

# Impact of Deflation on Real Interest Rate of Government Bonds

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This paper analyzes how deflation and inflation influences the real interest rates of government bonds by using an overlapping generations model. We find that deflation may lower the real interest rate of government bonds to the same level of public debt to capital, even if the fiscal consolidation rule is the same, as opposed to the conventional view that the real interest rate of government bonds is determined independent of deflation if the classical dichotomy holds. Our results are consistent with how the real interest rates of Japanese government bonds react in periods of deflation.

This paper also addresses the impact of fiscal inflation (i.e., monetizing all parts of the GB's default using monetary policy). We calculate the expected fiscal inflation when the default rate in the event of fiscal consolidation is raised. The fiscal inflation may be high if the extent of the required tax increase in fiscal consolidation is low.

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## 1. Introduction

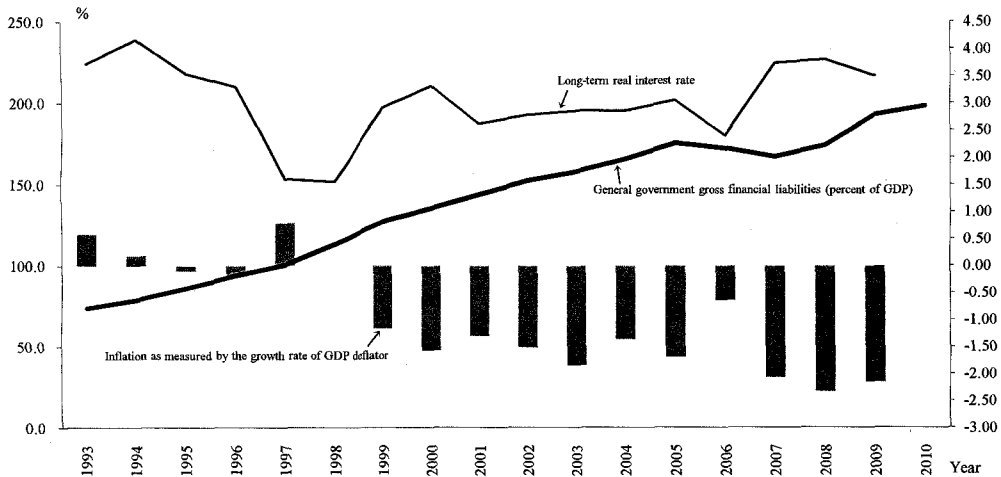
Although the fiscal burden has been increasing in all industrialized countries, Japan's debt-to-GDP ratio is the highest among developed nations, even beyond those of Italy and Greece, which have recently faced serious fiscal crises. The sustainability of the Japanese fiscal system is declining because of its low fertility rate and aging population, with the International Monetary Fund (2009) estimating that the gross public debt of Japan could reach 277% of GDP by 2016. FY 2010 was the first year in the post-War era that tax revenues declined below government bond (GB) issues in the initial budget. As the cumulative outstanding government debt continues to expand, there are growing concerns about a significant increase in interest payments should interest rates rise in the future.

The Japanese government, therefore, is aiming to raise consumption tax in two stages: to 8% in April 2014 and to 10% in October 2015. The Cabinet Office (2012) prudently analyzed Japan's economic and fiscal projections for the medium to long-

term and suggested that even if the consumption tax rate increases by 2015, the primary balance deficit of the central and local governments combined in 2020 will reach approximately 17 trillion yen, which is 3% of GDP. However, Japan's government will decide whether the planned consumption tax hike is feasible, based on indicators such as growth rates and prices. It doesn't clearly state any conditions for the decision. Thus, if the tax rate remains at the current level (i.e., 5%), the primary balance deficit of the central and local governments combined in 2020 will amount to 4.5% of GDP. These figures indicate that further balance improvement is necessary to maintain fiscal sustainability.

