Tax corruption, public debt and the policy interaction in emerging economies

(Work in progress, comments are welcome)

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Abstract

This study attempts to analyze the stabilization of public debt in emerging economies by incorporating the feature of tax corruption into the framework of a dynamic policy game between the fiscal and monetary authorities developed by Tabellini (1986). The policy game is analyzed using an open-loop Nash equilibrium. The main finding is that the level of tax corruption has non-trivial impacts on the steady state outcome as well as the speed of adjustment for debt stabilization. A more severe tax corruption increases the public debt stock and reduces government spending at the steady state. It also reduces the speed of adjustment for public debt stabilization. The impacts of the tax corruption on the tax rate and inflation at the steady state, however, are ambiguous.

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Key words: Corruption, tax leakage, public debt stabilization, monetary and fiscal policies, differential games

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1. Introduction

Public debt has been recently a prominent concern in emerging economies. IMF (2003) points out public debt has roughly averaged at the level of 70% of GDP and shown a sharp increase in early 1990s for almost emerging economies in Asia, Latin America, Middle East and Africa. For some countries, such as Argentina, Ecuador, Uruguay, Turkey, Pakistan and Lebanon, public debt climbed up to the range of 100%-150% of GDP in 2002 in spite of various efforts to implement public debt restructuring and privatization. Thus, debt stabilization is an important issue for policy discussions since the prolonged excessive public debt can have significant negative impacts on economic activities by crowding out investment as consequence of raising taxes or by reducing the rate of capital accumulation (see Blanchard (1985)).

In our study, a widely observed characteristic of emerging economies is taken into the consideration in examining public debt stabilization. As discussed in Martinez-Vazquez et al (2004), emerging economies often struggle against a serious problem in collecting public revenues due to corruptions or weak tax-related infrastructures. The term of *tax corruption* refers to the situation that tax leakage occurs since tax officials engage in corrupt activities by stealing from the treasury of public revenue or allowing widespread tax evasions. It is a basic explanation why there exist a significant negative correlation between the ratio tax collection over GDP and the level of corruption in Martinez-Vazquez (2004). A number of aspects relates to tax corruption in developing and emerging economies have been studied theoretically within the framework of agent-principal problem[1] and empirically in terms of analyzing its causes and consequences[2]. The issue on how such tax corruption affects the conduct of fiscal and monetary policies within a public debt stabilization in emerging economies, however, have not been extensively addressed in the literature on the interaction of fiscal and monetary policies which is mainly devoted to the developed economies.

The process of stabilizing the public debt is pointed out closely related with the conduct of monetary and fiscal policies in Sargent and Wallace (1981) since the government budget constraint implies a dynamic linkage among not only the fiscal and monetary operations but also the evolution of public debt. Tabellini (1986) postulates the argument that the strategic interaction between the decentralized central bank and fiscal authority plays a role in stabilizing public debt in many industrial economies with serious concern on the excessive stock of public debt. In emerging economies, as pointed out by Hawkin (2005) such a strategic interaction has been also observed as the trend of institutional reform that enables fiscal and monetary policies become relatively

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1 See Besley and McLaren (1993), Hindriks et al. (1999), Polinsky and Shavel (2001)..

2 See, for instance, Guppta et al (1999), Wane (2002)

independent since the end of 1990s. Therefore, it is reasonably brought our interest into studying the implication of the strategic policy interaction on the stabilization of government debt in emerging economies.

There have been a number of papers on the theoretical aspect of public debt as an outcome of strategic interaction between the monetary and fiscal authorities. Tabellini (1986) features the intertemporal link among public debt, fiscal balance and monetary base for the game theoretic analysis of the policy interaction. In Tabellini (1986), the outcome of public debt stabilization is intuitively considered as a public good jointly provided by the fiscal and monetary authority at their-own costs of policy target. In addition, each player are benefical from externality in debt stabilization process by policy measures of the opponent. The policy interaction is analyzed in a coordinated design of policy and a non-cooperative game. This study demonstrates theoretically that the design of coordinated policies by a social planner gives the first best outcome as externality of public debt stabilization from the opponent is fully internalized by the two players. It is also shown that the outcome in an open-loop equilibrium with commitment structure is preferred to the one in a closed-loop equilibrium

Aarle et al (1995) extends the work of Tabellini (1986) by modifying the objective functions of policy-makers to analyze the evolution of public debt, fiscal and monetary outcomes under the framework of the coordinated design and commitment structure. Van Aarle et al (1995) also considers effects of a more independent central bank on public debt, monetary and fiscal outcomes.

