UDK: 336.7
DOI: 10.2478/jcbtp-2020-0026

Journal of Central Banking Theory and Practice, 2020, special issue, pp. 125-164

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Monetary Consequences of Fiscal Stress in a Game Theoretic Framework[1]

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Abstract: This paper maps Leeper and Walker (2011) model into a game theory framework to study about the strategic aspects of monetary and fiscal interaction under a fiscal stress caused by an ageing population problem. The paper reveals that the outcomes of the game depend on the parameters of the underlying model, the size of the projected transfers and the public inflation expectation. The findings show that commitment to the target (inflation, government transfers) plays a crucial role in the policy interaction.

Keywords: Monetary-fiscal interaction; Game theory; Ageing population; Dynamic leadership; Stochastic timing.

JEL Classification Numbers: E63, C70

1. INTRODUCTION

The global financial crisis (GFC) and its aftermath, characterized by fiscal stimulus and bailout packages, have raised concerns about sovereign debt in advanced countries. The policymakers in advanced countries, however, are facing a much greater challenge which threatens their fiscal sustainability. This challenge is illustrated by Table 1, which shows

[1] The authors are grateful to Jan Libich for his helpful comments and suggestions. We also would like to thank Zulquar Nain and the audience at the 13th BMEB international conference. The usual disclaimer applies.

that the spendings related to ageing population is relatively much bigger than the impact of the GFC. In the advanced G20 countries, on average, ageing related spending is more than ten times bigger compared to the crisis related spending.

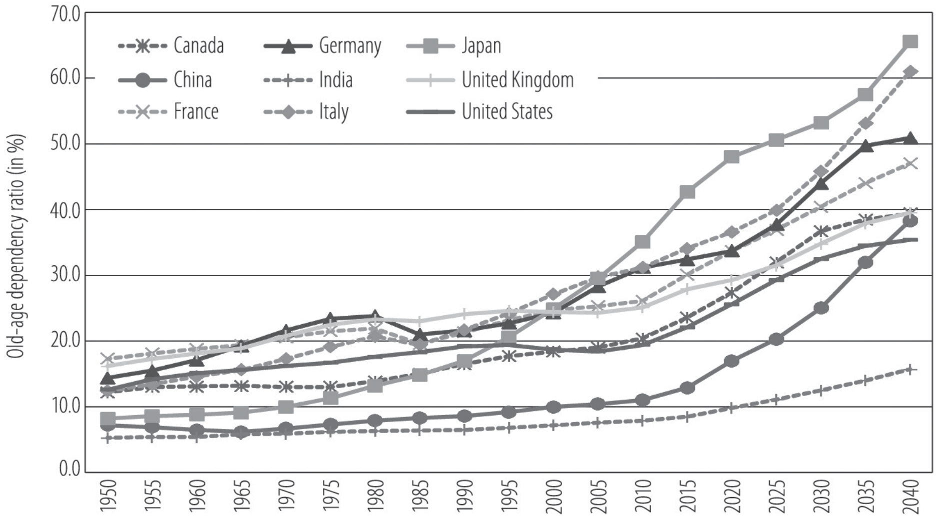
Table 1. Net Present Value of Impact on the Fiscal Deficit of Crisis and Ageing Related Spending (in percentage of GDP)

Country	Crisis	Ageing	Ageing/Crisis
Australia	30	482	16.07
Canada	21	726	34.57
France	31	276	8.90
Germany	29	280	9.66
Italy	35	169	4.83
Japan	35	158	4.51
Korea	20	683	34.15
Mexico	13	261	20.08
Spain	39	652	16.72
Turkey	22	204	9.27
United Kingdom	48	335	6.98
United States	37	495	13.38
Advanced G-20 Countries	35	409	11.69

Source: IMF (2009)

In the next few decades, the aged population will increase dramatically in the most advanced economies, and evidence from United Nations (UN) shows emerging countries, such as China and India, will soon face the same problem (see Figure 1). An ageing population problematic as there are more people who are entitled to old age benefits such as pensions and health care. As a result, this problem causes an upward pressure on government expenditures. Coupleing with a decrease in government revenue, because working age population is declining, it sets the public debt to grow significantly in the next few decades if government expenditures are not paired with increases in revenue. How can countries facing an ageing population ensure their fiscal sustainability? Potential solutions include: raising taxes to finance the fiscal shortfalls, reducing government expenditure in other areas, such as health care, and reforming the pension. Unfortunately, there are political difficulties in lowering public transfers and raising taxes. Convincing people to accept lower public benefits or higher taxes is challenging, especially given the powerful anti-tax. For this reason, there is a risk of a fiscal spillover on monetary policy, that is, the budget balancing is passed to the central bank, who can monetize the real debt.

Figure 1. Old-age dependency ratio (ratio of population aged 65+ per 100 population 15-64) of G7, China and India



Source: UN (2019)

While the interaction between fiscal and monetary policies has been well documented, surprisingly, an understanding about the ageing population implications on the strategic aspect of this interaction remains limited. This study is motivated not only to extend the literature on fiscal and monetary interaction but also attempts to address the implications of an ageing population on this. Particularly, we aim to shed light on the following questions: How fiscal stress caused by ageing populations is resolved? By a fiscal reform or by monetary monetization? Or will countries go bankrupt? A comprehensive understanding of these issues is critical to policymakers around the globe in institutional designing in order to ensure fiscal sustainability and avoiding spillover risk.

Our analysis is based on a game theoretic framework that is extended from the well-known model developed by Leeper and Walker (2011). By examining the interaction between fiscal and monetary policies in the presence of fiscal stress, this paper distinguishes itself from the prior research and contribute to the monetary - fiscal interaction literature through two important directions.

First, this paper extends the literature on the strategic aspect of monetary and fiscal interaction. Despite the broad and growing literature about the fiscal and monetary interaction, a very few of them addresses the implications of ageing population problem, exceptions include Leeper and Walker (2011) and Libich, Nguyen and Stehlik (2015). While the first study only discusses the consequences the fiscal spillover on monetary policy, the second one analyses the ageing population as a possible scenario in the aftermath of the global financial crisis and assumes that the policy interaction is a conflict game, namely Game of Chicken. Different from the previous literature, our study endogenizes the policy interaction scenarios and specifies which policy that are utilized in order to deal with the fiscal stress in each scenario. Various possible scenarios of the policy interaction are postulated, including Game Chicken, Tug of War, Symbiosis and Neglect. Each of these scenario features a different equilibrium policy mix. In line with Bianchi and Ilut (2017), this result helps to explain the changes in U.S. fiscal-monetary policy mix overtime as well as the differences across countries. In addition, our analysis allows us to suggest some policy recommendations regarding to ensuring fiscal sustainability and avoiding fiscal spillover on monetary policy.

Second, this research fills the literature gap by linking the model used by Leeper and Walker (2011) into a game theoretic framework. Following Backus and Driffill (1985) and the subsequence literature, the model is mapped into a 2×2 game. Assuming that the fiscal shortfall caused an ageing population can be thoroughly stabilized by only one policy, each policymaker can decide to take an action to balance the budget or leave it for the other player. The payoffs are the utility of the policymakers, which is dependent on the real debt, inflation rate and the public transfers. This mapping allows us to focus on the strategic aspect of the fiscal and monetary policies interaction without loss of generality, i.e. intertemporal aspects of the policy interaction.

In the modified game setup of this paper, both players move simultaneously at the beginning of the game and then one player called "reviser" has a chance to revise its initial action before the game ends. The follower, when given a chance to alter their action at the second stage, will play the best response which is anticipated by the leader; although there will be a cost of commitment due to the possibility that the follower plays their preferred action which is not the best response to the leader's strategy before the revision. The stochastic timing of moves allows the institutional features of monetary commitment and fiscal rigidity to be proposed, which refers to the inability to alter actions of the players. These institutional features can be thought as legislation that cannot be easily changed. For example, a legislated numerical target for average inflation cannot be readily adjusted due to institutional, political and reputational constraints. Similarly, the bigger the gap between projected future government expenditures and taxes, the more difficult it may be for the government to implement a reform. Different from Libich (2009), Libich (2011), and Libich et al. (2015), the 2-stage game setup allows for the incorporation of expectation which depends on the policy interaction outcome in stage 1 and then affects the outcomes of the policy interaction in stage 2.[2]

[2] Libich and Nguyen (2015) and Chortareas and Mavrodimitrakis (2017) also feature inflation expectation in their models, but it is formed at the beginning of the game rather than being path dependent.

Three main results are reported: (i) First, the analysis shows that appointing a conservative central banker does not always guarantee the social optimal outcome. To have this happens, we also need the government degree of reneging conservativeness is sufficiently low, i.e. the public debt is large enough. (ii) Second, the nature of the interaction between fiscal and monetary policy depends on the preferences of the policy authorities, such as conservatism towards inflation and conservatism towards public debt. It is also affected by the public inflation expectation, the size of the government transfers and the fiscal gap. For example, the more conservative the policymakers or the bigger the transfers, the more costly it is for the players to balance the budget. (iii) Third, the analysis shows that the outcome of the game depends not only on these variables but also the institutional design, that is, how strongly the policymakers commit to achieving their objectives. Sufficient thresholds are derived, θ_M and θ_F, which indicate the commitment/rigidity degree of the leader relative to that of the follower. In order to create a credible threat to the follower, the leader must strongly and adequately commit to his/her favorite action. In other words, the leader needs to commit as strongly as he/she can to ensure that the victory gain after the follower switches to the anticipated best response is greater than the conflict cost which they may bear in the first state of the game before the revision. These thresholds are arguably dependent on the public inflation expectation, which affects the real debt via the interest rate required for government debt.

The remainder of this paper proceeds as follows. Section 2 presents a brief review of previous literature. Section 3 describes the baseline model. The game theoretic presentation of fiscal and monetary interaction and the results are provided in section 4 and section 5, respectively. Finally, section 6 sets forth the conclusions and policy recommendations.

2. LITERATURE REVIEW

This study is built on two streams of literature: (1) the fiscal and monetary policy interaction; and (2) the game theoretic timing setup.

There is an enormous literature studying the interaction between fiscal and monetary policies that has been developed since the seminal contributions of Sargent and Wallace (1981) and Leeper (1991). These two studies highlight the fact that without a fiscal commitment to adjusting primary surplus and stabilizing public debt, monetary authorities are not able to control inflation. The main difference between Sargent and Wallace's (1981) unpleasant monetarist arithmetic and Leeper's (1991) Fiscal Theory of the Price Level is the reaction timing of inflation to an increase of public debt. While the former theory states that inflation has to increase eventually in order to stabilize the public debt, the later one explains that inflation could raise instantaneously via expectation channel.

