weights for the government constant, and manipulate the weights of the central bank. Fig. 2(c) shows the shift in the stable manifold towards the (CM, CF) equilibrium as ϕ_M increases. Consequently, the likelihood of (EM, EF) increases, while the likelihood of (CM, CF) decreases as the central bank places a higher weight on stabilizing the debt-to-GDP ratio. As demonstrated before, larger values for $\tilde{T}$ lead to equally sized basins of attraction as x_0 converges to $1/2$, while y_0 is only marginally reduced by changes to $\tilde{T}$ under reasonable parameter values which meet conditions (31) and (33).

These relations are in line with our previous results. If the government places stronger emphasis on curtailing public debt, the central bank can realize its mandate to stabilize price levels. Both are more likely to opt for a contractionary policy. If the government focuses more on meeting its political promise, the central bank has to resort to inflation to correct the large fiscal imbalance. Further note that as ϕ_M grows smaller, condition (31) is eventually violated and (EM, EF) becomes the global attractor in this case (which occurs at $\phi_M \leq 0.45$ in the case depicted in Fig. 2(b)). Similarly, if the central bank places a lower emphasis on debt stabilization and therefore, a higher weight on price stability, it imposes the mandate of lowering the debt-to-GDP on the government. A lower ϕ_M will also eventually violate condition (33) and lead to regime two in which (CM, CF) is the global attractor (at $\phi_F \leq 0.62$). At high levels of ϕ_F, the government can pass on debt stabilization to the central bank and increase transfers to households, granting a higher likelihood to equilibrium (EM, EF).

Note that the average time it takes to converge to each of the local attractors from any point in their respective basin of attraction is proportional to the basin's size. Trajectories from points in the state space that are further away from the attractor will need to go through points that are closer. As the basin of attraction shrinks, we are left only with those points which are nearer to the attractor and it therefore takes less time on average to reach that equilibrium state. Consequently, the smaller the basin of attraction is, the less time it takes for the government and the central bank to converge to a locally efficient state (i.e. strategy profile).



(a) Stable Manifold ϕ_F (c) Relative Size

(d) Stable Manifold ϕ_M (f) Relative Size

(g) Stable Manifold $\tilde{T}$ (i) Relative Size

Fig. 2. The figure shows the movement of the stable manifold indicating the border between the basin of attraction of equilibria $(0,0)$ and $(1,1)$ and their respective sizes ((EM, EF) in blue and (CM, CF) in orange) subject to changes in ϕ_F, ϕ_M and $\tilde{T}$.

5. Conclusion

This paper fills a gap in the growing literature on the interaction between monetary policy and fiscal policy during periods of fiscal stress induced by the imperative to deliver the targeted debt levels. We analyze the interplay between various macroeconomic factors and the dynamic and strategic implementation of fiscal and monetary policies by developing an evolutionary model with two actors — a representative central bank and a representative government. Both players have to decide on a strategy mix which constitutes a combination of expansionary and contractionary policies. The efficiency of the strategy mix of one actor in achieving the latter's policy goals depends not only on a set of critical conditions but also on the strategy mix of the other player. We study the dynamics and the ensuing evolutionary stable states by assuming that both actors update their strategy myopically but regularly. This process acknowledges the bounded rationality and limited far-sightedness of each actor, and in addition, eliminates implausible equilibria that are not locally optimal for achieving the policy objectives, while taking into account that usually, the interaction between a central bank and a government does not have a distinct first-mover.

We show that both actors can find themselves in one of four regimes characterized by different evolutionary stable equilibria- (i) a purely contractionary equilibrium as a global attractor, (ii) a purely expansionary equilibrium as a global attractor, (iii) both equilibria are local attractors separated by a separatrix, and (c) an equilibrium that is a global attractor in which the monetary authority opts for a contractionary policy while the government chooses an expansionary policy. We further demonstrate that an expansionary monetary policy is not a locally best response to a contractionary fiscal policy and vice versa.