Jensen (1994) and Beestma and Bovenberg (1997, 1999) among others also investigate the implication of the policy interaction on the evolution of public debt although their focus is the role of central bank independence in the context of forming of European monetary union. Recently, Dixit and Lambertini (2003) studies extensive types of interaction between the fiscal and monetary authority in a well-microfounded structure and stochastic environment. This research, however, is not aimed at examining a dynamic link over the evolution of public debt.

In the literature on the fiscal and monetary policies interaction, Huang and Wei (2003, 2005) may be a few works to incorporate explicitly tax corruption as a prevalent dimension of corruption into the analysis on the implementation of fiscal and monetary policies in developing countries. Their focus, however, is on the endogenoues credibility problem of monetary policies initiated by Alesina and Tabellini (1987). Hence, Huang and Wei's static model explores the effect of tax corruption on the monetary institutions designed to deal with the credibility problem in emerging economies.

In our study, we attempt to examine how the tax corruption influences the evolution of economy within the framework of dynamic strategic interaction between the fiscal and monetary authorities. Our analysis is most closely related to the analytical framework of Tabellini (1986) and Huang and Wei (2003). To our best knowledge, however, this study is the first attempt to explicitly incorporate the tax corruption into the dynamic analysis of fiscal and monetary interaction in managing public debt the context of emerging economies.

Based on the work of Tabellini (1986), we formulate a policy game for analyzing the strategic interaction induced by possible conflicts that whether fiscal or monetary instruments should be mainly utilized in reducing excessive public debt.

The feature of tax corruption for emerging economies is introduced into the budget constraint of government. Tax inefficiency leads to tax leakage and lower revenues collection which negatively affects government's capacity to manage primary budget balance. As a result, the evolution of public debt and fiscal outcome linked through the government's budget constraint can be significantly altered.

The game is analyzed in a concept of open-loop Nash equilibrium[3]. In an open loop Nash equilibrium, the two policy-makers are assumed to access to a commitment technology that enforce them to pre-commit to a specific course of action even when they interact strategically. The commitment technology can be justified by the form of legislatively binding rule in conformity with Tabellini (1986).

The main results of this study are the level of tax corruption have non-trivial impacts on the steady state outcome and the speed of adjustment for debt stabilization. A more severe tax corruption increases the public debt stock. A higher level of tax corruption reduces government spending at the steady state and the speed of adjustment for public debt stabilization. The remainder of this study is structured as follows. Section 2 describes the basic elements of our analytical framework. Section 3 characterizes the solution of model. Section 4 discusses our results and Section 5 concludes.

2. A model

We consider a model of small open economy with continuous time under an infinite horizon and deterministic environment.

In this economy, output is governed the tax-aumengted Lucas-type equation in conformity with Alesina and Tabellini (1987) and Jensen (1994) [4],:

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[3] A closed-loop Nash equilibrium is left for the future study due to its technical complexity. In this study, our focus is policy interaction rather a coordinated policies design.

[4] Based on Alesina and Tabellini (1987), we consider in this economy workers are represented by trade unions whose purpose is to achieve a real wage target. At the beginning of each period and before the implementation of any policies, trade unions decide the nominal wage to minimize the deviation of real wage $\frac{W_t}{P^e{}_6}$ from this target assumed equal to 1 for simplicity, given the expected price level $P^e{}_t$.

Detailed explanation to derive a tax-aumengted Lucas-type supply schedule in (1) is given in Appendix A1.

$$y_t = \alpha(\pi_t - \pi_t^e - \tau_t) \quad \text{with } \alpha > 0 \qquad (1)$$

Where y_t is logs of real output, π_t is inflation, $\pi^e{}_t$ is expected inflation, τ_t is tax rate on the total output and the subscript denotes the time period.