Many subsequent studies have followed these two works and modelled the fiscal and monetary interaction that features a conflict in objectives, i.e. fiscal spending for the government and inflation for the central bank (see Tabellini, 1985; Nordhaus, 1994; Woodford, 1994; Bassetto, 2002; Dixit and Lambertini, 2003a; Benhabib and Eusepi, 2005; Mochtar, 2005; Gordon and Leeper, 2006; Lambertini, 2006; Adam and Billi, 2008; Branch, Davig and McGough, 2008; Kirsanova, Leith and Wren-Lewis, 2009; Simorangkir and Adamanti, 2010; Davig and Leeper, 2011; Saulo, Rego and Divino, 2013; Mayandy, 2019; Juhro and Iyke 2019). Based on these theories, a number of studies attempt to estimate fiscal and monetary policy mix changes in the U.S. over the last few decades. Some empirical works that follow this trend can be listed, for example Cochrane (2001), Sims and Zha (2006), Sims (2011), Bianchi (2013) and Bianchi and Ilut (2017).

Other studies investigate the policy strategic interaction in different contexts, such as, an inflation pressure (see Libich, 2011), the aftermath of 2008 financial crisis features a stagnation risk in short run and excessively high inflation in long run due to fiscal imbalances (see Libich et al., 2015), a turbulent period where a stimulation is needed (see Libich and Nguyen, 2015; Nwosu, Salisu, Hilili, Okafor, Okoro-Oji, and Adediran, 2019), on exchenge rate stability (Jia, Guo and Wang, 2015; Kim & Kim, 2017; Cekin, 2018) and financial assets (see Wang, 2018, Hu, Han and Zhang, 2018; Qureshi, Khan, Rehman, Qureshi and Ghafoor, 2019). Especially after the establishment of the European Monetary Union (EMU), fiscal and monetary policy interactions have been focused by many researchers. Some representative studies belong to this literature are Dixit (2001), Van Aarle, Engwerda and Plasmans (2002), Chortareas and Mavrodimitrakis (2017), Foresti (2018), Jarocinski and Mackowiak (2018) and Corsetti, Dedola, Jarocinski, Mackowiak and Schimidt (2019).

Despite the broad and growing literature about the fiscal and monetary interaction, a very few of them addresses the implications of ageing population problem. Notable exceptions are Leeper and Walker (2011) and Libich et al. (2015). Leeper and Walker (2011) employ a simple intertemporal model to examine the impacts of fiscal stress caused by ageing population. The study shows that unresolved fiscal gap, due to increasing government spending in form of old-age benefits, raises the possibility of hitting fiscal limits. As a result, the central bank may lose its control over inflation because taxes and spending are no longer adjusted to stabilize debt. Libich et al. (2015) put the ageing population stress (together with the fiscal imbalances accumulated during the 2007-2009 crisis) and a deflation pressure into a strategic interaction where the policymakers are not sure which scenario they are dealing with. The policy interaction outcomes are shown to be influenced by some underlying parameters, including (deterministic) payoffs, probability of each scenario and institutional design.

In term of game theoretic timing setup, related literature follows three lines of research. The first postulates the interaction between the central bank and the government as a simultaneous moves game, see Nordhaus (1994), Bassetto (2002), Adam and Billi (2008), Branch et al. (2008) and Kirsanova et al. (2009). Under simultaneous moves, however, neither standard nor evolutionary game theory provides a way to select a pure Nash equilibrium in the Game of Chicken. The second line of thought examines the interaction as a Stackelberg leadership, see Sargent and Wallace (1981), Leeper (1991), Dixit and Lambertini (2003a,b), Gordon and Leeper (2006) and Lambertini (2006). The leadership gives the leader an upper hand and enables it to achieve its preferred long-run policy regime by forcing the follower to stabilize the real debt. The last literature branch can be thought as a bridge between the two former ones. This literature investigates the policy interaction under generalised timing of moves, that is the players are allowed to make decision more than one time and with some probability. A number of papers follow this line, namely, Libich (2009), Libich (2011), Libich and Nguyen (2015), Libich et al. (2015) and Chortareas and Mavrodimitrakis (2017).

3. THE MODEL

This paper takes a simple macroeconomic model from Leeper and Walker (2011).[3] In the model, there is a representative household who both receives transfer payments and pays taxes. The central bank and the government have the same task of stabilizing the public debt. In addition, they have their own objectives which are to control inflation and provide transfers to the households, respectively.

3.1. Households

A representative household receives endowment y_t of goods each period and chooses a sequence of consumption c_t and bonds (investment) B_t to maximize the expected present value of utility:

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

with β being a subjective discount factor, subject to a budget constraint:

$$c_t + \frac{B_t}{P_t} + T_t = y_t + \lambda_t z_t + \frac{R_{t-1} B_{t-1}}{P_t} . \tag{2}$$

The right-hand side of (2) indicates the income of the household received every period t. This income includes the initial endowment y_t and an interest payment received from the previously purchased bonds $R_{t-1} B_{t-1}$. Also, the household receives a transfer from the government $\lambda_t z_t$ in which z_t is the promised transfer and $\lambda_t \in [0,1]$ is the

[3] This illustrative model is also used in Leeper (1991) and its generalized version is used in numerical works by Davig, Leeper and Walker (2010, 2011).

proportion of z_t that the government actually delivers to the household. $(1 - \lambda_t)$ is a reneging ratio that implies that the government will renege a part of its "promised" transfer when $\lambda_t < 1$ and deliver a full transfer when $\lambda_t = 1$.

The left-hand side states that the household spends c_t on its consumption and must pay a lump sum tax T_t. The private saving is in the form of a stock of bonds B_t which yield interest at a rate of R_t. The nominal interest rate R in this model implies a gross nominal interest rate rather than a net interest rate i, i.e. $R = (1 + i)$. Similarly, the inflation rate π is the gross increase in the price level, i.e. $\pi_t = \frac{P_t}{P_{t-1}}$.

Imposing the market clearing condition, $c_t = y_t$, the household's consumption Euler equation reduces to a simple Fisher relation:

$$\frac{1}{R_t} = \beta E_t\left(\frac{P_t}{P_{t+1}}\right) = \beta E_t\left(\frac{1}{\pi_{t+1}}\right). \tag{3}$$

This relation implies that if the (expected) inflation is zero the gross real interest rate will be equal to the personal subjective interest rate of the household, $R_t = 1/\beta$. Therefore, the Fisher relation simply states that the nominal interest rate approximately equals to the real interest rate r plus the inflation rate π.[4]

3.2. The Behavior of Fiscal and Monetary Policy

The central bank (player M for monetary) has an inflation target π^T and controls the nominal interest rate which is subject to a monetary rule:

$$\frac{1}{R_t} = \frac{1}{R^*} - \alpha\left(\frac{1}{\pi_t} - \frac{1}{\pi^T}\right). \tag{4}$$

The nominal interest rate, in each period, is set subject to an inflation gap, i.e. M will raise the interest rate when the actual inflation is higher than the inflation target and lower the rate if inflation is observed to be lower than the target. According to the Taylor principle, when $\alpha > 1/\beta$, the monetary policymaker will sufficiently aggressively raise the interest rate in response to an increase in inflation to stabilize it around the target rate. This is called an *active* monetary policy. A *passive* monetary policy means the central bank's response to an inflation deviation is too weak, i.e. $\alpha \leq 1/\beta$.

The government (player F for Fiscal) sets the lump sum tax subject to the following rule:

$$T_t = T^* + \gamma\left(\frac{B_t}{P_t} - b^T\right). \tag{5}$$

[4] Formally, $1 + r = \frac{1+i}{1+\pi}$.

$\frac{B_t}{P_t} = b_t$ is the real public debt level and T^* is the long-run steady state tax. When $y > 1/\beta - 1$, an increase in the real debt level above the target will lead to an increase in tax in order to deliver the real debt target $b^T = \frac{B_T}{P_T}$. This is called a *passive* fiscal policy. It is an active fiscal policy when the government's adjustment is insufficiently aggressive, $y \leq 1/\beta - 1$. Under *active* fiscal policy, the tax will be raised, but the increase in tax revenue will not be enough in order to achieve the real debt target.

The above, given $\pi_t = \frac{P_t}{P_{t-1}}$, implies the government's budget constraint:

$$\frac{B_t}{P_t} + T_t = \lambda_t z_t + \frac{R_{t-1} b_{t-1}}{\pi_t}. \tag{6}$$

Imposing the Euler equation into the budget constraint, generates

$$\frac{B_t}{P_t} + T_t = \lambda_t z_t + \frac{\frac{1}{\beta} E_{t-1}(\pi_t) b_{t-1}}{\pi_t}.$$

Every period, the government receives lump sum tax revenue T_t from the household and an income generated from issuing bonds $\frac{B_t}{P_t}$. On the other hand, the right-hand side of (6) indicates the government expenditure on transfers to the household $\lambda_t z_t$ and interest payment on previous debt $\frac{R_{t-1} b_{t-1}}{\pi_t}$. It is assumed that an *active* transfer means the government delivers the promised transfer to the public $\lambda_t = 1$. A *passive* transfer policy occurs when instead of transferring the promised amount, the government only transfers a proportion of it $\lambda_t z_t$, with $0 < \lambda_t < 1$.

The policymakers' utility function in period t then can be postulated as:

$$U_{i,t} = -\varphi_i(\pi_t - \pi^T)^2 - \left(\frac{B_t}{P_t} - b^T\right)^2 - \delta_i(1-\lambda_t)^2, i = M, F \text{ and } \delta_M = \varphi_F = 0. \tag{7}$$

The utility functions are consistent with the intuition of Leeper (1991) and Leeper and Walker (2011), as they feature the same objectives of the policymakers. For simplicity, it is assumed that the central bank pays no attention to transfers delivering, $\delta_M = 0$, and the government's utility is not affected by inflation gap, $\varphi_F = 0$. This assumption will not affect the results of the interaction between the central bank and the government. The monetary authority's utility is a function of the inflation gap and the real debt gap. From the government's perspective, these objectives are the real debt gap and the reneging ratio. For parsimony, fiscal and monetary policymakers have the same real debt targets, however, the central bank and the government will attach different weights to their own objectives. These objectives are inflation target for the central bank and promised transfers for the government. The weights depend on the central bank and the government's institutional design and preferences, for example, the central bank's priority is having the real debt target when $0 < \varphi_M < 1$, and achieving the inflation target is the primary objective if $\varphi_M > 1$.