In a country with such huge public debt, the interest rate on GBs would then rise to reflect this default risk. Manganelli and Wolswijk (2009) pointed out that within the GBs of EU countries, a well-established empirical pattern shows that interest rate spreads are expanding because of increasing public debt-to-GDP ratios and that these spreads could be interpreted as reflecting the risk of governments defaulting on their debt

Figure 1. Public debt to GDP, Long-term Real Interest Rate and Deflation



obligations. Codogno *et al.* (2003), Bernoth *et al.* (2004), and Akitobi and Stratmann (2008) also found the existence of spreads that may be interpreted as a risk premium. Consequently, IMF (2011) warned that market concerns over Japanese fiscal sustainability may provide a sudden spike in Japanese GB yields that quickly renders the public debt unsustainable.

By contrast, the interest rate on Japanese GBs is currently lower than those of other developed countries and it is declining even though Japanese public debt continues to increase. In order to solve this paradox, Oguro and Sato (2011) constructed an overlapping generations model within an endogenous and stochastic growth setting. They analyzed the relationship between the interest rate of GBs and the consolidation fiscal rule and made three key findings. First, the interest rate of GBs may be declining because public debt is accumulated relative to private capital (where the former crowds out the latter) as opposed to the conventional view that public debt accompanies a rise in the interest rate. Second, the fiscal consolidation rule plays a key role in determining the interest rate in equilibrium. According to this view, the interest rate of Japanese GBs continues to remain relatively low because the government is promoting fiscal reform and because domestic investors may believe

that the Japanese government will not default on its debt obligations. Third, depopulation also lowers the interest rate of GBs to the same level as public debt to capital, even if the fiscal consolidation rule is the same. However, economic changes imply that the relatively low interest rate of GBs may not continue in the future.

Furthermore, Oguro and Sato (2011) abstracted the role of monetary policy (e.g., the effect of deflation and inflation on the "real" interest rate of GBs). If the classical dichotomy holds, the real interest rate of GBs would be determined independent of deflation, by using the Fisher equation proposed by Fisher (1930). However, according to the recent view of the New Keynesian model developed by Mankiw and Romer (1991), Walsh (2003), and Woodford (2003), inflation targeting policy affects real economic growth and the real interest rate. Therefore, if price dynamics is involved in the model proposed by Oguro and Sato (2011), new findings may be shown. As presented in Figure 1, the long-term real interest rate is stable, even though Japanese public debt continues to increase. In this mechanism, deflation may suppress the real interest rate of GBs because of the arbitrage between private capital and GBs, thereby pulling down the real return on capital.

Therefore, in the present study we

provide a macroeconomic model in order to analyze the effect of deflation and inflation on the real interest rate of GBs by integrating price dynamics into the model of Oguro and Sato (2011). We find that deflation may lower the real interest rate of GBs to the same level of public debt to capital, even if the fiscal consolidation rule is the same, as opposed to the conventional view that the real interest rate of GBs is determined independent of deflation if the classical dichotomy holds. Our results are consistent with how the real interest rate of Japanese GBs reacts in periods of deflation. This paper also addresses the impact of fiscal inflation (i.e., monetizing all parts of the GB's default using monetary policy). We calculate expected fiscal inflation when the default rate in the event of fiscal consolidation is raised. Fiscal inflation may be extremely high if the extent of the required tax increase in fiscal consolidation is low.

The remainder of the present paper is organized as follows. Section 2 describes the model. In section 3, we consider fiscal consolidation and establish the equilibrium of the real interest rate of GBs and the expected fiscal inflation. In section 4, we describe the parameters and scenarios for the presented simulation and discuss the implications of the results. Section 5 concludes.

## 2. Model Setting

### 2.1 Basic Setting

Based on the setting proposed by Oguro and Sato (2011), we use an overlapping generations model with price dynamics (e.g., deflation and inflation). Specifically, we suppose that each generation contains a representative household who lives for two periods. Each period is composed of several stages. In stage 1, production shock is shown. The household of the young generation supplies labor in stage 2. Then, in stage 3, output is realized, wages are paid to the young and the return on capital is distributed to the old. The government collects taxes and

repays public debt in stage 4. In stage 5, young and old households consume the former but also save by choosing a portfolio. Public debt and private capital are carried over into the next period. Our analysis has two steps. First, we establish the intra-period or static equilibrium given the degree of public debt and capital carried over from the previous period. We then turn to their dynamics in which economic growth is endogenous and stochastic.