The dynamic link in the model is given by the government budget constraint. The public expenditures and debt payments have been financed by its actual tax collection, creating monetary base against the central bank's holding of Treasury bill and issuing new debt. The budget constraint of the government can be approximated by[5]:

$$\dot{d}_t = \mu d_t + g_t - \phi\tau_t - \pi_t \qquad (2a)$$

It is assumed that indexed public debt d_t as a ratio over real output could be sold in the world market with an exogenous interest rate, leading to a constant interest rate net growth rates namely μ (i.e., a net interest rate of indexed debt). Other terms expressed as a ratio over real output g_t and τ_t are public expenditures and tax rates respectively. The last term on the right hand side is approximation of monetary seigniorage from the quantity money equation (where π_t is inflation) in conformity with Alesina and Tabellini (1987), Jensen (1994).

The tax corruption is introduced into the budget constraint in the parameter ϕ ($0<\phi<1$) as suggested by Huang and Wei (2003). The more inefficient tax collection is, the lower ϕ is, implying that if the tax rate over output paid by firms to government is τ_t the actual revenue is only $\phi.\tau_t$ due to tax corruption.

We may offer a brief discussion on a rationale of tax corruption introduced in a form of tax leakage in the analysis of public debt stabilization within the strategic fiscal and monetary interaction. Bribery by firms to tax officials for evading tax liability or relaxing tax collection enforcement are widespread over an emerging economy with a weak tax related infrastructure in term of legal and enforcement framework (see Martin-Vazquez et al (2004)). This causes the leakage of tax revenue. The amount of tax revenue leakage $(1-\phi)\tau_t$ may be jointly shared by corrupted tax officials and firms owners. Consequently, the more serious degree of tax corruption is associated with the reduction in the actual accrue of tax collection to the government, resulting in the reduced capability of government to control over the primary budget balance $(\phi\tau_t - g_t)$ and the overall balance as ϕ drop to a lower level, i.e. the more severe tax corruption.

The solvency of government is imposed by the following condition to rule out the Ponzi-scheme of public borrowing:

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[5] A detailed derivation of dynamic budget constraint of government in (2a) is explained in the appendix A2

$$\lim_{t \to \infty} d_t . e^{-\mu . t} = 0 \qquad (2b)$$

We consider the central bank and the fiscal authority who are independently responsible for conducting monetary and fiscal policy respectively. The central bank controls over inflation π_t by adjusting monetary base upon the quantity money theory and the fiscal authority regulates the tax rates τ_t and public spending g_t

The central bank is assumed to pursue the stabilization of deviation of inflation, real output and public debt from the target levels. The central bank chooses the inflation path to minimize the instantaneous loss function defined as follows

$$\underset{\pi}{Min} \;\; L_C = \frac{1}{2} \int_0^{\infty} \left[(\pi_s{}^2 + y_s{}^2 + d_s{}^2 \right] e^{-\beta s} ds \qquad (3)$$

The target inflation, the target for output and public debt level are normalized at 0. The central bank is usually motivated to stabilize the economy on the two key variables such as output and inflation. The motivation for stabilizing public debt by the central bank is justified the situation of excessive public debt as discussed in IMF (2003) as well as mentioned in Mihaljeck and Tissot (2003) that fiscal sustainability has recently become a real concern among central banks in emerging economies

The fiscal authority chooses the tax rate, public spending path to minimize the following intertemporal loss function:

$$\underset{g,\tau}{Min} \;\; L_F = \frac{1}{2} \int_0^{\infty} \left[(g_s - \bar{g})^2 + y_s{}^2 + d_s{}^2 \right] e^{-\beta s} ds \qquad (4)$$

Where $\bar{g}$ is the target public spending, the targets for output and public debt level are normalized at 0. In addition to the preference over the stabilization of output and public debt, the fiscal authority dislikes any the divergence of public expenditure from a positive target ratio level, reflecting its citizens' utility from various type of government spending.