We show that the four regimes are supported empirically and demonstrate that the type of regime depends on whether none, one, or both of two conditions are met. Each condition relates to the time preferences of the respective actor, i.e. (a) the relative preference of a central bank in favor of current price stability over the future impact of new government borrowing, and (b) the relative preference of the government in favor of keeping its fiscal promises over maintaining a balanced budget. Both authorities coordinate policies in three of the four regimes, in which either the central bank or the government is assigned the debt stabilizing task. However, in one of these regimes, the task of debt stabilization is repeatedly transferred between both authorities, leading to transitory periods of an inefficient policy mix between periods of coordination. We show that paradoxically, such a scenario occurs if both authorities place too much weight on debt stabilization. The scenario is therefore avoided if the commitment of both authorities is clear and one of the authorities puts a stronger emphasis on their primary target, passing debt stabilization on to the other authority. In addition, we study how changes in policy preferences affect the likelihood that debt stabilization is assigned to either authority in this case.

We further show that a fourth regime exists in which both authorities commit to their primary targets, i.e. to ensure price stability for the central bank and to honor their political promises for the government. In this case, since no party is responsible for managing debt, public debt ratio exceeds its target. The central bank maintains price stability while the government pursues an expansionary fiscal policy. Based on our results, we argue that this regime is likely to occur under a populist government. We further show that such a regime will eventually become unstable. Under enough political pressure and once the debt-to-GDP ratio is getting out of hand, the central bank will feel obliged to reduce public debt via inflation using an expansionary monetary policy — a situation that we recently observe in a number of advanced economies.

Our paper has a few potential shortcomings based on the assumptions of the simplified dynamical system which we studied in this paper. We ignore that a critical element of the government's fiscal policy relates to public spending. While we argue that in the given context, the addition of public spending does not change the results we obtain, a more general model that explicitly models the political implication of different fiscal policies as well as their impact on long-term economic growth will need to include public spending. Similarly, since central banks have increasingly shifted to inflation targeting and consider financial stability and thus avoiding high debt ratios of higher importance in the given context, we ignore the central bank's mandate to address output gaps. Including the latter into a more general model may lead to interesting non-linear dynamics, since the output gap is both tied to price stability and public debt, which we hope will be addressed in future work.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. The equivalence of the dynamics

Section 3 establishes the existence of four possible regimes based on conditions (31) and (33). By the definition of an evolutionarily stable strategy, any strict Nash is defined by a strategy profile of evolutionarily stable strategies (see Propositions 2.1 and 2.18 in Weibull, 1997). Here, we explicitly show that the identified stable nodes are the strict pure Nash equilibria of the normal form game. The payoff matrix of the game is given by Eqs. (22)–(29):

M ∖ F	**CF** $(\alpha_t = \alpha_t^C)$	**EF** $(\alpha_t = 1)$
CM $(\pi_t = \bar{\pi})$	$0, -\varphi_F \left(\frac{\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}}{\tilde{T}} \right)^2$	$-\phi_M \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g} \right)^2, -\phi_F \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g} \right)^2$
EM $(\pi_t^E > \bar{\pi})$	$-\phi_M \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g} \right)^2 - \delta_M \left(\frac{R\bar{d}}{(\bar{d} + \tau - \tilde{T}) g} - \bar{\pi} \right)^2,$ $-\phi_F \left(\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g} \right)^2 - \varphi_F \left(\frac{\tilde{T} - \bar{d} - \tau + \frac{R\bar{d}}{\bar{\pi} g}}{\tilde{T}} \right)^2$	$-\delta_M \left(\frac{R\bar{d}}{(\bar{d} + \tau - \tilde{T}) g} - \bar{\pi} \right)^2, 0$

If condition (31) does not hold, the government's dominant strategy is an expansionary fiscal policy, and similarly, if (33) is violated, the dominant strategy of the central bank is a contractionary monetary policy. The Nash equilibria are then given by the four regimes and their respective conditions. The mixed Nash equilibrium in the coordination game setup of regime 3 is identical to the frequencies given by Eqs. (36).[20] Fig. A.3 shows the corresponding best response functions of both players in each of the four regimes. Note that the interior saddle point constitutes a Nash equilibrium in mixed strategies. Assuming sufficiently small adjustment steps, we can see that gradient-based learning algorithms with x and y defined as before, whose dynamics are defined by the sign of the adjustment

$$\Delta_C(y) = U_C^{CM}(y) - U_C^{EM}(y)$$
$$\Delta_G(x) = U_C^{CF}(x) - U_C^{EF}(x)$$

converges to the identified fixed points.