### 2.2 Production

We use  $Y_t$  to denote the aggregate real output at period  $t$  that is produced by a representative private firm. The production function of the economy is given as

$$Y_t = AK_t^\mu (\varepsilon_t k_t)^\alpha l_t^{1-\alpha} \quad (1)$$

where  $A (>0)$  is constant,  $\mu > 0$ , and  $0 < \alpha < 1$ .  $\varepsilon_t$  is the productivity shock. For the sake of simplicity, we assume that the shock is distributed according to the distribution function  $F(\varepsilon_t)$  over the interval  $[\underline{\varepsilon}, \bar{\varepsilon}]$  with  $E_t \varepsilon_t = 1$ .  $k_t$  refers to private real capital that is invested in the previous period and  $l_t$  is labor supply per worker at period  $t$ .<sup>1)</sup> Given that the population of each generation is normalized to one,  $L_t = 1 \times l_t$  becomes the total labor supply.  $K_t$  refers to the average real capital investment, which represents the external effect of capital accumulation. Following the literature on endogenous growth, this may be interpreted as knowledge spillover that generates a scale economy. In equilibrium, we have  $k_t = K_t$ .

We denote the price level as  $P_t$  in period  $t$ . Let  $\pi_t = P_t/P_{t-1} - 1$  be the inflation rate. We treat the inflation rate as a policy instrument in the present model. Another key assumption is that the after tax (disposal) "nominal" wage  $\bar{W}_t$  is determined prior to period  $t$  and is sticky. Specifically, this is defined by  $\bar{W}_t = P_{t-1} \bar{w}_t$ , where  $\bar{w}_t$  is the real wage given as

$$\bar{w}_t = \xi (1 - \alpha) \bar{Y}_t$$

where  $\xi$  captures the notion of the bargaining power of workers (or of the labor union) relative to that of employers. The wage tax

rate  $\tau_t$  is added to  $\bar{w}_t$  in order to determine the labor cost accruing to employers and thus their labor demand.

The wage rigidity is a source of influence of inflation on the real economy. In addition, the assumption that the after tax wage is predetermined highlights the degree to which the wage tax rate distorts the economy. In a more general context,  $\xi$  may imply that nominal wage rate is partially adjusted to inflation between periods with  $\xi < \pi_t$ . Instead we can regard it as the degree to which the wage tax burden is split between workers and employers. Admittedly the present model lacks micro-foundation of determining  $\xi$ . We leave it for the future research but take it as parameter for analytical convenience. Let  $\check{Y}_t \equiv A k_t^\alpha K_t^\mu$  be average output (evaluated at  $\varepsilon_t=1$ ) at full employment ( $l_t=1$ ). In this regard, workers (i.e., the labor union) do not incorporate the feedback effect of their nominal wage setting within labor demand.

We next turn to the demand for labor and capital. Given that  $(1+\tau_t)\bar{w}_t$  is the tax-inclusive labor cost in real terms and that  $K_t$  is constant, we have:

$$(1+\tau_t) \frac{P_{t-1}}{P_t} \bar{w}_t = (1-\alpha) Y_t / l_t; \quad r_t = \alpha Y_t / k_t \quad (2)$$

Throughout the model, we restrict parameters so that  $l_t < 1$ , namely unemployment exists.

### 2.3 Household Problem

The household's lifetime utility is assumed to take the following form:

$$U_t = (c_t^y)^\theta c_t^o \quad (3)$$

where  $\theta > 0$ .  $c_t^y$  denotes the young period real consumption, whereas  $c_t^o$  is the old period one. Eq. (3) implies that the household's preference is neutral to these risks. One may find it odd that risk and time preferences are separately defined. Our specification deviates from the standard setting, which assumes that the lifetime utility is additive over periods and over different states of the

economy. The inter-temporal elasticity is therefore not tied to the inverse of the risk aversion in the present context. Eq. (3) is useful to isolate the household's portfolio choice between private capital and GB from the decision about total real saving  $S_t$ .