The objective functions of the two policy makers may be based on a well micro-founded structure which is similar to what are discussed by Dixit and Lambertini (2003)

In our model, we consider the same subjective rates of time preference for both policy makers (i.e., β>0). The higher β is the more impatient the central bank and the fiscal authority are. We make an important assumption (in conformity with Aarle et al (1995)) that policy makers are impatient to a certain extent such that $\beta > \mu$, i.e., the subjective marginal benefit of additional public debt stock is lower than the its objective marginal cost which induces policy makers directly feature public debt stock in their objective function rather than prefer unbounded public debt accumulation.

Since our concern is the excessive stock of public debt in the economy, it is assumed that the initial level of public debt is considerably high. As discussed in Tabellini (1986), the strategic interaction arises from a possible conflict between the two branches of policy-makers in managing public debt. The central bank would like to reduce excessive public debt mainly through raising taxes or reducing government spending while the fiscal authority would like a to receive substantial support for debt management from debt monetization by the central bank. The conflict intensifies as the central bank and fiscal authority become relatively decentralized.

The policy interaction is analyzed under the following structure. Initially, nominal wages are determined upon the wage-setting rule and the expected inflation is formed. Subsequently, the fiscal and monetary policies are conducted to minimize the intertemporal loss functions defined in (3) and (4) respectively subject to the dynamic budget constraint in (2a). Finally, output is produced accordingly the resulting aggregate schedule by firms. Within the above described settings, in the next section, we solve the dynamic policy game in an open-lop Nash equilibrium.

3. Analysis of equilibrium outcome

An open-loop Nash equilibrium for the policy game is achieved if the specific course of choosing inflation rates to which the central bank commits himself is the best response to the time path of chosen tax rate to which the fiscal authority has committed. This setting of commitment technology has been described in Tabellini (1986) such that both policy makers submit their plans for future actions to a legislative body who is able to enforce those plans in the form of binding commitment. The commitment structure makes the time path of policy instruments are independent with the state of dynamic system. It is contrast to a closed-loop Nash equilibrium of such a policy game which does not require the commitment structure. In a closed-loop Nash equilibrium, taking the best response of its opponent as given each policy player optimally chooses its controlled instruments taken into the account both current and future influences of its opponent's moves through the evolution of state (i.e., public debt) of the game. Hence, in a closed-loop Nash equilibrium the time path of policies instrument are contingent on the state of dynamic system[6].

As the time path of policy instruments are independent with the state of dynamic system, we form the current value Hamiltonian for the central bank and the fiscal authority separately as following (we may drop time subscript without any miscomprehension)

[6] In comparison with an open Nash equilibrium, a closed-loop Nash equilibrium has an advantage in relaxing the commitment structure of the game at the cost of more analytical complexity.

$$H_C = \frac{1}{2}\left[\pi^2 + y^2 + d^2\right] + m_1.\left[\mu d + g - \phi.\tau - \pi\right] \quad (5)$$

$$H_F = \frac{1}{2}\left[(g-\bar{g})^2 + y^2 + d^2\right] + m_2.\left[\mu d + g - \phi.\tau - \pi\right] \quad (6)$$

Where m_1 and m_2 are costate variables associated with (5) and (6) respectively. It is noted that y (output) is linked with π (inflation) and τ (tax rate) by (1) such that: $\alpha\ (\pi - \pi^e - \tau) = y$

The first order conditions for the two optimization problems which characterize the outcome of open-loop Nash equilibrium are presented as follows

$$\pi + \alpha^2(\pi - \pi^e - \tau) = m_1 \Leftrightarrow \pi + \alpha\ y = m_1. \quad (7a)$$

$$-\dot{m}_1 = (-\beta + \mu)m_1 + d \quad (7b)$$

$$-\alpha^2(\pi - \pi^e - \tau) = m_2.\phi \Leftrightarrow -\alpha\ y = m_2.\phi \quad (7c)$$

$$g - \bar{g} + m_2 = 0 \quad (7d)$$

$$-\dot{m}_2 = (-\beta + \mu)m_2 + d \quad (7e)$$

The transversality conditions require:

$$\lim_{t \to \infty} m_{it}.d_t = 0 \text{ for i=1,2} \quad (8)$$

Equations including (2a), (7a), (7b), (7c), (7d), (7e) forms a dynamic system which characterizes the optimal path of government spending, public debt, tax rate and inflation under the open Nash equilibrium. Since the transversality conditions and the no-Ponzi game condition (2b) are assumed to hold, the dynamic system will show a saddlepoint equilibrium corresponds to negative stable roots. As it is assumed that the policy makers are impatient in our analysis, it can be proved that there exists an unique stable root of the dynamic system.