Appendix B. Sketch of a model with an output gap

In the following, we sketch a version of the model, which accounts for the impact of actual government transfers on g and includes the output gap in the objective functions. We assume

$$\begin{aligned} g_t &= g\left(a_t\tilde{T}\right) \\ U_{M,t} &= -\phi_M\left(d_t - \bar{d}\right)^2 - \delta_M\left(\pi_t - \bar{\pi}\right)^2 - \psi_M\left(g_t - g_0\right)^2 \\ U_{F,t} &= -\phi_F\left(d_t - \bar{d}\right)^2 - \varphi_F\left(1 - \alpha_t\right)^2 - \psi_F\left(g_t - g_0\right)^2 \end{aligned} \tag{B.1}$$

For the four possible strategy profiles, we obtain the following:

- Contractionary monetary policy CM and contractionary fiscal policy CF:

$$\pi_t = \bar{\pi}, \alpha_t = \alpha_t^C = \left(\bar{d} + \tau - \frac{R\bar{d}}{\bar{\pi} g\left(a_t\tilde{T}\right)}\right)\Big/\tilde{T}, d_t = \bar{d}, g_t = g\left(a_t\tilde{T}\right)$$
$$U_{M,t} = -\psi_M\left[g\left(a_t\tilde{T}\right) - \overline{g}\right]^2$$
$$U_{F,t} = -\varphi_F\left(1 - \alpha_t^C\right)^2 - \psi_F\left[g\left(a_t\tilde{T}\right) - \overline{g}\right]^2$$

- Contractionary monetary policy CM and expansionary fiscal policy EF:

$$\pi_t = \bar{\pi}, \alpha_t = 1, g_t = \overline{g}, d_t = \tilde{T} + \frac{R\bar{d}}{\bar{\pi}\overline{g}} - \tau > \bar{d}$$
$$U_{M,t} = -\phi_M\left(\tilde{T} + \frac{R\bar{d}}{\bar{\pi}\overline{g}} - \tau - \bar{d}\right)^2$$
$$U_{F,t} = -\phi_F\left(\tilde{T} + \frac{R\bar{d}}{\bar{\pi}\overline{g}} - \tau - \bar{d}\right)^2$$

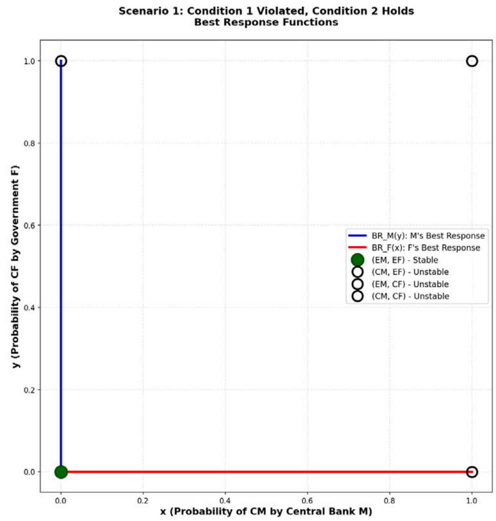
- Expansionary monetary policy EM and contractionary fiscal policy CF:

$$\pi_t = \pi_t^E = \frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right)\overline{g}} > \bar{\pi}, \alpha_t = \alpha_t^C, g = g\left(a_t\tilde{T}\right), d_t = \alpha_t^C\tilde{T} - \tau + \frac{\left(\bar{d} + \tau - \tilde{T}\right)\overline{g}}{g\left(a_t\tilde{T}\right)} < \bar{d}$$
$$U_{M,t} = -\phi_M\left(\frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right)\overline{g}} - \bar{d}\right)^2 - \delta_M\left(\frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right)\overline{g}} - \bar{\pi}\right)^2 - \psi_M\left[g\left(a_t\tilde{T}\right) - \overline{g}\right]^2$$
$$U_{F,t} = -\phi_F\left(\frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right)\overline{g}} - \bar{d}\right)^2 - \varphi_F\left(1 - \alpha_t^C\right)^2 - \psi_F\left[g\left(a_t\tilde{T}\right) - \overline{g}\right]^2$$