We now turn to the household's budget constraints. Denoting the price level at period  $t$  as  $P_t$ , the household's budget constraints for the young and old periods are given by

$$P_t c_t^y + P_t s_t = P_{t-1} \bar{w}_t l_t \equiv P_t \frac{\bar{w}_t l_t}{1+\pi_t} \quad (4.1)$$

$$P_{t+1} \check{c}_{t+1}^o = q_t P_t s_t (1 - \check{\zeta}_{t+1}) R_{t+1} + (1 - q_t) P_{t+1} s_t \check{r}_{t+1} \quad (4.2)$$

where  $R_t$  is the "nominal" interest rate of GBs (one plus) and  $q_t$  represents the share of GBs in the household's saving.  $\check{\zeta}_{t+1}$  is the default rate, taking a value between zero and unity. The variables with tilde state that they are not known when saving at period  $t$ .  $R_t$  is determined at period  $t$  but with a default risk ( $\check{\zeta}_{t+1}$ ), the net return on GBs is not certain.<sup>2)</sup> In (4.2), the first term of the right-hand side ( $P_t s_t (1 - \check{\zeta}_{t+1}) R_{t+1}$ ) is interpreted as the net return on GBs of the nominal saving ( $P_t s_t$ ) and the second term of the right-hand side ( $P_{t+1} s_t \check{r}_{t+1}$ ) as the return on capital of the nominal saving ( $P_t s_t$ ), where  $P_{t+1} \check{r}_{t+1} / P_t$  represents (one plus) "capital gain" per saving. Based on the hypothesis of the Fiscal Theory of Price Level developed by Leeper (1991), Woodford (1994, 1995), Sims (1994), and Cochrane (1998, 2010), we can interpret the default rate ( $\check{\zeta}_{t+1}$ ) as the effect of fiscal inflation ( $\Delta\pi_{t+1}$ ).<sup>3)</sup> If the government chooses to monetize all parts of the default using monetary policy,  $\check{\zeta}_{t+1} = \Delta\bar{\pi}_{t+1} / (1 + \Delta\bar{\pi}_{t+1})$  and  $\check{P}_{t+1} = P_{t+1} (1 + \Delta\bar{\pi}_{t+1})$  holds.<sup>4)</sup>

In the young period, the household decides real saving  $s_t$  and chooses portfolio  $q_t$  in order to maximize

$$E_t U_t = (c_t^y)^\theta E_t [c_{t+1}^o]$$

subject to Eq. (4), where the expectation is taken over  $\check{\zeta}_{t+1}$  and  $r_{t+1}$ . The household's optimization yields the following:

$$s_t^* = \frac{1}{1+\theta} \frac{\bar{w}_t l_t}{1+\pi_t} \quad (5.1)$$

$$\frac{R_{t+1}}{1+\pi_{t+1}} E_t(1-\tilde{\xi}_{t+1}) = E_t \tilde{r}_{t+1} \quad (5.2)$$

where

$$l_t = \left( \frac{(1+\pi_t)}{(1+\tau_t)\xi} \right)^{1/\alpha} \varepsilon_t \quad (5.3)$$

Owing to the Cobb-Douglas specification, the real saving is a fixed share of real wage income after tax. The income effect and substitution effect offset one another as given in (5.1).

(5.2) gives the arbitrage condition between private capital and GBs. Given that the household is risk-neutral, the arbitrage leads the expected return of both assets to be equated, which should be intuitive.

## 2.4 Market Equilibrium

This section considers the market equilibrium given the prevailing fiscal policy. In every period, both labor and capital markets are cleared. Given  $\varepsilon_t$  and  $k_t$ , the equilibrium values of real wage and real return on private capital at period  $t$  are determined by substituting (1) and (5.1) into (2) so that

$$\bar{w}_t = \xi(1-\alpha) A k_t^\alpha K_t^\mu \quad (6.1)$$

$$r_t = \alpha \varepsilon_t A K_t^\mu k_t^{\alpha-1} \left( \frac{(1+\pi_t)}{(1+\tau_t)\xi} \right)^{(1-\alpha)/\alpha} \quad (6.2)$$

Consider the external effect. In equilibrium, we have  $K_t = k_t$ , the capital investment in market being exactly equal to the average in the economy. In addition, we set the parameter associated with the externality so that the equilibrium real output is proportional to private capital. The following assumption provided by Romer (1986) is imposed:

(Assumption)  $\mu = 1 - \alpha$

Then, real output turns out to be

$$Y_t = \varepsilon_t A K_t \left( \frac{(1+\pi_t)}{(1+\tau_t)\xi} \right)^{(1-\alpha)/\alpha} \quad (7)$$

The above is familiar in the endogenous growth model, which yields constant real growth rate as a function of policy parameters. The real wage rate is linear with respect to  $k_t$  as well, whereas the real return on

private capital turns out to be independent of  $k_t$ :

$$\bar{w}_t = \xi(1-\alpha) A k_t \quad (6.1')$$

$$r_t = \alpha \varepsilon_t A \left( \frac{(1+\pi_t)}{(1+\tau_t)\xi} \right)^{(1-\alpha)/\alpha} \quad (6.2')$$

Lastly, we turn to the capital market. Because of the closed economy, household savings must meet the demand of private firms and the government. Denoted by  $b_{t+1}$  is the real value of GBs issued at period  $t$  and repaid at  $t+1$ .<sup>5)</sup> Given that the total real saving at period  $t$  is  $s_t$ , which is allocated between  $k_{t+1}$  and  $b_{t+1}$ , the equilibrium condition is expressed by

$$\begin{aligned} k_{t+1} + b_{t+1} &= s_t^* \\ &= \frac{\varepsilon_t A (1-\alpha) k_t}{1+\theta} \left( \frac{1}{1+\tau_t} \right)^{1/\alpha} \left( \frac{1+\pi_t}{\xi} \right)^{(1-\alpha)/\alpha} \end{aligned} \quad (8)$$

Manipulating the above establishes the dynamics of private capital accumulation as the following:

$$\begin{aligned} \left( 1 + \frac{b_{t+1}}{k_{t+1}} \right) \frac{k_{t+1}}{k_t} &= \frac{\varepsilon_t A (1-\alpha)}{1+\theta} \left( \frac{1}{1+\tau_t} \right)^{1/\alpha} \left( \frac{1+\pi_t}{\xi} \right)^{(1-\alpha)/\alpha} \end{aligned} \quad (8')$$

## 2.5 Government Budget

The government raises revenue by issuing GBs and taxing wage income. It then spends on debt repayment and the real value of public expenditure, the latter being denoted by  $G_t$ .  $G_t$  is assumed not to contribute to production (1) or directly enter the household's utility (3). This assumption is motivated to simplify our analysis, but it may be plausible when the government spending comprises mostly political rents or pork diverted to special interest groups. The fund flow of the government budget at period  $t$  is written as

$$P_t b_{t+1} = P_{t-1} R_t b_t - P_t \{T_t - G_t\} \quad (10)$$

where  $T_t = \frac{\tau_t}{1+\tau_t} (1-\alpha) Y_t$  and  $Y_t$  is given in (7).  $P_t b_{t+1}$  denotes the nominal value of GBs issued at period  $t$ . In the other two terms,  $P_t$

is multiplied to convert them to nominal variables.

At this point, we distinguish the fiscal rule between the pre-fiscal consolidation and the fiscal consolidation regimes. This is denoted by  $\Omega t \equiv \{\tau_t, \lambda_t, \zeta_t\}$ , which contains tax rate  $\tau_t$ , government expenditure ratio  $\lambda_t$ , and default rate  $\zeta_t = \Delta \tilde{\pi}_{t+1} / (1 + \Delta \tilde{\pi}_{t+1})$ , and may be state contingent in the consolidation regime. The fiscal rules are assumed to be public information, implying that they are incorporated into the pricing of GBs as discussed below. In the present mode, we instead take the pragmatic view that government policy is largely politically constrained, so it does not aim to optimize social welfare.