These utility functions also implicitly include stabilisation of the output gap as it is arguably related to the real debt gap. The real debt gap is positively related to the government spending and negatively related to the tax revenue, so it affects the level of output in the short-run. Such an attempt to cut the real debt by reducing the transfers will lead to a reduction in disposal income of the households and therefore temporarily decrease the aggregate demand.

3.3. Sources of Fiscal Stress and Its Solutions

Equation (6) can be used to summarize the long-term sources of the fiscal stress and its solutions:

a) *Ageing population problem*: results in high promised transfers z_t and low taxes T_t.
b) *Past fiscal excessive spending and/or bail out*: high B_{t-1}.[5]

Various solutions can be used to address the fiscal stress:

(i) *Structural fiscal reform*: decreasing z_t and/or increasing T_t

(ii) *Reneging on promised transfer*: choosing $\lambda_t < 1$.

(iii) *Monetization of debt*: the central bank raises the inflation π_t by increasing the money supply to reduce the real payment for previous debt $\frac{R_{t-1}b_{t-1}}{\pi_t}$, and therefore pins down the real debt $\frac{B_t}{P_t}$ that the government has to borrow in order to balance the budget constraint.

Solution (i) is mathematically equivalent to solution (ii). Since there is only one representative household in this model, both structural fiscal reform and reneging on promised transfer will reduce the disposal income of the household. Therefore, the political effects of implementing these solutions on the government will be identical in the context of this paper. For simplicity, this paper provides a discussion for the last two solutions in which the reneging on promised transfer is used by the government and the monetization of debt is used by the central bank to balance the budget.[6] While Leeper and Walker (2011) only mention which policy is possible to deal with the fiscal shortfalls, this paper extends the work by endogenizing the policy regimes the specified policy authority has can utilize in order to deal with the fiscal stress.

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[5] This also leads to a high debt service payment, $\frac{R_{t-1}b_{t-1}}{\pi_t}$, which is suggested to have pernicious macroeconomic consequences (Fullwiler, 2007).

[6] There are other possible solutions such as increasing the retirement age to encourage more contribution to the economic growth from the old and delay the claim for pension and healthcare benefits. By encouraging an increase in the birth rate, there would be an increase in the workforce which would act to help reduce the ageing population. However, this solution would take a long time to have an effect on the population structure.

4. A GAME THEORETIC PRESENTATION OF MONETARY AND FISCAL POLICY INTERACTION

This section looks at the strategic aspect of monetary and fiscal policy. In order to map the model in Section 3 into a game theoretic framework, the best responses of the central bank and the government are simplified. Assuming that the real debt now can be thoroughly stabilized by only one policy, the best responses for the central bank and the government when the other authority is setting inflation target/promised transfers is stabilizing the real debt to its target level b^T. This assumption takes into account the fact that the real debt cannot be consistently positive, it eventually has to be retired (at least to the real debt target b^T). These best responses are referred to passive policies, which are discussed in the next section. On the other hand, active policies are exempt from the public debt and are set following the policymakers' objectives.

The interaction between two policymakers is presented as a 2 × 2 game. The first payoff is received by the row player *M* and the second received by the column player *F*. *A* stands for active and *P* stands for passive.

		F	
		AF	*PF*
M	*AM*	*a, w*	*b, x*
	PM	*c, y*	*d,z*

(8)

The payoffs {*a, b, c, d*} and {*w, x, y, z*} express policymakers' utility across the interaction's outcomes. Two policymakers will make a decision of moves taken from a binary choice set (active, passive). The interaction between the two policies is examined in a single period setup. Then, the result under this simple set up is used to build a framework allowed for multi-period interaction between *M* and *F*. It is assumed that the government cannot use or does not want to use the tax instrument to adjust the real debt. Therefore, the only way that the fiscal policymaker can stabilize real debt is using transfer policy through manipulating λ_t. This assumption is consistent with the fiscal stress source (b), since the effect of an increase in transfer to the households will be cancelled out by a raise in taxes levied on them. To reduce the number of free variables involved, it is assumed that in the previous period $t-1$ there is no fiscal stress. The central bank could actively adjust the interest rate to obtain the inflation target, and the government's tax revenue was enough to cover the transfer costs and deliver the real debt target. This is equivalent to inflation and real debt at their target in the previous period, $\pi_{t-1} = \pi^T$ and $\frac{B_{t-1}}{P_{t-1}} = b_{t-1} = b^T$. Then, using (6), the budget constraint is represented as:

$$\frac{B_t}{P_t} + T_t = \lambda_t z_t + \frac{R_{t-1} b^T}{\pi_t} \tag{9}$$

Assume there is a fiscal stress in period t caused by the promised transfer z_t that exceeds the tax revenue T_t. This is the first source of fiscal stress discussed in Section 2.3. Thus, the fiscal gap is positive, $z_t - T_t > 0$, and the government is running primary deficits. To solve the unbalanced budgetary problem, the budget constraint (9) suggests the solutions are a monetization of debt, a reneging on promised transfers or a combination of both. The first solution will lead to a higher price level and reduce the real value of the real interest payment, while the second indicates a direct reduction in both the nominal and real value of the transfers.

4.1. Active and Passive Policies

According to Leeper and Walker (2011), the policymakers are called active (A) when they are free to pursue their objectives, and they are passive (P) when their behavior is constrained by the fiscal stress. In particular, an active central bank aggressively and sufficiently adjusts to any inflation deviation from the target, $\pi_t - \pi^T$, via its interest rate instrument. The government, with a preference towards being re-elected, has an objective to maintain the promised transfers to the households. Active fiscal policy is then equivalent to the government setting $\lambda_t = 1$. When the policy authorities pay attention to stabilization of real debt and adjust their policy instruments, they are called passive. *A* and *P* policies are defined by the parameter ranges. In order to reduce this multiplicity and focus on the strategic set up, *A* and *P* are defined differently. The policies are referred to two extreme cases which are the most natural candidates. Specifically, *AM* (active monetary policy) and *AF* (active fiscal policy) indicate the policy authorities do not pay attention to achieving the real debt target and the control variables are set to obtain their individual targets. In the passive policy stance, *PM* (passive monetary policy) and *PF* (passive fiscal policy), the policymakers are constrained by the real debt, so a full sufficient adjustment of the control instruments is provided to maintain the real value of government debt at its target level b^T. The value of π_t and λ_t under passive policy stances are derived using (9). Therefore, in this model, it is assumed that the inflation rate is always at the central bank's target level under the active monetary regime, however, the inflation target will not be achieved under passive monetary regime since the central bank does not respond strongly enough to any deviation in inflation. Under an active transfer regime, $\lambda_t = 1$, the promised transfers will be delivered to households. The transfers will be reduced in order to balance the budget under passive transfer policy, $\lambda_t < 1$.

Under *Passive* monetary policy:

$$b^T + T_t = \lambda_t z_t + \frac{R_{t-1} b^T}{\pi_t^P},$$

which rearranging provides:

$$\pi_t^P = \frac{R_{t-1} b^T}{b^T - (z_t - T_t)} = \frac{\frac{1}{\beta} E_{t-1}(\pi_t) b^T}{b^T - (z_t - T_t)} > E_{t-1}(\pi_t). \tag{10}$$

Remark 1. *The passive inflation rate π_t^P is higher than the expected inflation.*

To completely monetize the real debt and bring it to the target level, the central bank must raise the inflation rate above the public inflation expectation $E_{t-1}(\pi_t)$, i.e. an inflation shock can reduce the real value of the interest payment on bonds required by the household. This is in order to reduce the real value of nominal bond stocks purchased by the public in previous periods. Obviously, the bigger the primary deficit $(z_t - T_t)$, the higher the inflation rate that the central bank must raise. This is equivalent to the central bank prints more money in order to deflate the real interest payment of the government debt. Moreover, if households expect a higher inflation, the monetary policymaker must raise the inflation rate even higher, implying a higher loss to the central bank indicated by (7). Therefore, the higher the expected inflation, the more difficult real debt stabilization is, when using monetary instrument.

Noticeably, when the size of the primary deficit is equal to the real debt target $(z_t - T_t) = b^T$, the denominator of (10) becomes zero and the passive inflation chosen by the central bank is infinite. Clearly, the central bank alone cannot deliver a debt target level when the primary deficit is larger than the debt target since a negative gross inflation rate is infeasible. In this case, coordination of the government is required to sufficiently reduce the real debt to the target. Alternatively, it will take more than one period for the central bank to individually stabilize the public debt.

Under *Passive* fiscal policy:

$$b^T + T_t = \lambda_t^P z_t + \frac{R_{t-1} b^T}{\pi^T},$$

which rearranging provides:

$$\lambda_t^P = \frac{b^T + T_t - \frac{R_{t-1} b^T}{\pi^T}}{z_t} = \frac{b^T + T_t - \frac{1}{\beta} E_{t-1}(\pi_t) \frac{b^T}{\pi^T}}{z_t} < 1. \tag{11}$$

Remark 2. *The higher the expected inflation or the bigger the promised transfer, the more aggressively the government needs to cut their transfers in order to stabilize the real debt, under a passive fiscal policy regime.*

The real debt stabilization requires the government to cut some of its promised transfers. λ_t^P is negatively related to the inflation expectation $E_{t-1}(\pi_t)$ and the size of the transfers z_t or the deficit $(z_t - T_t)$ since it is assumed that the government does not want to adjust tax, or cannot adjust taxes due to political constraints. The higher the expected inflation, the higher the required interest payment by the government for the last period bonds. Since the government could not generate enough revenue to finance this payment, some transfers must be cut in order to reduce the expenditure and balance the budget. If the public expectation is sufficiently large, i.e. $\frac{1}{\beta} E_{t-1}(\pi_t) \frac{b^T}{\pi^T} > b^T + T_t$, the real debt target will not be achieved even if the government cuts all of its promised transfers to the public. Therefore, in this scenario, either the two policymakers have to coordinate in stabilizing the real debt, or a gradual transfer reduction is implemented by the government for more than one period in order to achieve the real debt target.[7] In addition, the bigger the promised transfer z_t the bigger the primary deficit and, therefore, in order to achieved the real debt target, the government has to renege some of its transfers to the public more aggressively.

In summary:

- Active monetary policy *AM*: choosing $\pi_t = \pi^T$;
- Passive monetary policy *PM*: choosing $\pi_t = \pi_t^P(\lambda_t = 1, b^T, z_t, R_{t-1}, T_t) > \pi^T$;
- Active fiscal policy *AF*: choosing $\lambda_t = 1$;
- Passive fiscal policy *PF*: choosing $\lambda_t = \lambda_t^P(\pi_t = \pi^T, b^T, z_t, R_{t-1}, T_t) < 1$.