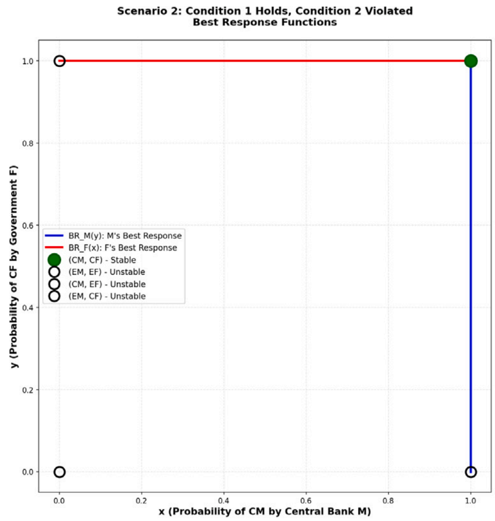
- Expansionary monetary policy EM and expansionary fiscal policy EF:

$$\pi_t = \pi_t^E, \alpha_t = 1, d_t = \bar{d}, g_t = \overline{g}$$
$$U_{M,t} = -\delta_M\left(\frac{R\bar{d}}{\left(\bar{d} + \tau - \tilde{T}\right)\overline{g}} - \bar{\pi}\right)^2$$
$$U_{F,t} = 0$$

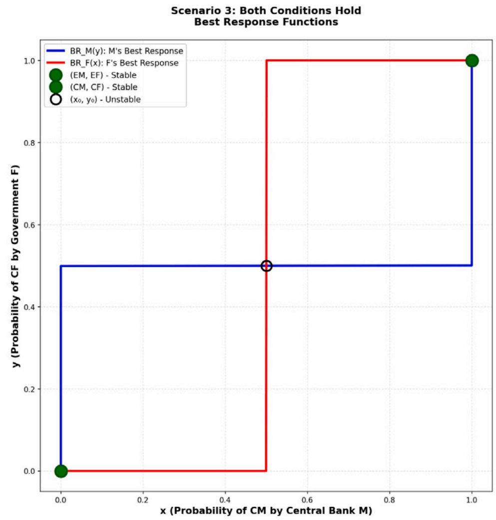
[20] We are making here the simplifying assumption that a strategy that combines expansionary and contractionary elements can be represented as a convex combination of the two pure strategies. Since regimes 1, 2, and 4 have a unique and strict Nash equilibrium, the assumption does not affect the validity of our qualitative results as long as there is a monotonic relationship between the degrees in the players' policy mix and the value of their objective function. In regime 3, the mixed strategy is not optimal in the vicinity of the mixed state, and neither should a policy mix under the assumption of a monotonic relationship.



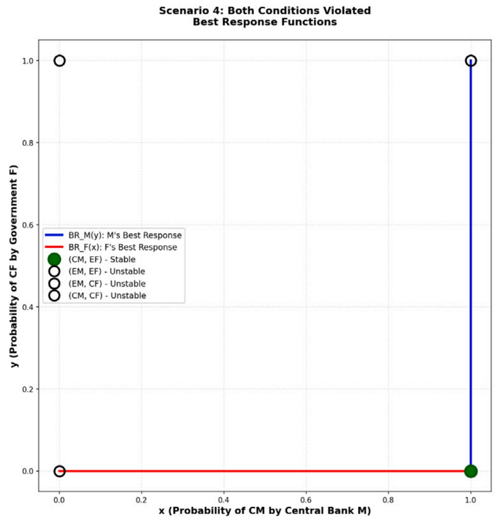
(a) Regime 1.