The unique stable root denoted by $\bar{r}$ is determined in the following equation[7]

$$h^2 - (\beta - 2\mu)h - (\frac{\phi^2}{\alpha^2} + \phi + 2) = 0 \quad where \quad h = \beta - \mu - \bar{r} \quad (9a)$$

Equations from (7a) to (7e) imply how fiscal and monetary policies are optimally conducted to achieve the defined objectives. Regarding the optimal trajectory

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[7] The detailed proof for determining $\bar{r}$ by equation (9a) is provided in the appendix A3

for the central bank's instrument, Eq. (7a) states inflation is set that the per- period marginal loss from an increase in inflation in term of output and inflation itself must be equally offset with its marginal gain from reducing public debt in the next period. Eq. (7b) says that in term of affecting the central bank's objective, the decrease in the marginal valuation of public debt would be balanced with the current and future marginal contribution it creates.

Concerning the optimal paths of the fiscal instruments, Eq. (7c) implies that the tax rate is set such that the per-period marginal loss from raising tax in term of reducing output must be balanced with its marginal gain in term of lowering public debt in the next period. Eq. (7d) implies that public spending is too low, the current period marginal gain from raising public expenditure must equate its marginal loss from inducing a higher public debt in next period. Eq. (7e) states that in attempt to achieve the featured objective of fiscal authority, the reduction in the marginal valuation of public debt must be equally offset by the current and future marginal contribution it generates.

Imposing an ex-post condition of rational expectation: $\pi^e = \pi$ in the system of F.O.Cs and combining with the steady state conditon, we arrive at the observations for outcome of public debt, tax rate, government spending and inflation respectively in the steady state as following[8]:

$$d^S = \frac{(\beta - \mu).\bar{g}}{\frac{\phi^2}{\alpha^2} + \phi + \mu^2 - \mu\beta + 2} \qquad 9(b)$$

$$g^S = \bar{g}\left[1 - \frac{1}{\frac{\phi^2}{\alpha^2} + \phi + \mu^2 - \mu\beta + 2}\right] \qquad 9(c)$$

$$\tau^S = \frac{\phi^2.\bar{g}}{\frac{\phi^2}{\alpha^2} + \phi + \mu^2 - \mu\beta + 2} \qquad 9(d)$$

$$\pi^S = \frac{(\phi + 1).\bar{g}}{\alpha^2(\frac{\phi^2}{\alpha^2} + \phi + \mu^2 - \mu\beta + 2)} \qquad 9(e)$$

The time path of public debt, government spending, tax collection and inflation is characterized as following:

$$d(t) = (d(0) - d^S)e^{\bar{r}t} + d^S$$

$$g(t) = (g(0) - g^S)e^{\bar{r}t} + g^S$$

$$\tau(t) = (\tau(0) - \tau^S)e^{\bar{r}t} + \tau^S$$

$$\pi(t) = (\pi(0) - \pi^S)e^{\bar{r}t} + \pi^S$$

[8] The detailed derivation for outcome at the steady state is given in the appendix A3

Where $\bar{r}$ is the stable root of dynamic system and d(0), g(0), $\tau(0)$ $\pi(0)$ are respectively the initial level of public debt, government spending, tax collection and inflation.

4. Discussion

In this section, we discuss how the level of tax corruption affects the speed of adjustment of dynamic system and the outcome of public debt, government spending and tax rate at the steady state.