In order to focus on the strategic interaction and eliminate the extreme results of an infinite inflation and an infeasibility of fiscal debt stabilization, it is assumed that the policymakers can individually obtain the real debt target in a single period without any coordination from the other policymakers. This requires the following conditions to be satisfied:

$$(z_t - T_t) < b^T, \tag{12}$$

and

$$\frac{1}{\beta} E_{t-1}(\pi_t) \frac{b^T}{\pi^T} < b^T + T_t. \tag{13}$$

These conditions imply that the fiscal deficit and the inflation expectation, i.e. the required interest rate on public debt, must be sufficiently small in order have the real debt stabilized by only one policy.

4.2. Outcomes under Various Policy Combinations

Under the active monetary and passive transfer regime, (*AM*, *AF*), because both policies are active, the economy will end up with an inflation level at target $\pi_t = \pi^T$.

[7] There is another solution: raising the taxes T_t. However, in this paper T_t is assumed to be unchanged, since the adjustment will have the same political affect as adjusting λ_t or due to the fiscal limit that does not allow the government to raise taxes (see Leeper and Walker, 2011).

On the other hand, because the government is also active, the transfer expenditure is therefore higher than the tax revenue. Consequently, the debt is increased:

$$\frac{B_t}{P_t} = z_t - T_t + \frac{R_{t-1} b^T}{\pi^T} > b^T. \tag{14}$$

Obviously, this outcome cannot be a long-run equilibrium since a country is unable to accumulate debt forever. Therefore, if (*AM*, *AF*) is observed, in the future at least one of the policymakers has to step in and stabilize the real debt.

Under the active monetary and passive transfer regime, (*AM*, *PF*), the inflation will be at its target since the central bank implemented an active policy $\pi_t = \pi^T$. As the transfer policy is passive, the real debt will be driven to its target by reneging on the public transfers, $\lambda_t = \lambda_t^P < 1$.

Under the passive monetary and active transfer regime, (*PM*, *AF*), the central bank takes the debt stabilizing role and ignores the inflation deviation. As a consequence, the inflation rate will increase. The government, therefore, can pass the promised transfer to the household. The inflation level under this scenario is higher than the target in order to reduce the real debt, $\pi_t = \pi_t^P > \pi^T$ and $b_t = b^T$.

Under the passive monetary and passive transfer regime, (*PM, PF*), both the central bank and the government simultaneously stabilize the real debt. As a consequence, the real debt is reduced even lower than the target level and the price level is higher as the central bank is passive, $\pi_t = \pi_t^P$.

$$\frac{B_t}{P_t} + T_t = \lambda_t^P z_t + \frac{R_{t-1} b^T}{\pi_t^P}. \tag{15}$$

Using (10), (11) and (15) provides:

$$\frac{B_t}{P} = 2b^T - (z_t - T_t) - \frac{R_{t-1} b^T}{\pi^T} < b^T. \tag{16}$$

Using the above results, the outcomes of the interaction between fiscal and monetary policies are presented in the following matrix:

		F	
		AF ($\lambda_t = 1$)	*PF* ($\lambda_t = \lambda_t^P$)
M	*AM* ($\pi_t = \pi^T$)	Stable inflation, Increasing real debt	Stable inflation, Stable real debt
	PM ($\pi_t = \pi_t^P$)	Increasing inflation, Stable real debt	Increasing inflation, Decreasing real debt

The outcome under (*AM*, *PF*) is featured as the social optimum since it has both stable inflation and stable real debt. Due to the fact that the real debt cannot be consistently positive over the medium to long-run, a sustainable outcome requires at least one of the policymakers to stabilize the real debt. Under a passive monetary scheme, the budget constraint can be balanced in the short-run, however, in the medium-run, the public will revise the expectation since the inflation is no longer pegged at the target rate. This will make the monetary policy insufficient to reduce the real debt, as an increase in inflation will be fully expected by the household and therefore, the real interest rate $\frac{R_{t-1}}{\pi_t}$ cannot be lowered in the medium-run. In a passive monetary and passive transfer regime, the real debt is decreased but the inflation is unnecessarily high.

4.3. Payoffs

Substituting the inflation rate, real debt level and reneging ratio into the utility functions, the payoffs of each player in each regime in (13) are presented as follows:

For the central bank, *M*:

$$a = U_{M,t}(AM, AF) = -\frac{1}{(\pi^T)^2}[(z_t - T_t - b^T)\pi^T + R_{t-1}b^T]^2,$$

$$b = U_{M,t}(AM, PF) = -\varphi_M(0)^2 - (0)^2 = 0,$$

$$c = U_{M,t}(PM, AF) = -\frac{\varphi_M}{(b^T - (z_t - T_t))^2}[R_{t-1}b^T - \pi^T(b^T + -(z_t - T_t))]^2,$$

$$d = U_{M,t}(PM, PF) = -\frac{1}{(\pi^T)^2}(z_t - T_t + R_{t-1}b^T - b^T)^2 - \frac{\varphi_M}{(b^T - (z_t - T_t))^2}[R_{t-1}b^T - \pi^T(b^T + -(z_t - T_t))]^2.$$

For the government, *F*:

$$w = U_{F,t}(AM, AF) = -\frac{1}{(\pi^T)^2}[(z_t - T_t - b^T)\pi^T + R_{t-1}b^T]^2,$$

$$x = U_{F,t}(AM, PF) = -\frac{\delta_F}{z_t^2(\pi^T)^2}[(z_t - b^T - T_t)\pi^T + R_{t-1}b^T]^2,$$

$$y = U_{F,t}(PM, AF) = -(0)^2 - \delta_F(0)^2,$$

$$z = U_{F,t}(PM, PF) = -\frac{1}{(\pi^T)^2}[(z_t - T_t - b^T)\pi^T + R_{t-1}b^T]^2 - \frac{\delta_F}{z_t^2(\pi^T)^2}[(z_t - b^T - T_t)\pi^T + R_{t-1}b^T]^2.$$

Without loss of generality, the payoffs can be simplified by diminishing $\frac{[(z_t - T_t - b^T)\pi^T + R_{t-1}b^T]}{(\pi^T)^2}$. The payoffs matrix can be presented by a reduced form as follows:

<table>
<tr><td></td><td></td><td colspan="2">F</td></tr>
<tr><td></td><td></td><td>AF</td><td>PF</td></tr>
<tr><td rowspan="2">M</td><td>AM</td><td>-1, -1</td><td>$0,\ -\frac{\delta_F}{z_t^2}$</td></tr>
<tr><td>PM</td><td>$-\frac{\varphi_M}{(b^T-(z_t-T_t))^2},\ 0$</td><td>$-\frac{\varphi_M}{(b^T-(z_t-T_t))^2}-1,\ -\frac{\delta_F}{z_t^2}-1$</td></tr>
</table>

(17)

The payoffs to the players not only depend on the parameters in the underlying model but also the fiscal gap and the real debt target. This, in turn, will affect the nature of the interaction between *M* and *F*.

4.4. Possible Scenarios

Apparently, in (17), the payoff under (*AM, PF*) is the best for the central bank. Therefore, the central bank always plays active if the government decides to be passive and reneges on its transfers to stabilize the debt. On the other hand, the government's best response to *PM* is *AF*. Clearly, the payoffs under (*PM, PF*) are worse for both players since under this outcome there is not only an increase in inflation but also a reduction in real debt level below its target.

According to (17), the payoffs for the policymakers under the passive action are negatively related to how conservative they are on their objectives. The higher the central bank's inflation conservatism φ_M and the higher the government's reneging conservatism δ_F, the higher the cost of inflation and transfer deviations are. Therefore, both of the players lean towards their own targets and ignore the real debt level. This means the players are willing to stabilize the real debt when their level of debt conservatism is relatively high, i.e. smaller φ_M and δ_F.

It is clear that the nature (scenario) of the interaction between *M* and *F* depends on the values of the underlying parameters. The possible scenarios are summarised and presented in Table 2.

Table 2. Description of Possible Scenarios

Scenarios	NE(s)	Conflict	Coordination Problem	Socially Optimal Outcomes
Game of Chicken	(*AM, PF*), (*PM, AF*)	Yes	Yes	Only one policy
Tug of War	(*AM, AF*)	Yes	No	No
Symbiosis	(*AM, PF*)	No	No	Yes
Neglect	(*PM, AF*)	No	No	No

4.4.1. The Game of Chicken

The game is the Game of Chicken if (*AM, PF*) and (*PM, AF*) are the two Nash Equilibria (NE), where the central bank prefers the former and the government prefers the latter. To have this form of game the payoffs must satisfy the following conditions:

$$\frac{\varphi_M}{\left(b^T - (z_t - T_t)\right)^2} < 1 \text{ , and } \frac{\delta_F}{z_t^2} < 1 \,. \tag{18}$$

Rearranging (18) indicates the transfers must satisfy the following condition:

$$\sqrt{\delta_F} < z_t < b^T + T_t - \sqrt{\varphi_M} \,.$$

An example of the game of chicken, with the NE in bold, is:[8]

		F	
		AF	*PF*
M	*AM*	-1, -1	**0, -0.8**
	PM	**-0.8, 0**	-1.8, -1.8

(19)

The policy interaction features a Game of Chicken when both policymakers are not too conservative on their target. In addition, the transfer is small enough to reduce the cost of inflation from the monetary passive policy of the central bank. However, the size of z_t should be large enough to increase the cost of high real debt compared to the cost of reneging on the promised transfers. Under these conditions, the payoff for the central bank in passive monetary policy and active transfer policy regime is higher than the payoff under the outcome when both players are active. Therefore, if the government does not implement any fiscal reform to reduce the real debt, the central bank will play passive by adjusting the nominal interest rate to raise inflation and reduce the value of real debt. Similarly, the government's payoff under the (*AM, PF*) regime is higher than that under the (*AM, AF*) regime. This is equivalent to the government focusing more on having the real debt target rather than delivering promised transfers to households. This means the government is willing to renege on the transfer and drive the debt level down rather than leave the real debt higher than its target level.

The game features two NEs, (*AM, PF*) and (*PM, AF*) in which the central bank prefers the former and the government prefers the latter. Because there is no agreement upon the preferred outcome, hence in the Game of Chicken, the players may ran-

[8] It is set that $\varphi_M = \delta_F = 0.2$. The real debt target is 55% of GDP, the promised transfers z_t and the primary deficit $(z_t - T_t)$ are 50% and 5% of GDP respectively.

domly switch between active and passive. Thus, the social inferior outcomes such as high inflation (*PM, AF*) or increasing real debt (*AM, AF*) may happen.