(b) Regime 2.



(c) Regime 3.



(d) Regime 4.

Fig. A.3. The figure shows the best response functions of each player in each of the four regimes.

As in the original model, strategy profile $\{EM, CF\}$ is not a Nash equilibrium and not evolutionarily stable. The condition for a strict Nash $\{CM, CF\}$ is

$$\phi_F > \frac{\varphi_F \left(1-\alpha_t^C\right)^2 + \psi_F \left[g\left(a_t\tilde{T}\right)-\overline{g}\right]^2}{\left(\tilde{T}+\frac{R\bar{d}}{\bar{\pi}\bar{g}}-\tau-\bar{d}\right)^2}$$

where the numerator is the combined weighted impact of the withheld share of promised transfer and the output gap (both squared) — in other word, the negative political impact of the government's policy mix, while the denominator is the squared value of the temporary deficit. Consequently, the inequality holds if the government faces little political pressure or the deficit is small.

The condition for a strict Nash equilibrium $\{EM, EF\}$ is

$$\frac{\delta_M}{\phi_M} < \left(\frac{\tilde{T}+\frac{R\bar{d}}{\bar{\pi}\bar{g}}-\tau-\bar{d}}{\frac{R\bar{d}}{(\bar{d}+\tau-\tilde{T})\bar{g}}-\bar{\pi}}\right)^2$$

which is the squared ratio of the temporary deficit to the inflation gap. Therefore, the inequality holds if the inflation gap is small or the temporary deficit is large.

We can see that the two conditions identify the same four regimes as found in the initial model. Since the pure Nash equilibria are again strict, they also define the asymptotically stable fixed points of the modified dynamical system given by the set of equations in (34).

Data availability

No data was used for the research described in the article.

References

Acharya, V. V., Eisert, T., Eufinger, C., & Hirsch, C. (2019). Whatever it takes: The real effects of unconventional monetary policy. *The Review of Financial Studies*, *32*(9), 3366–3411.

Adam, K., & Billi, R. M. (2008). Monetary conservatism and fiscal policy. *Journal of Monetary Economics*, *55*(8), 1376–1388.

Afonso, A., Alves, J., & Balhote, R. (2019). Interactions between monetary and fiscal policies. *Journal of Applied Economics*, *22*(1), 132–151.

Altavilla, C., Giannone, D., & Lenza, M. (2016). The financial and macroeconomic effects of the OMT announcements. *International Journal of Central Banking*, *12*(2), 199–237.

Auerbach, A. J., & Gorodnichenko, Y. (2011). *Fiscal multipliers in recession and expansion*: *Working paper 17447*, National Bureau of Economic Research.

Auerbach, A. J., & Gorodnichenko, Y. (2012). Measuring the output responses to fiscal policy. *American Economic Journal: Economic Policy*, *4*(2), 1–27.

Bassett, W. F., Burkett, J. P., & Putterman, L. (1999). Income distribution, government transfers, and the problem of unequal influence. *European Journal of Political Economy*, *15*(2), 207–228.

Bassetto, M. (2002). A game-theoretic view of the fiscal theory of the price level. *Econometrica*, *70*(6), 2167–2195.

Benchimol, J. (2024). Central bank objectives, monetary policy rules, and limited information. *Journal of Macroeconomics*, *80*, Article 103604.

Benchimol, J., & Bounader, L. (2023). Optimal monetary policy under bounded rationality. *Journal of Financial Stability*, *67*, Article 101151.

Benhabib, J., & Eusepi, S. (2005). The design of monetary and fiscal policy: A global perspective. *Journal of Economic Theory*, *123*(1), 40–73, Monetary Policy and Capital Accumulation.

Bertsch, C., Hull, I., Lumsdaine, R. L., & Zhang, X. (2025). Central bank mandates and monetary policy stances: Through the lens of federal reserve speeches. *Journal of Econometrics*, *249*, Article 105948.

Bianchi, F. (2012). Evolving monetary/fiscal policy mix in the United States. *American Economic Review*, *102*(3), 167–172.