Computing derivative of d with respect to ϕ from (9b) yields how tax corruption affects the steady state level of public debt:

$$\frac{\partial d^S}{\partial \phi} = \frac{-2.\phi.(\beta - \mu).\bar{g}}{\alpha^2(\frac{\phi^2}{\alpha^2} + \phi + \mu^2 - \mu\beta + 2)^2} < 0 \qquad (10b)$$

Since the two policy makers are considered to be impatient (i.e., $\beta > \mu$), the steady state level of public debt and ϕ are inversely related, implying that the more serious tax corruption induces the higher debt accumulation at the steady state. The intuition is as follows. Since the more severe tax leakage associated with the more serious inefficiency in tax collection weaken the fiscal authority's ability to improve the primary budget. It creates more burden for the fiscal authority in reducing the public debt on her own side. This burden of debt stabilization, however, can not be mitigated by externality from the inflation tax which is determined in the optimization program of the central bank. The strategic policy interaction matters because the central bank's optimization program which is not in common with that of the fiscal authority in term of focusing on inflation stabilization. As a result, an immitigable heavier burden of debt stabilization on the fiscal authority leads to a higher stock of public debt in the long-run. Therefore, debt stock is higher for an economy associated with more serious inefficiency in tax collection at the steady state.

From (9d), we can compute derivative of g with respect to ϕ as following:

$$\frac{\partial g^S}{\partial \phi} = \frac{2.\phi.\bar{g}}{(\frac{\phi^2}{\alpha^2} + \phi + \mu^2 - \mu\beta + 2)^2} > 0 \qquad (10d)$$

From (10c) we see that the steady state level of government spending reduces as ϕ decreases which implies higher level of tax corruption. The higher level of tax corruption associated with the lower steady state level of government spending have the intuition as follows. The more severe inefficiency in tax collection suppresses the actual revenue and result in a reduction of its spending in attempt to stabilize public debt when the externality from inflation tax is restrained. The impact on reducing public spending is dominant over the fiscal authority's effort to stabilize public spending. As a result, a lower level of government spending at the steady state is implied for a country with more serious tax corruption.

The effect of tax corruption on inflation and tax rate at the steady state is generally ambiguous since we observe:

$$\frac{\partial \pi^S}{\partial \phi} = \frac{(\mu^2 - \mu\beta + 2 - 2\frac{\phi}{\alpha^2} - \frac{\phi^2}{\alpha^2})\bar{g}}{\alpha^2(\frac{\phi^2}{\alpha^2} + \phi + \mu^2 - \mu\beta + 2)^2} \quad \text{and} \quad \frac{\partial(\tau^S)}{\partial \phi} = \frac{(\mu^2 - \mu\beta + 2 - \frac{\phi^2}{\alpha^2})\bar{g}}{(\frac{\phi^2}{\alpha^2} + \phi + \mu^2 - \mu\beta + 2)^2} > 0$$

Finally, computing derivative of the speed of adjustment with respect to ϕ from (9a) by implicit function theorem implies how the level of tax corruption affects the speed of adjustment for debt stabilization:

$$\frac{\partial(-\bar{r})}{\partial \phi} = \frac{\partial \bar{h}}{\partial \phi} = \frac{2\frac{\phi}{\alpha^2} + 1 + \beta - 2\mu}{2\bar{h} - (\beta - 2\mu)} > 0 \qquad \text{(10a)}$$ [9]

It is shown that the more severe tax corruption (i.e., lower ϕ) is associated with slower speed of adjustment to the steady state for public debt. Tax inefficiency increases the burden of public debt stabilization on the fiscal authority as she has to reduce public spending and deviate more from its spending target. On the other hand, lower actual tax collection implies less externality of reducing public debt on the central bank. The two effects together bring about the slower speed of debt stabilization.

5. Concluding remarks

In many emerging economies, public debt has been recently a big concern in policy discussion. The strategic interaction between fiscal and monetary authority is expected to play a role in stabilizing public debt as it is observed an increasingly decentralized trend of policies formulation in those economies. In this study, we examine impacts of the feature of tax corruption associated with corruptions or weak-tax related infrastructure in emerging economies within a framework of strategic policy interaction aimed at stabilizing public debt. We incorporate tax corruption into the framework of policy game developed by Tabellini (1986) to analyze the evolution of public debt, fiscal and monetary outcome in emerging economies. The policy game is analyzed in an open-loop Nash equilibrium which requires a symmetric commitment from the two policies players on the time path of their moves. The main results are an economy associated with a more severe tax corruption ends up with a higher level of

[9] A derivation of the inequality in (10a) is explained in the appendix A4

public debt, lower level of public spending at the steady state and a slower speed of adjustment for public debt stabilization. However, the impacts of tax corruption on tax rate and inflation at the steady state are ambiguous.