4.4.2. The Tug of War

The game will take the form of Tug of War if both policymakers have a dominant strategy to be active, i.e. (*AM, AF*) is the only Nash equilibrium. Both of the policymakers enter a fight, and neither wants to stabilize the real debt and surrender their own objectives. The payoffs must satisfy the following conditions:

$$\frac{\varphi_M}{\left(b^T - (z_t - T_t)\right)^2} > 1, \text{ and } \frac{\delta_F}{z_t^2} > 1. \tag{20}$$

Rearranging (20) provides:

$$b^T + T_t - \sqrt{\varphi_M} < z_t < \sqrt{\delta_F}.$$

An example of the Tug of Wars is shown as follows:[9]

		F	
		AF	*PF*
M	*AM*	**-1, -1**	0, -1.13
	PM	-1.08, 0	-2.08, -2.13

In this scenario, the size of the transfers z_t is too large for the bank to stabilise and too small to be a concern of the government. This is because the central bank and the government conservatisms on their target (inflation and reneging respectively) are too strict. Therefore, their priority is to achieve the favorite target. The central bank puts more weight on the inflation target compared to the Game of Chicken, so the monetary policymakers always try to achieve the inflation target rather than switch to *passive* and stabilize the debt. The government also finds that the dominant strategy is *active*. This is because the government's reneging conservatism is high, and the payoff for it to have promised transfers that are delivered to the households is higher than that of getting the real debt target. Due to the disutility of reneging and losing voters being much higher than the disutility from the increasing debt, the government always wants to transfer the full amount of z_t that it promised the public. As a result, the inflation target will be achieved, but the real debt level is higher than the target. As the real debt is increased, this outcome cannot be achieved in the long term according to Buiter (2002), so this cannot be a long-run set up for fiscal and monetary interaction.

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9 With $\varphi_M = \delta_F = 0.2$, $b^T = 0.55$, $T_t = 0.3$ and $z_t = 0.42$.

4.4.3. The Symbiosis

The Symbiosis game occurs when there is only one pure NE, (*AM, PF*), i.e. the following conditions are satisfied:

$$\frac{\varphi_M}{\left(b^T - (z_t - T_t)\right)^2} > 1, \text{ and } \frac{\delta_F}{z_t^2} < 1, \tag{21}$$

which rearranging provides:

$$z_t > max\{b^T + T_t - \sqrt{\varphi_M}, \sqrt{\delta_F}\}.$$

An example of the symbiosis game is displayed as follows:[10]

		F	
		AF	*PF*
M	*AM*	-1, -1	**0,-0.8**
	PM	-1.63, 0	-2.63, -1.8

In this game, the equilibrium regime is featured by the active monetary and passive transfer policies. Because M's inflation conservatism φ_M is sufficiently high, hence a higher real debt is less costly than having a higher inflation rate, so the central bank always finds it is optimal to play active. On the other hand, the government have a sufficient low δ_F, hence the deficit is large enough to induce the fiscal policymaker to renege on its promised transfer. Therefore, under the Symbiosis scenario, the social optimum, where both inflation and real debt are stable, is always achieved.

Different from Rogoff (1985), the above result shows that appointing a conservative central banker does not always guarantee the social optimal regime, i.e. (*AM, PF*). To have this happens, we also need the government degree of reneging conservativeness is sufficiently low, i.e. the public debt is large enough. Therefore, to avoid the fiscal distress caused by an ageing population, countries should both adopt an inflation strict central banker and an accountable fiscal rule. An enforceable rule about real debt level will make it easier for the government to implement a fiscal reform and cut the public transfer. The later section will discuss a different channel where the social optimal regime can be delivered when the policy interaction does not take the form of the Symbiosis.

[10] With $\varphi_M = \delta_F = 0.2$, $b^T = 0.55$, $T_t = 0.3$ and $z_t = 0.5$.

4.4.4. The Neglect

The Neglect Game takes a form where (*PM, AF*) is the only NE. This requires the following condition to be satisfied:

$$\frac{\varphi_M}{\left(b^T - (z_t - T_t)\right)^2} < 1\text{, and } \frac{\delta_F}{z_t^2} > 1, \tag{22}$$

which implies:

$$z_t < min\{b^T + T_t - \sqrt{\varphi_M}, \sqrt{\delta_F}\}.$$

An example of the Neglect Game is presented as follows:[11]

		F	
		AF	*PF*
M	*AM*	-1, -1	0, -1.63
	PM	**-0.8, 0**	-1.8, -2.63

When the central bank's level of conservativeness is not too high and the government is not willing to renege on its promised transfer, the interaction between the two policymakers takes the form of a Neglect game. The condition (22) implies the transfer z_t is not large enough to induce the government to reduce the transfers, but is small enough for the central bank to raise the inflation rate and monetize the nominal debt. The game results in a social inferior outcome where the real debt is stabilized but with a high inflation rate.

5. POLICY INTERACTION UNDER GENERALISED TIMING OF MOVES

A large body of literature describes the interaction between *M* and *F* as a Game of Chicken which features a conflict combined with a coordination problem.[12] Both of the policymakers try to avoid the undesired mixed NEs in which the outcomes randomly switch between different regimes and each of them prefers different NE. There are two NEs: a social optimal outcome (*AM, PF*) with low inflation/stabilized real debt and a socially sup-optimal outcome (*PM, AF*) with high inflation/stabilized

[11] With $\varphi_M = \delta_F = 0.2$, $b^T = 0.55$, $T_t = 0.3$ and $z_t = 0.35$.

[12] For example, Sargent and Wallace (1981), Alesina and Tabellini (1987), Petit (1989), Leeper (1991), Nordhaus (1994), Sims (1994), Woodford (1994), Blake and Weale (1998), Dixit and Lambertini (2001) and (2003a), Benhabib and Eusepi (2005), Hughes Hallett and Libich (2007), Adam and Billi (2008), Branch, et. al. (2008), Libich et al. (2015), Libich and Nguyen (2015) and Franta, Libich and Stehlik (2011, 2018).

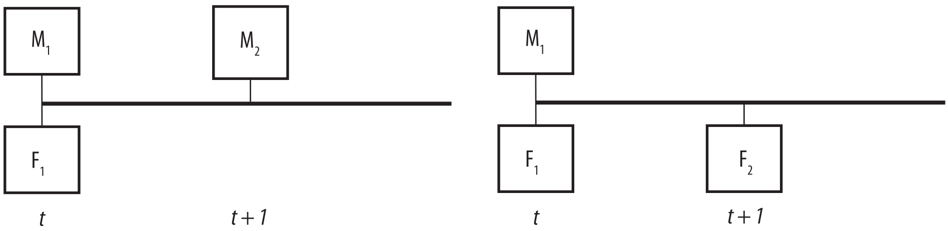
real debt. Of these two NEs, the former is preferred by the central bank, and the latter is preferred by the government. In reality, several of the scenarios listed in Figure f-scenarios can arguably occur, however, as these games have only one NE, they neither describe the social optimum nor explain the possibility of deviation from the social optimal outcome (*AM, PF*). For these reasons, this paper focuses on the Game of Chicken scenario when discussing the intuition of the monetary and fiscal policy interaction.

As the Game of Chicken has two NEs and each player prefers a different one, there is a NE selection problem. Neither the standard repeated game in which both players move simultaneously nor the alternating moves framework in Maskin and Tirole (1988) have a solution where both players can deviate from the undesired mixed NEs. The problem of avoiding mixed NEs can be solved using the standard Stackelberg leadership framework. In this framework, the leader is assumed to commit his action and then forces the follower to comply by playing the best response to the committed action of the leader. Since the follower always plays its best response to the leader's action, the game ends up with the NE preferred by the Stackelberg leader. This is implicitly used by Sagent and Wallace (1981), Leeper (1991) and Leeper and Walker (2011) in which the follower can alter their action immediately. However, there is no cost of commitment from the leader and revision from the follower since the concept of commitment in the standard leadership framework is static. In conclusion, neither standard nor evolution game theory is realistic in *M* and *F* policy interaction context.

In order to shed some insights to the outcomes of the interaction game, we apply Libich's (2009) timing set up, i.e. combining the features of both the standard simultaneous moves game and the Stackelberg leadership framework. In particular, one of the policymakers can now revise their action with some probability but not necessarily certainty. In the first state, when the game starts, both players move simultaneously. Then, in the second state, one of these players is allowed to change their action. The revision opportunity is assumed to be exogenous and common knowledge to the players.

Incorporating generalized timing of moves allows for a postulation of two institutional features: *M* commitment and *F* rigidity. Both concepts refer to the respective policymakers' inability to change their initial actions. The commitment concept is now changed from static to dynamic. It is dynamic in the sense that because it takes time for the follower to revise their action to the best response to the leader's action, there may be a cost of commitment before the revision. For this reason, the outcome of this strategic interaction is no longer the NE which the leader prefers. The outcome will depend on the cost and benefit of the commitment. Figures 3 provides an example of the timing of moves. The initial moves of two players are denoted as M_1 and F_1 and the revisions are denoted as M_2 and F_2.

Figure 2. Fiscal and Monetary Leadership



In literature, it can be seen central bank is often viewed as the follower in Stackelberg equilibrium (for example, Sargent and Wallace, 1981; Leeper, 1991; and Leeper and Walker; 2011). However, monetary leadership is arguably achieved under an inflation-targeting framework, since this modest approach associated with narrow mandates and rules help to avoid harmful discretion (Orphanides, 2015). In other words, the degree of *M* commitment is increased with the legislation of a numerical inflation target, because such a transparent objective cannot be altered due to institutional and reputational constraints. On the other hand, *F* rigidity is related to size of fiscal shortfalls implied by the existing legislation. The greater the gap between future government expenditures and taxes, the more difficult the government can implement a reform towards sustainability.

5.1. Dynamic of Monetary and Fiscal policy interaction

Since, in reality, the *M* and *F* interaction game has more than one period, the payoffs for two players are path dependent. For example, if an active monetary policy and active transfers regime is observed in the previous period, it means the real debt would increase. Therefore, in order to retire the real debt to its target, it requires a higher inflation rate generated by the central bank or a bigger transfer cut from the government. If no one steps in to stabilize the past debt, the utility losses are higher in current period. In addition, changes in public inflation expectation and differences in the budget deficit across states also affect the payoffs for the two policymakers. An upwards inflation expectation, $E_{t-1}(\pi_t)$, will generate a requirement of higher interest payments of the bonds. Also, an explosiveness in the primary deficit clearly is the main contributor to the increasing trend of the real debt. If these are the cases, the policymakers are required to adjust their policy instruments more aggressively to sufficiently bring the real debt to the target. Therefore, the payoffs for the players in the next period are equal to the payoffs of this period augmented by a weight parameter which depends on the previous policy interaction outcome and positively relates to the inflation expectation and budget deficit.