Bilbiie, F. O., Monacelli, T., & Perotti, R. (2024). Stabilization vs. Redistribution: The optimal monetary–fiscal mix. *Journal of Monetary Economics*, *147*, Article 103623, Monetary Policy challenges for European Macroeconomies.

Blackburn, K., & Christensen, M. (1989). Monetary policy and policy credibility: Theories and evidence. *Journal of Economic Literature*, *27*(1), 1–45.

Blinder, A. S. (1982). *Issues in the coordination of monetary and fiscal policy*: *NBER working papers 0982*, National Bureau of Economic Research, Inc.

Börgers, T., & Sarin, R. (2000). Naive reinforcement learning with endogenous aspirations. *International Economic Review*, *41*(4), 921–950.

Branch, W. A., Davig, T., & McGough, B. (2008). Monetary-fiscal policy interactions under implementable monetary policy rules. *Journal of Money, Credit and Banking*, *40*(5), 1095–1102.

Brzoza-Brzezina, M., Kotłowski, J., & Miśkowiec, A. (2013). How forward-looking are central banks? Some evidence from their forecasts. *Applied Economics Letters*, *20*(2), 142–146.

Canzoneri, M., Cumby, R., & Diba, B. (2010). Chapter 17 - The interaction between monetary and fiscal policy. In B. M. Friedman, & M. Woodford (Eds.), *Handbook of monetary economics*: *vol. 3*, (pp. 935–999). Elsevier.

Cardoso-Costa, J.-M., & Lewis, V. (2017). Fiscal policy and inflation in a monetary union. *Economica*, *84*(336), 779–796.

Cawley, C., & Finnegan, M. (2019). Transmission channels of central bank asset purchases in the irish economy. *Economies*, *7*(4).

Checherita-Westphal, C., Rogantini-Picco, A., Schmidt, S., & Sigaux, J.-D. (2024). Trade-offs between macroeconomic and financial stability objectives. European Central Bank Discussion Paper 26.

Chortareas, G., & Mavrodimitrakis, C. (2017). Strategic fiscal policies and leadership in a monetary union. *European Journal of Political Economy*, *47*, 133–147.

Cochrane, J. H. (2001). Long-term debt and optimal policy in the fiscal theory of the price level. *Econometrica*, *69*(1), 69–116.

Cooper, J. P., & Fischer, S. (1974). Monetary and fiscal policy in the fully stochastic St. Louis econometric model. *Journal of Money, Credit and Banking*, *6*(1), 1–22.

Corsetti, G., Mavroeidi, E., Thwaites, G., & Wolf, M. (2019). Step away from the zero lower bound: Small open economies in a world of secular stagnation. *Journal of International Economics*, *116*, 88–102.

Court of Justice of the European Union (2015). Judgment of the Court (Grand Chamber) of 16 June 2015, Peter Gauweiler and Others v Deutscher Bundestag. ECLI:EU:C:2015:400, Case C-62/14.

Davig, T., & Leeper, E. M. (2011). Monetary-fiscal policy interactions and fiscal stimulus. *European Economic Review*, *55*(2), 211–227.

De Grauwe, P. (2011). Animal spirits and monetary policy. *Economic Theory*, *47*(2), 423–457.

De Grauwe, P. (2013). The design of a fragile eurozone. *CESifo Forum*, *14*(2), 17–21.

De Grauwe, P., & Foresti, P. (2023). Interactions of fiscal and monetary policies under waves of optimism and pessimism. *Journal of Economic Behavior and Organization*, *212*, 466–481.

De Grauwe, P., & Ji, Y. (2019). *Behavioural macroeconomics*. Oxford.

Debelle, G., & Fischer, S. (1994). How independent should a central bank be? In *Conference series; [Proceedings] Federal reserve bank of San Francisco*: *vol. 38*, (pp. 195–225).

Dennis, R. (2007). Optimal policy in rational expectations models: New solution algorithms. *Macroeconomic Dynamics*, *11*(1), 31–55.