There are several ways to further study those related issues. We may study outcomes of this game in a coordinated policy design and a closed-loop concept for comparative purposes. On the other hand, we may consider to endogenize the level tax efficiency. Those issues should be interesting and important for further researches.

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Appendices

Appendix A1

We show how to derive a Lucas- type supply equation in (1)

In conforming with Alesina and Tabellini (1987), for each period, aggregate output and labor are determined from profit maximization behavior of representative firms which features a Cobb-Douglas technology with a fixed capital stock: $\underset{L_t}{Max}\ (1-\tau_t).P_t.L_t^{\gamma} - W_t.L_t$, yields: $y_t = \frac{\gamma}{1-\gamma}(p_t - \tau_t - w_t - \ln\gamma)$ by a logarithms transformation and an approximation such that $\ln(1-\tau_t) = \tau_t$. Substituting from wage-setting rule such that $w_t = p_t^e \Leftrightarrow \frac{W_t}{P^e_t} = 1$ and normalize output at a certain level we arrive at (1) in the main text:

$$y_t = \alpha(\pi_t - \pi_t^e - \tau_t) \quad \text{where} \quad \alpha = \frac{\gamma}{1-\gamma}$$

Appendix A2

We explain how to approximate the government budget constraint in (2a). For a given period, the government finances its indexed public debt and spending by raising tax, creating monetary base and issuing new debt

$$\dot{D}_t.P_t + \dot{MB}_t + \phi.\tau_t.Y_t.P_t = i.D_t.P_t + g_t.Y_t.P_t \Leftrightarrow \dot{D}_t = i.D_t + g_t.Y_t - \phi.\tau_t.Y - \frac{\dot{MB}_t}{P_t}$$

Where variables in characters are anti-logs of real variables

Hence, $$\dot{d}_t = \frac{\dot{D}_t}{Y_t} - g.d_t = (i-g).d_t + \phi.\tau_t - g_t - \frac{\dot{M}_t}{P_t.Y_t} = u.d_t + \phi\tau_t - g_t - \frac{\dot{MB}_t}{P_t.Y_t} \quad (11a)$$

The last term is approximated by: $\dot{MB}_t \approx \frac{MB_{t+\delta t} - MB_t}{\delta t}$

By money quantity equation $MB_t = P_t.\bar{Y}_t$ where $\bar{Y}_t$ is out put in the absence of tax and non-tax distortions in conformity with Alesina and Tabellini (1987), Jensen (1994). Hence, we arrive at the approximation of the seigniorage revenue as

$\frac{MB_{t+\delta t} - MB_t}{Y_t.P_t.\delta t} = \frac{(P_{t+\delta t} - P_t)\bar{Y}_t}{Y_t.P_t.\delta t} \approx \dot{P}_t = \pi_t\ (11b)$ if Y_t is not much different from $\bar{Y}_t$. This yields (2a) in the main text by substituting (11b) into (11a)

Appendix A3

We show how to derive the steady state level and speed of adjustment in the main text. Imposing ex-post condition of rational expectation: $\pi^e = \pi$ for the F.O.Cs of the optimization programs of the two policy makers yields

$$\pi - \alpha^2 \tau = m_1 . \tag{7a'}$$

$$\dot{m}_1 = (\beta - \mu) m_1 - d \tag{7b'}$$

$$\alpha^2 \tau = m_2 . \phi \tag{7c'}$$

$$g - \bar{g} + m_2 = 0 \tag{7d'}$$

$$\dot{m}_2 = (\beta - \mu) m_2 - d \tag{7e'}$$

Differentiating with respect to time both sides of (7a') and both side of (7c') with (7d'), substituting resutls into (7b') and (7e') respectively, rearranging terms and combining with (2a) yields the following systems

$$\dot{\pi} = (\beta - \mu) \ \pi - (\phi + 1) d$$

$$\dot{\tau} = (\beta - \mu)\tau - \frac{\phi}{\alpha^2} d$$

$$\dot{g} = (\beta - \mu)(g - \bar{g}) + d$$

$$\dot{d} = \mu d + g - \phi\tau - \pi$$

From the above dynamic system, imposing $\dot{\pi} = \dot{\tau} = \dot{g} = \dot{d} = 0$, we arrive at (9b), (9c), (9d), (9e) for outcome at the steady state in the main text