The budget constraint in period $t + 1$ is:

$$\frac{B_{t+1}}{P_{t+1}} + T_{t+1} = \lambda_{t+1} z_{t+1} + \frac{R_t \frac{B_t}{P_t}}{\pi_{t+1}}. \tag{23}$$

Similar to Section 3.1, under *Passive* monetary policy:

$$\pi^P_{t+1} = \frac{R_t \frac{B_t}{P_t}}{b^T - (z_{t+1} - T_{t+1})} = \frac{\frac{1}{\beta} E_t(\pi_{t+1}) \frac{B_t}{P_t}}{b^T - (z_{t+1} - T_{t+1})}.$$

Under *Passive* fiscal policy:

$$\lambda^P_{t+1} = \frac{b^T + T_{t+1} - \frac{R_t \frac{B_t}{P_t}}{\pi^T}}{z_{t+1}} = \frac{b^T + T_{t+1} - \frac{\frac{1}{\beta} E_t(\pi_{t+1}) \frac{B_t}{P_t}}{\pi^T}}{z_{t+1}}.$$

Following the same steps as Section 3.3, the reduce payoffs matrix in period $t + 1$ are presented as followed:

		F	
		AF	*PF*
M	*AM*	$-\omega, -\omega$	$0, \ -\omega \frac{\delta_F}{z^2_{t+1}}$
	PM	$-\omega \frac{\varphi_M}{(b^T - (z_{t+1} - T_{t+1}))^2}, 0$	$-\omega \left[\frac{\varphi_M}{(b^T - (z_{t+1} - T_{t+1}))^2} - 1\right], \ -\omega \left(\frac{\delta_F}{z^2_{t+1}} - 1\right)$

(24)

where the future payoffs are augmented with a weight:

$$\omega = \left[\frac{R_t \frac{B_t}{P_t} - \pi^T(b^T - (z_{t+1} - T_{t+1}))}{R_{t-1} b^T - \pi^T(b^T - (z_t - T_t))}\right]^2 = \left[\frac{\frac{1}{\beta} E_t(\pi_{t+1}) \frac{B_t}{P_t} - \pi^T(b^T - (z_{t+1} - T_{t+1}))}{\frac{1}{\beta} E_{t-1}(\pi_t) b^T - \pi^T(b^T - (z_t - T_t))}\right]^2.$$

Since all the payoffs are augmented by the same parameter ω, the nature of the interaction between the central bank and the government is unchanged. For example, unless there is change in the policy preferences, if we observed a Game of Chicken in the past, the current interaction should also be characterized by the same type of game.

In order to reduce the number of free parameters, it is assumed that there is no change in the promised transfers and the taxes by the government, i.e. $z_{t+1} = z_t = z$ and $T_{t+1} = T_t =$ T. The weight then becomes:

$$\omega = \left[\frac{\frac{1}{\beta} E_t(\pi_{t+1}) \frac{B_t}{P_t} - \pi^T(b^T - (z - T))}{\frac{1}{\beta} E_{t-1}(\pi_t) b^T - \pi^T(b^T - (z - T))} \right]^2. \qquad (25)$$

Proposition 1. *The future payoffs for the monetary and the fiscal policymakers are negatively related to the future inflation expectation and the current real debt.*

Proof. The weight ω is positively dependent on the expected inflation of the second state $E_t(\pi_{t+1})$ the real debt in the first state B_t/P_t. The payoffs matrix (24) indicates a negative relationship between the payoffs and the weight. Therefore, the payoffs for the players in the second state are decreased when the expected inflation and the real debt in the previous state increases.

Obviously, this weight parameter ω is path dependent. Its value depends on the outcome of *M* and *F* interaction in the previous period. If, in period *t*, both policymakers are active, the inflation rate is at target, but the real debt is increased since no one can stabilise it. Therefore, substituting (3) and (14) into (25) yields:

$$\omega_{AF}^{AM} = \left[\frac{\frac{1}{\beta^2} E_{t-1}(\pi_t) E_t(\pi_{t+1}) \frac{b^T}{\pi^T} + \frac{1}{\beta} E_t(\pi_{t+1})(z - T) - \pi^T(b^T - (z - T))}{\frac{1}{\beta} E_{t-1}(\pi_t) b^T - \pi^T(b^T - (z - T))} \right]^2.$$

If only one of the players was passive, i.e. the regime (AM, PF) or (PM, AF), the debt would be at the target level. In this case, the weight is:

$$\omega_{PF}^{AM} = \omega_{AF}^{PM} = \left[\frac{\frac{1}{\beta} E_t(\pi_{t+1}) b^T - \pi^T(b^T - (z - T))}{\frac{1}{\beta} E_{t-1}(\pi_t) b^T - \pi^T(b^T - (z - T))} \right]^2.$$

When the passive monetary policy and passive transfer regime is realized in period *t*, the weight is:

$$\omega_{PF}^{PM} = \left[\frac{\frac{2}{\beta} E_t(\pi_{t+1}) b^T - \frac{1}{\beta} E_t(\pi_{t+1})(z - T) - \frac{1}{\beta^2} E_{t-1}(\pi_t) E_t(\pi_{t+1}) \frac{b^T}{\pi^T} - \pi^T(b^T - (z - T))}{\frac{1}{\beta} E_{t-1}(\pi_t) b^T - \pi^T(b^T - (z - T))} \right]^2.$$

5.2. The Game Setup

To investigate the interaction between monetary and fiscal policies in a medium to long-run, this paper utilizes the least complicated setup which involves only two states, namely the present and the future. In the current state, both the central bank and the government move simultaneously, and only one player has a chance to revise its action in the next state. For example, if the central bank is the leader, its initial action is kept in the whole game. On the other hand, the government, in the second state, will play the best response to the leader's action as its revision. The game follows similar steps when the government is the leader. Without loss of generality the length of the game is normalized into 1. In summary, the following setup is considered:

1. The players move simultaneously at $\tau = 0$, i.e. the first state.[13]
2. One of the players can move again at $\tau \geq 0$, i.e. the second state, with some positive probability observing the initial move of the other player. All the past moves and the revision's timing of moves are common knowledge to all the players.
3. The payoffs are accrued continuously over $\tau \in [0, 1]$. The general payoffs matrices for two states are presented as followed:

State 1

		F	
		AF_1	PF_1
M	AM_1	a_1, w_1	b_1, x_1
	PM_1	c_1, y_1	d_1, z_1

State 2

		F	
		AF_2	PF_2
M	AM_2	a_2, w_2	b_2, x_2
	PM_2	c_2, y_2	d_2, z_2

where the payoff values correspond with (17) for the first state and (24) for the second. Also, the payoffs satisfy (18) as the conditions for the Game of Chicken.

This timing allows us to postulate the concept of M commitment and F rigidity of the players.[14] The commitment degree relates to the duration that the players are unable to change their actions. It implies that the commitment degree of the leader in this setup is 1, and the commitment degree of the follower is from start until their revision.

The revision function, $R(\tau)$: $[0, 1] \rightarrow [0, 1]$ with $F(0) = 0$, is an arbitrary non-decreasing cumulative distribution function (CDF) summarizing the timing of the revisions, for example, normal uniform or the Calvo (1983) scheme binomial distributions. Figure 4 provides three examples of probability distribution function (PDF)

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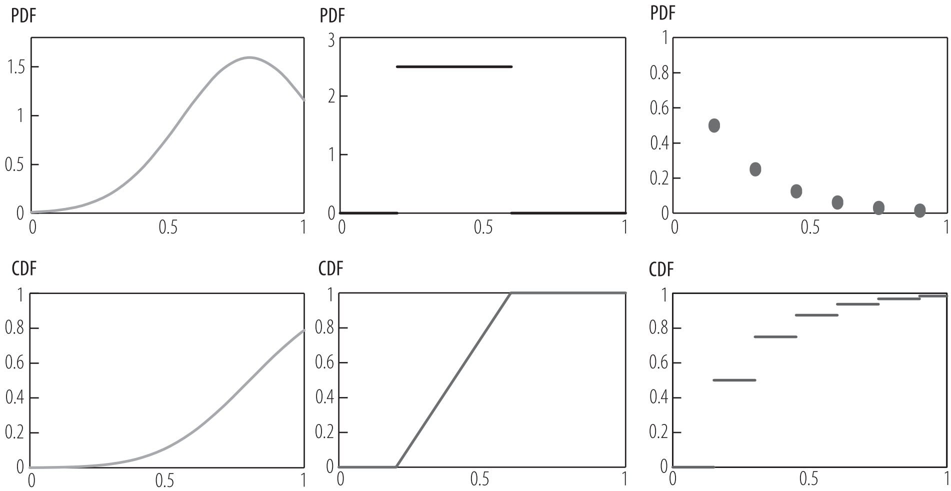
[13] The notation of time is changed to τ to distinguish with the previous time notation t. t corresponds with the current $\tau = 0$ and $t + 1$ is the future $\tau \geq 0$.

[14] Libich (2009) defines this as a commitment for the central bank and a rigidity for the government.

and the corresponding CDFs. The CDF then expresses the probability that the reviser has had an opportunity to revise no later than time t. Given the revision function, the speed of the reviser's reaction to the committed player can be defined as $\int_0^1 R_i(\tau)\, d\tau \leq 1,\ (i = \{M, F\})$. The follower does not necessarily revise their action any time during the game. The case in which none of the players revises until $\tau = 1$ is equivalent to the situation when the follower has a chance to alter their action at the end of the game $\tau = 1$. This revision will not change the payoffs for the central bank and the government during the game.

Figure 3. Three Examples of Timing: (Truncated) Normal, Uniform, and Binomial Distributions, and the Corresponding Cumulative Distribution Functions



Source: Libich et al. (2015)

The commitment degree of the reviser is:

$$1 - \int_0^1 R_i(\tau) d\tau \tag{26}$$

which is equal to the duration between the initial simultaneous moves and the revision action. The relative degree of commitment of the leader to the reviser can be defined as:

$$\frac{1}{1 - \int_0^1 R_i(\tau) d\tau} \tag{27}$$

This is equal to the duration between the initial simultaneous moves and the revision action. The relative degree of commitment of the leader to the reviser can be defined as (27) in which the commitment degree of the leader is normalized to 1.