Dennis, R. (2010). When is discretion superior to timeless perspective policymaking? *Journal of Monetary Economics*, *57*(3), 266–277.

Dixit, A., & Lambertini, L. (2001). Monetary & fiscal policy interactions and commitment versus discretion in a monetary union. *European Economic Review*, *45*(4), 977–987, 15th Annual Congress of the European Economic Association.

Dixit, A., & Lambertini, L. (2003). Interactions of commitment and discretion in monetary and fiscal policies. *The American Economic Review*, *93*(5), 1522–1542.

Fernández-Villaverde, J., Guerrón-Quintana, P., Kuester, K., & Rubio-Ramírez, J. (2015). Fiscal volatility shocks and economic activity. *American Economic Review*, *105*(11), 3352–3384.

Fialho, M., & Portugal, M. (2005). Monetary and fiscal policy interactions in Brazil: An application of the fiscal theory of the price level. *Estudos Econômicos (São Paulo)*, *35*.

Foresti, P. (2018). Monetary and fiscal policies interaction in monetary unions. *Journal of Economic Surveys*, *32*(1), 226–248.

Fouejieu, A., Popescu, A., & Villieu, P. (2019). Trade-offs between macroeconomic and financial stability objectives. *Economic Modelling*, *81*, 621–639.

Friedman, M. (1948). A monetary and fiscal framework for economic stability. *The American Economic Review*, *38*(3), 245–264.
Goodfriend, M. (2011). Central banking in the credit turmoil: An assessment of federal reserve practice. *Journal of Monetary Economics*, *58*(1), 1–12, Carnegie-Rochester Conference Series on Public Policy: The Future of Central Banking April 16-17, 2010.
Gordon, D. B., & Leeper, E. M. (2006). The price level, the quantity theory of money, and the fiscal theory of the price level. *Scottish Journal of Political Economy*, *53*(1), 4–27.
Gregory, R. P. (2022). ESG scores and the response of the S&P 1500 to monetary and fiscal policy during the Covid-19 pandemic. *International Review of Economics & Finance*, *78*, 446–456.
Kianercy, A., & Galstyan, A. (2012). Dynamics of Boltzmann *Q* learning in two-player two-action games. *Physical Review E*, *85*, Article 041145.
Kirsanova, T., Leith, C., & Wren-Lewis, S. (2009). Monetary and fiscal policy interaction: The current consensus assignment in the light of recent developments. *Economic Journal*, *119*(541), 482–496.
Lambertini, L. (2006). Monetary–fiscal interactions with a conservative central bank. *Scottish Journal of Political Economy*, *53*(1), 90–128.
Leeper, E. M. (1991). Equilibria under 'active' and 'passive monetary and fiscal policies. *Journal of Monetary Economics*, *27*(1), 129–147.
Leeper, E., & Walker, T. (2011). Fiscal limits in advanced economies*. *Economic Papers: A Journal of Applied Economics and Policy*, *30*, 33–47.
Leith, C., & Wren-Lewis, S. (2000). Interactions between monetary and fiscal policy rules. *The Economic Journal*, *110*(462), C93–C108.
Libich, J. (2009). A note on the anchoring effect of explicit inflation targets. *Macroeconomic Dynamics*, *13*(5), 685–697.
Libich, J. (2011). Inflation nutters? Modelling the flexibility of inflation targeting. *The B.E. Journal of Macroeconomics*, *11*(1).
Libich, J., & Nguyen, D. T. (2015). Strategic monetary–fiscal interactions in a downturn. *The Economic Record*, *91*(293), 172–190.
Libich, J., Nguyen, D. T., & StehlÃk, P. (2015). Monetary exit and fiscal spillovers. *European Journal of Political Economy*, *40*, 184–206.
Lodge, M., & Wegrich, K. (2014). Rational tools of government in a world of bounded rationality. Centre for Analysis of Risk and Regulation (LSE), Discussion Paper 75.
Miao, J., & Su, D. (2024). Fiscal and monetary policy interactions in a model with low interest rates. *American Economic Journal: Macroeconomics*, *16*(4), 35–76.