For solving the speed of adjustment, the above system can be rewritten as following:

$$\dot{X} = A.X + R$$

Where: $X = \begin{bmatrix} \pi \\ \tau \\ g \\ d \end{bmatrix}$ and $A = \begin{bmatrix} (\beta-\mu) & 0 & 0 & -(\phi+1) \\ 0 & (\beta-\mu) & 0 & -(\frac{\phi}{\alpha^2}) \\ 0 & 0 & (\beta-\mu) & 1 \\ -1 & -\phi & 1 & \mu \end{bmatrix}$ and $R = \begin{bmatrix} 0 \\ 0 \\ (\mu-\beta)\bar{g} \\ 0 \end{bmatrix}$

This canonical system could be solved explicitly by computing the eigenvalues of matrix A from the characteristic equation: $\det(A - r.I) = 0$ (I is identity matrix, r is vector of eigenvalues)

The characteristic equation: $\det(A - r.I) = 0$ (I is identity matrix, r is vector of eigenvalues) can be solved by investigating

$$\det(\text{A-}r.\text{I}) = h^2\left[h^2 - (\beta - 2\mu)h - (\frac{\phi^2}{\alpha^2} + \phi + 2)\right] = 0 \quad (12)$$

Where $h = (\beta - \mu - r)$. It is obvious the negative stable root $\bar{r}$ of (12) can be only derived from the root $\bar{h}$ of (12) such that $\bar{h} > \beta - \mu$ imposed by $\bar{r} = \beta - \mu - \bar{h} < 0$.

Since the policy-makers are assumed to be impatient such that $\beta - \mu > 0$, the stable root exists uniquely if and only if there exist uniquely $\bar{h}$ which is a root of g(h) such that $\bar{h} > \beta - \mu$, where *g(h)* is a quadratic function derived from (12) as following:

$$g(h) = h^2 - (\beta - 2\mu)h - (\frac{\phi^2}{\alpha^2} + \phi + 2)$$

It is trivially shown that *g(h)* has two roots as $-(\frac{\phi^2}{\alpha^2} + \phi + 2) < 0$ and strictly increasing in $(\frac{\beta - 2\mu}{2}, \infty)$, $\bar{h} > \beta - \mu$ if and only if $g(\beta - \mu) < 0$.

It is easy to verify that: $g(\beta - \mu) = (\beta - \mu)\mu - 2 - \frac{\phi^2}{\alpha^2} - \phi < 0$ when μ *and* β are respectively the net interest rate on indexed public and the time preferences of policy makers which should be less than 1 (Note that $0 < \phi \leq 1$)

Appendix A4

We show how to derive (10a) in the main text.

Since the quadratic function $g(h) = h^2 - (\beta - 2\mu)h - (\frac{\phi^2}{\alpha^2} + \phi + 2)$ has two roots, i.e., $\ddot{h}$ *and* $\bar{h}$ such that $\bar{h} > \beta - \mu > 0 > \ddot{h}$ and $2\bar{h} + 2\ddot{h} = (\beta - 2\mu)$, it is obvious that $2\bar{h} > (\beta - 2\mu)$. Thus, it is clear to see:

$$\frac{\partial(-\bar{r})}{\partial\phi} = \frac{\partial\bar{h}}{\partial\phi} = \frac{2\frac{\phi}{\alpha^2} + 1 + \beta - 2\mu}{2\bar{h} - (\beta - 2\mu)} > 0 \quad \text{as} \quad 2\frac{\phi}{\alpha^2} + 1 + \beta - 2\mu = 2\frac{\phi}{\alpha^2} + (1 - \mu) + (\beta - \mu) > 0$$