5.3. Results

The *M* leadership and *F* leadership scenarios can be described by Figure 3. For example, in the *M* leadership scenario, at $\tau = 0$ both players take the actions and then the government can revise its initial action at $t = 1 - \int_0^1 R_F(\tau)d\tau$. With the payoffs satisfied under (18), the central bank prefers the outcome (*AM, PF*) in which the government will undertake the fiscal reform by reneging its promised transfers, and the inflation is stabilized at the target level. Unlike the normal Stackelberg leadership in which the central bank chooses to be active, and then force the government to play passive as the best response, there may be a cost to the central bank for the commitment. The government has an incentive to transfer the promised amount to the household, because its preferred outcome is the case in which the central bank monetizes the real debt. The government's chance of being re-elected is not affected as *F* is not going to renege its promised transfer to the public. Therefore, in order to win the game and achieve the targeted inflation, the central bank needs not only to commit their action as *AM* but also hold a sufficiently strong degree over the fiscal policymaker. The same intuition is applied under *F* leadership scenario.

Proposition 2.

(i) Under M leadership, the central bank wins the game and forces the government to reduce their transfers if and only if long-term M commitment is sufficiently high relative to F rigidity,

$$\frac{1}{1 - \int_0^1 R_F(\tau)d\tau} > \theta_M = \frac{\varphi_M(\omega_{AF}^{PM} - 1) + \left(b^T - (z - T)\right)^2}{\omega_{AF}^{PM}\varphi_M} > 1\,. \tag{28}$$

(ii) Under F leadership, the government wins the game and forces the central bank to raise the inflation if and only if F rigidity is sufficiently high relative to long-term M commitment,

$$\frac{1}{1 - \int_0^1 R_M(\tau)d\tau} > \theta_F = \frac{\delta_F(\omega_{PF}^{AM} - 1) + z^2}{\omega_{PF}^{AM}\delta_F} > 1\,. \tag{29}$$

Proof. The committed player only makes one move at time $\tau = 0$. Therefore, to prove this result, it needs to be shown that the committed player finds it is uniquely optimal to play its preferred NE action regardless of what the reviser plays in $\tau = 0$. For example, if *M* is the leader, it suffices to show that AM_1 is the unique best response to not only PF_1 but also AF_1 simultaneously played by F. This is because *F* will play the unique best response to AM_1 on every node of the equilibrium path which also includes the first move.

Using backwards induction, it is known that when the fiscal policymaker receives their chance to revise, they will play the best response to current actions of *M*, i.e. passive if the central bank plays active and vice versa. This is because *F* knows that *M* is unable to alter its action until the end of the game $\tau = 1$. Therefore, solving backwards, the central bank will take into account the anticipated revisions as well as the anticipated initial moves of the government in choosing its own action at $\tau = 0$. Obviously, with the payoffs satisfying (18), AM_1 is the best response to PF_1 for the central bank. Since the government carries the fiscal reform, there is no incentive for the central bank to monetize the debt by raising the inflation. However, for AM_1 also to be the best response to AF_1, i.e. it is optimal for the central bank to enter into a tug of war with the government, it needs to be shown that the gain from committing and forcing the government to stabilize the real debt is greater than the cost of fighting at $\tau = 0$ until the *F*'s revision. In other words, the following condition needs to be satisfied:

$$\begin{aligned} &\underbrace{a_1\left[1-\int_0^1 R_F(\tau)\,d\tau\right]}_{(AM_1,AF_1)} + \underbrace{b_2(\omega_{AF}^{AM})\int_0^1 R_F(\tau)\,d\tau}_{(AM_2,PF_2)} \\ &> \underbrace{c_1\left[1-\int_0^1 R_F(\tau)\,d\tau\right]}_{(PM_1,AF_1)} + \underbrace{c_2(\omega_{PF}^{AM})\int_0^1 R_F(\tau)\,d\tau}_{(PM_2,AF_2)} . \end{aligned} \tag{30}$$

The left-hand side of (30) reports the payoffs under which the central bank commits to an active strategy and the right-hand side is the payoffs that it receives for committing to passive. Specifically, the left-hand side states that *M* will get the conflict payoff a_1 when they play active at $\tau = 0$ and then will be rewarded by the b_2 as the victory payoff. $[1 - \int_0^1 R_F(\tau)\,d\tau]$ is the duration of the conflict and, therefore, $\int_0^1 R_F(\tau)\,d\tau$ is the duration that *M* is rewarded for his commitment. The right-hand side reports the payoffs that *M* receives if they want to avoid conflict with *F* at $\tau = 0$. Substituting (17) and (24) into (30) provides:

$$-1\left[1-\int_0^1 R_F(\tau)d\tau\right]+0\int_0^1 R_F(\tau)d\tau > -\frac{\varphi_M}{(b^T-(z-T))^2}\left[1-\int_0^1 R_F(\tau)d\tau\right]-\omega_{AF}^{PM}\frac{\varphi_M}{(b^T-(z_{t+1}-T_{t+1}))^2}\int_0^1 R_F(\tau)d\tau,$$

which is rearranged as:

$$\frac{1}{1-\int_0^1 R_F(\tau)d\tau} > \frac{\dfrac{\varphi_M}{(b^T-(z-T))^2}(\omega_{AF}^{PM}-1)+1}{\omega_{AF}^{PM}\dfrac{\varphi_M}{(b^T-(z-T))^2}} = \frac{\varphi_M(\omega_{AF}^{PM}-1)+(b^T-(z-T))^2}{\omega_{AF}^{PM}\varphi_M} > 1,$$

and complete (28).

Analogously, if F is the committed player, the sufficient condition for F to win the game is:

$$\begin{aligned}&\underbrace{w_1\left[1-\int_0^1 R_M(\tau)d\tau\right]}_{(AM_1,AF_1)}+\underbrace{y_2(\omega_{AF}^{AM})\int_0^1 R_M(\tau)d\tau}_{(PM_2,AF_2)}\\&>\underbrace{x_1\left[1-\int_0^1 R_M(\tau)d\tau\right]}_{(AM_1,PF_1)}+\underbrace{x_2(\omega_{PF}^{AM})\int_0^1 R_M(\tau)d\tau}_{(AM_2,PF_2)}.\end{aligned} \tag{31}$$

Substituting (17) and (24) into (31) yields:

$$\frac{1}{1-\int_0^1 R_M(\tau)d\tau}>\frac{\frac{\delta_F}{z^2}(\omega_{PF}^{AM}-1)+1}{\omega_{PF}^{AM}\frac{\delta_F}{z^2}}=\frac{\delta_F(\omega_{PF}^{AM}-1)+z^2}{\omega_{PF}^{AM}\delta_F}>1,$$

which completes the proof.

This result is different to the standard Stackelberg leadership because in this framework the leader cannot always win the game unless they sufficiently strongly commit, relative to the other player. In this model, the relative commitment of the player must exceed the specified threshold in order to win the game and achieve their preferred NE on every node of the game path. The thresholds are calculated as θ_M and θ_F for the central bank and the government, respectively. These thresholds not only depend on the conservatism parameters of the policymakers towards inflation gap, real debt gap and reneging ratio but also depend of the size of budget deficit/transfers and the public inflation expectation via the weight ω_{PF}^{AM} and ω_{AF}^{PM}. These results provide some useful intuitions for the policymakers about how they should commit relative to the other in order to achieve their own policy objective and force the other to stabilize the real debt.

The intuition of the sufficient condition for the committed player to win the game, i.e. to commit to their preferred NE, is that the benefit of commitment outweighs the cost when the player commits. When the player commits to their preferred NE, there is a conflict cost in the first state of the game because the reviser also plays their different preferred NE. Since there is a victory gain in the second state when the reviser switches to the best response to the committed player's action, the higher the cost in the first state the stronger the leader needs to commit. By committing more firmly, i.e. lengthening the duration of the second state, the leader can increase the relative benefit to the conflict cost. Thus, the bigger the cost of commitment, the stronger the commitment must be. This is to ensure the victory gain is larger than the conflict cost.

The commitment costs can be described by $\left[1-\frac{\varphi_M}{\left(b^T-(z-T)\right)^2}\right]$ and $\left(1-\frac{\delta_F}{z^2}\right)$ for the central bank and the government respectively. These costs equal to the difference between the payoffs received if the policymakers fight with each other initially and the payoffs under the situation that the reviser tries to avoid a conflict with the other at the start of the game. The victory gains, therefore, are the difference between the payoffs if the leader can force the follower to comply after the revision and the payoffs if the leader conceives to avoid a fight in the first place. These gains, which take into account the payoffs after the revision is dependent on the strategic interaction before the revision, are $\omega_{AF}^{PM}\frac{\varphi_M}{\left(b^T-(z-T)\right)^2}$ and $\omega_{PF}^{AM}\frac{\delta_F}{z^2}$ for M and F respectively.

Corollary 1. *The higher the conflict cost relative to the victory gain, the more strongly the leader needs to commit in order to achieve their preferred outcome and force the follower to stabilize the real debt.*

Proof. Rearranging (28) and (29) provides:

$$\frac{1}{1-\int_0^1 R_F(\tau)d\tau}-1=\frac{\int_0^1 R_F(\tau)d\tau}{1-\int_0^1 R_F(\tau)d\tau}>\frac{1-\frac{\varphi_M}{\left(b^T-(z-T)\right)^2}}{\omega_{PF}^{AM}\frac{\varphi_M}{\left(b^T-(z-T)\right)^2}}=\left(\frac{\text{conflict cost}}{\text{victory gain}}\right)_M,$$

and

$$\frac{1}{1-\int_0^1 R_M(\tau)d\tau}-1=\frac{\int_0^1 R_M(\tau)d\tau}{1-\int_0^1 R_M(\tau)d\tau}>\frac{1-\frac{\delta_F}{z^2}}{\omega_{PF}^{AM}\frac{\delta_F}{z^2}}=\left(\frac{\text{conflict cost}}{\text{victory gain}}\right)_F.$$

Since the payoffs are accumulated, the corollary indicates that the leader only wins the game, i.e. sufficiently threaten the follower, if and only if the total benefit of commitment/rigidity is larger than the cost of the tug of war in the first state.

Corollary 2.

(i) θ_M is decreasing in φ_M, therefore the long-term M commitment and the inflation conservatism are substitutes.

(ii) θ_F is decreasing in δ_F, therfore the F rigidity and the reneging conservatism are substitutes.

The higher the inflation/reneging conservatism, the smaller the sufficient thresholds. Therefore, the policymakers are required to commit less strongly to achieve their preferred outcomes. Since an increase in the conservatism parameters will increase the loss for the players if they play passive, i.e. raising inflation for the central bank and cutting the public transfers for the government, the likelihood that the leader surrenders and stabilizes the real debt is therefore reduced.