Mundell, R. (1962). The appropriate use of monetary and fiscal policy for internal and external stability. *IMF Staff Papers*, *9*(1), 70–79.
Nguyen, D. T., & Hoang, V. A. (2020). Monetary consequences of fiscal stress in a game theoretic framework. *Journal of Central Banking Theory and Practice*, *9*(special i), 125–164.
Nordhaus, W. D. (1994). Policy games: Coordination and independece in monetary and fiscal policies. *Brookings Papers on Economic Activity*, *25*(2), 139–216.
Ogami, M. (2024). The conditionality of political short-termism: A review of empirical and experimental studies. *Politics and Governance*, *12*, 1–19.
Sargent, T. J., & Wallace, N. (1981). Some unpleasant monetarist arithmetic. *Quarterly Review*, *5*(Fall).
Sargent, T. J., & Wallace, N. (1984). Some unpleasant monetarist arithmetic. In B. Griffiths, & G. E. Wood (Eds.), *Monetarism in the United kingdom* (pp. 15–41). London: Palgrave Macmillan UK.
Saulo, H., Rêgo, L., & Divino, J. (2013). Fiscal and monetary policy interactions: a game theory approach. *Annals of Operations Research*, *206*(1), 341–366.
Semmler, W., & Haider, A. (2018). Cooperative monetary and fiscal policies in the Euro area. *Southern Economic Journal*, *85*(1), 217–234.
Sims, C. A. (1994). A simple model for study of the determination of the price level and the interaction of monetary and fiscal policy. *Economic Theory*, *4*(3), 381–399.
Sims, C. A. (2011). Stepping on a rake: The role of fiscal policy in the inflation of the 1970s. *European Economic Review*, *55*(1), 48–56, Special Issue on Monetary and Fiscal Interactions in Times of Economic Stress.
Sims, C. A., & Zha, T. (2006). Were there regime switches in U.S. monetary policy? *American Economic Review*, *96*(1), 54–81.
Stawska, J., Malaczewski, M., Malaczewska, P., & Stawasz, E. (2022). The central bank or the government – who really dictates the terms of the policy-mix cooperation in economies with an independent monetary policy? *Economic Research-Ekonomska IstraŽivanja*, *36*(2), 1–22.
Stojanovikj, M., & Petrevski, G. (2024). The choice of monetary regimes in emerging market economies: Inflation targeting versus its alternatives. *International Review of Economics & Finance*, *93*, 237–260.
Svensson, L. E. (2017). Cost-benefit analysis of leaning against the wind. *Journal of Monetary Economics*, *90*, 193–213.
Tabellini, G. (1985). Accommodative monetary policy and central bank reputation. *Giornale degli Economisti e Annali di Economia*, *44*(7/8), 389–425.
Tanner, E., & Ramos, A. M. (2003). Fiscal sustainability and monetary versus fiscal dominance: evidence from Brazil, 1991–2000. *Applied Economics*, *35*(7), 859–873.
Tinbergen, J. (1954). *International economic integration*. Elsevier.
van Aarle, B., Engwerda, J., & Plasmans, J. (2002). Monetary and fiscal policy interaction in the EMU: A dynamic game approach. *Annals of Operations Research*, *109*(1), 229–264.
Walsh, C. E. (2001). Transparency in monetary policy. *FRBSF Economic Letter*, (sep7).
Wang, L. (2018). Monetary-fiscal policy interactions under asset purchase programs: Some comparative evidence. *Economic Modelling*, *73*, 208–221.
Weibull, J. W. (1997). *Evolutionary game theory*. MIT Press.
Woodford, M. (1994). Monetary policy and price level determinacy in a cash-in-advance economy. *Economic Theory*, *4*(3), 345–380.
Zhao, J. (2023). Wealth in utility, the taylor principle and determinacy. *Journal of Macroeconomics*, *76*, Article 103525.
Zhu, J., & Zhang, L. (2022). Evolutionary game analysis of the implementation of fiscal policy in resource-based cities. *Resources Policy*, *76*, Article 102618.