Corollary 3. *The higher the future inflation expectation, the lower the relative degree of commitment of the leader to the reviser it requires for the leader to win the game.*

If (18) is satisfied, the thresholds are decreasing in ω_{PF}^{AM} and ω_{AF}^{PM}. As both ω_{PF}^{AM} and ω_{AF}^{PM} positively depend on $E_t(\pi_{t+1})$, the sufficient thresholds θ_M and θ_F are negatively dependent on the future inflation expectation $E_t(\pi_{t+1})$. This is because the higher the public expectation, the higher the compensation required for the stock of bonds. Therefore, to retire the real debt entirely, the policymakers must adjust their policy instruments more aggressively, however, this is obviously associated with a bigger loss to the players. For this reason, the relative victory gain for the leader is increased when future expected inflation increases. This is equivalent to a lower sufficient commitment degree is required for the leader.

Corollary 4. *The bigger the transfers that the government promises the households, the more likely that the optimal outcome (AM, PF) happens under both M leadership and F leadership.*

As the discussion in Section 3.1 outlines, the primary deficit is required to satisfy the condition $(z - T) < b^T$. If it is at least equal to the real debt target, then it would lead to a hyperinflation under passive monetary policy. Therefore, the sufficient threshold for M is negatively related to the size of the primary deficit and therefore the transfer z. An increase in the transfer will increase the required inflation rate the central bank must raise in order to achieve the real debt target. Consequently, the increase in the size of the transfer will increase the relative victory gain for the central bank. Therefore, the monetary authority can reduce the commitment degree. Similarly, to the same time interval of State 2, the accumulated victory gain is increased. On the other hand, the sufficient threshold for F is positively related to the transfer z because the victory gain for the government is decreasing in z. In summary, the larger the size of transfer z, the less strongly the central bank - but the more strongly the government - needs to commit in order to win the game.

The framework also provides an insight to the result under the condition that both the central bank and the government cannot meet the required threshold of commitment, i.e. (28) and (29) are not satisfied. This means that neither player can force the other to play their preferred NE at the start of the game. This can be specified as an intermediate region in which any of the four outcomes (AM_1, AF_1), (AM_1, PF_1), (PM_1, AF_1) and (PM_1, PF_1) can occur in the first state. Therefore, the results are different from those under the scenarios that the leader sufficiently strongly commits. The real debt is stable and the inflation rate is at its target under M leadership, or there is an increasing inflation rate under F leadership. In addition to these two possible outcomes, there is a possibility of an increasing real debt under (AM_1, AF_1) when both players are waiting for the other to stabilize the debt. It is also possible to have the outcome (PM_1, PF_1) in which both of the policymakers try to achieve the debt target. This leads to an increasing price level, but the real debt is unnecessarily lower than its target.

The intermediate region features the same result with the standard simultaneous moves game when the revision occurs at the end of the game, i.e. the sufficient thresholds are equal to 1. Under the standard game framework, any of the four regimes can occur. In addition, when $\int_0^1 R_F(\tau)\, d\tau$ and $\int_0^1 R_M(\tau)\, d\tau$ approach to 1, i.e. the revisions come right after the initial simultaneous moves, and the game becomes a standard static Stackelberg leadership in which the leader always can achieve their preferred outcomes.

5.4. Empirical evidence

This section provides the evidence that a strong monetary commitment, in terms of an explicit inflation target, may indirectly improve the fiscal outcome by expanding the empirical work in Franta el al. (2011, 2018).[15] The sample size is enlarged and includes more explicit inflation target countries (EIT). Therefore, the result of the test is arguably more robust. The macroeconomic outcomes of the EIT countries (Australia, Canada, Chile, Mexico, New Zealand, South Africa, Sweden) pre- and post- inflation target adoption, are compared and contrasted with the main non-explicit inflation target (non-EIT) countries (Japan, Switzerland, US).[16] The evidence is shown in both gross government debt and net government debt behavior.[17]

Figure 4 reports the government gross and net debt to GDP ratio separately for two groups of countries. In all the EIT countries, there is a reduction in gross government debt starting about one year after the adoption which is marked by a lozenge, except for Canada, which experiences this after three years. On the other hand, the non-EIT countries have either experienced non-decreasing (US) or increasing trends in the gross government debt (Japan and Switzerland). The net government debt to GDP ratio shows the same behavior between two groups of countries. The net debt in EIT countries is decreased after the adoption, whereas for those non-EIT countries

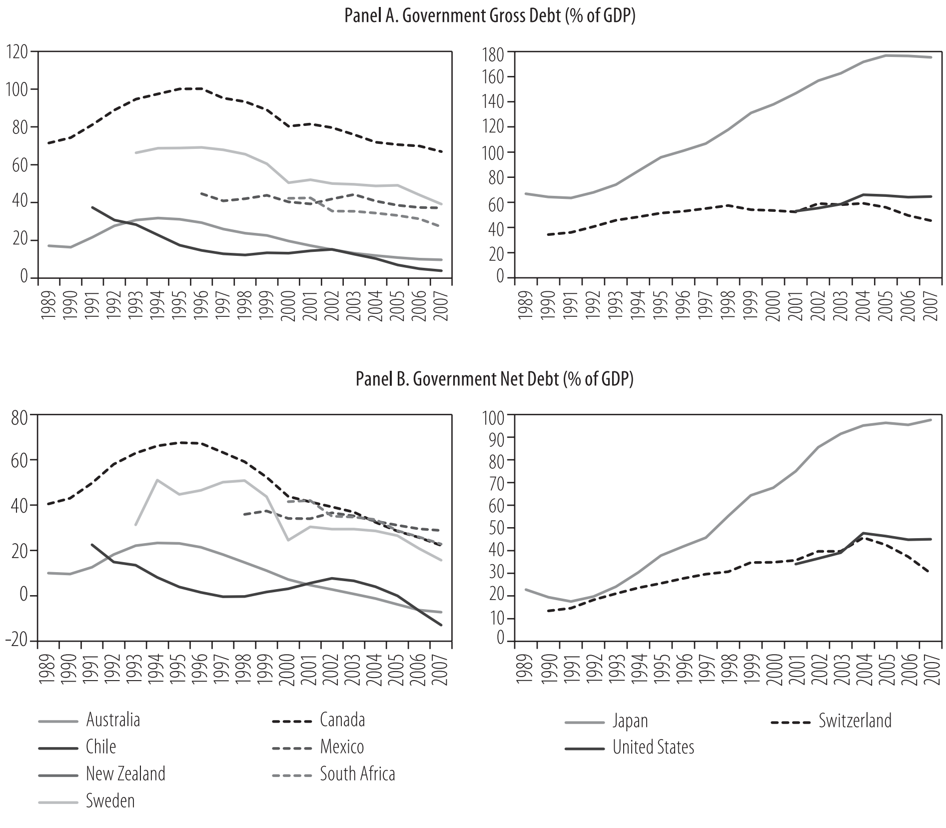
[15] Franta et al. (2018) empirically investigate the monetary and fiscal policies interaction in a time varying parameter vector autoregression. Their estimations offer some evidence for the possible disciplining role of explicit inflation targets.

[16] To eliminate the effect from the GFC, data is plotted only up to 2007.

[17] Gross debt consists of all liabilities that require payment or payments of interest and/or principal by the debtor to the creditor at a date or dates in the future. This includes debt liabilities in the form of Special Drawing Rights (SDRs), currency and deposits, debt securities, loans, insurance, pensions and standardized guarantee schemes, and other accounts payable. Net debt is calculated as gross debt minus financial assets corresponding to debt instruments. These financial assets are monetary gold and SDRs, currency and deposits, debt securities, loans, insurance, pension, and standardized guarantee schemes, and other receivable accounts.

the outcome is not improved, it is even worsened. Thus, there might be a correlation between fiscal outcome and explicit inflation targeting, however, this does not constitute evidence of causal relation between these two variables. This result is also supported by Combes, Debrun, Minea and Tapsoba (2017) who suggest that inflation targeting (and fiscal rule) has a beneficial effect on the coordination between fiscal and monetary policies.

Figure 4. Evolution of the Gross government debt (panel A) and Net government debt (panel B) to GDP ratio (in percent) in explicit inflation target countries (left) and non-explicit inflation target countries (Right).



Note: The lozenge mark indicates the regime's adoption.

Source: IMF (2019).

6. CONCLUDING REMARKS

The aftermath of the 2008 financial crisis combined with projected ageing related spending has posed a global concern about fiscal sustainability. This problem is not only an issue for advanced countries, but is expected to be faced by developing countries in the next few decades. How can a country ensure its sustainability in the presence of an ageing population? To answer this question, this paper postulates the interaction between fiscal and monetary policy under a game theoretic framework. There is a fiscal gap caused by a persistent increase in ageing related spending. A different framework to Leeper and Walker (2011) allows us to focus on the strategic aspects of monetary and fiscal policy interaction and for the policy regimes to be endogenized.

The asynchronous timing of action and stochastic revision not only allow modification of the game framework from static to dynamic. They also allow for proposition of the concepts of *M* commitment and *F* rigidity. It is shown that these institutional features affect the outcomes of the policy interaction together with other variables, such as policymakers' conservatism towards inflation, real debt and transfer reforming, the greatness of the projection primary deficit and the public inflation expectation.

The outcome of the game is found to be path dependent, because the past policy stance has an effect on the current payoffs for the players. It is also affected by public expectation. The thresholds θ_M and θ_F are derived. These are the sufficient commitment degree that the leader needs to commit to in order to achieve their preferred outcome and force the follower to stabilize the real debt. Importantly, the framework allows for the intermediate region in which neither the central bank nor the government commits sufficiently strongly enough over the other player, i.e. the derived thresholds cannot be satisfied. In this region, there is multi-equilibria, all four policy regimes are potentially outcomes of the game. Interestingly, it is found that the greater the promised transfer, i.e. greater fiscal planned spending, then the closer the outcome to the active monetary and passive transfer regime (*AM, PF*).

The values of these thresholds are arguably dependent on policymakers' preferences and the projected government expenditures as well as debt level. Therefore, there are differences in institutional design across countries. This helps explain why some countries have adopted an explicit numerical inflation target while others still maintain the implicit target rate.

While more studies are required to provide a definitive answer regarding the outcome of *M* and *F* interaction for an individual country, the paper provides a general lesson: the stronger the commitment, the more likely the leader will win the game. Interestingly, under *M* commitment, in which the threshold θ_M is satisfied, the central bank can not only achieve the inflation target but also indirectly discipline the government behavior by forcing them to stabilize the real debt and, therefore, improve the fiscal sustainability. The evidence shows a strong correlation between monetary commitment, such as an explicit inflation target, and improvement in the fiscal stance. This result supports Orphanides' (2015) claim that this modest approach frees the monetary policy from being "optimal", i.e. supporting for employment, growth and other good things, and can deliver a higher economic welfare than alternative approaches.

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