Let  $\Omega^0 \equiv \{\tau, \lambda, \zeta\}$  with  $\zeta = 0$ . In the pre-consolidation regime, the government taxes wage income at the rate of  $\tau_t = \tau$  and spends a given portion  $\lambda_t = \lambda$  of the potential real output that calculates  $Y_t$  at the mean of  $\varepsilon_t$ , i.e.,  $\varepsilon_t = 1$  and at  $\tau_t = \tau$ , so that  $G_t = \lambda \bar{Y}_t$  where

$$\bar{Y}_t = Ak_t \left( \frac{1 + \pi_t}{(1 + \tau)\xi} \right)^{(1-\alpha)/\alpha} \quad (11)$$

$G_t$  remains proportional to  $\bar{Y}_t$  defined above in the consolidation regime as illustrated later. With (11) and (12), the real value of the primary surplus at period  $t$  is defined by

$$PS_t = T_t - G_t = Ak_t \left( \frac{1}{\xi} \right)^{(1-\alpha)/\alpha} \Delta(\tau_t, \lambda_t, \varepsilon_t) \quad (12)$$

where

$$\begin{aligned} \Delta(\tau_t, \lambda_t, \varepsilon_t) &\equiv \left( \frac{\tau_t}{(1 + \tau_t)^{1/\alpha}} \varepsilon_t (1 - \alpha) (1 + \pi_t)^{(1-\alpha)/\alpha} \right. \\ &\quad \left. - \lambda_t \left( \frac{1 + \pi_t}{(1 + \tau)} \right)^{(1-\alpha)/\alpha} \right) \end{aligned}$$

Substituting (12) into (10) and manipulating it establishes the dynamics of the public debt over periods:

$$\begin{aligned} \frac{b_{t+1}}{k_{t+1}} \frac{k_{t+1}}{k_t} &= \frac{1}{1 + \pi_t} R_t \frac{b_t}{k_t} \\ &\quad - A \left( \frac{1}{\xi} \right)^{(1-\alpha)/\alpha} \Delta(\tau_t, \lambda_t, \varepsilon_t) \end{aligned} \quad (13)$$

where  $k_{t+1}/k_t$  is as given in (8').

Note that in the present economy,  $b_{t+1}/k_{t+1}$  as well as  $k_{t+1}$  serve as state variables that are determined at period  $t$  and carried over to period  $t+1$ . This affects the risk of fiscal consolidation at  $t+1$ , as discussed in section 3.

### 3. Equilibrium

#### 3.1 Fiscal Sustainability

The fiscal rule  $\Omega^0 \equiv \{\tau, \lambda, \zeta\}$  in the pre-consolidation regime does not ensure that public debt remains at a fiscally sustainable level. The tax rate may be too low and/or the expenditure ratio too high, which structurally generates a primary deficit, i.e.,  $\Delta(\tau, \lambda, \varepsilon_t) < 0$  for most of  $\varepsilon_t$ . Then, public debt may reach a level at which the status quo fiscal rule cannot be sustained.

Given the use of the overlapping generations model in this study, the capital market may not discipline government financing because households are not necessarily concerned about long-run fiscal sustainability. Unless  $\zeta_{t+1} = 1$  for sure, with risk-neutral preferences, households are willing to purchase GBs as long as (5.3) holds, with the default risk compensated by a higher ex ante promised nominal interest rate.

In the present context, therefore, the government can access credit as long as the GB level does not exceed domestic saving with the interest rate fulfilling (5.3). Suppose, however, that the economy reaches  $b_{t+2} = s_{t+1}$ , that is, the domestic saving at period  $t+1$  is fully absorbed by government borrowing. Given that the economy is closed, no private investment can take place, which implies that there is no production in the subsequent period or  $Y_{t+2} = 0$  for all  $\varepsilon_{t+2}$ . Once this occurs, the government can find no resource for repayment. It then has to default on the debt so that  $\zeta_{t+2} = 1$  is certain and that there is no return on GBs.<sup>6)</sup> This in turn implies that the household ceases to lend to the government. The government is then forced to undertake fiscal consolidation without further borrowing. This entails tax

increases, expenditure reductions, and the default on GBs.

**Lemma 1:** Full default is inevitable at period  $t+1$  irrespective of  $\varepsilon_{t+2}$  when  $b_{t+2}=s_{t+1}$ .

### 3.2 Threshold

With  $b_{t+2}=s_{t+1}$  or  $k_{t+2}=0$ , we have  $b_{t+1}/k_{t+2} = \infty$  at period  $t+1$ . Inserting this into (13) and manipulating it yields the following condition of the threshold level of  $\varepsilon_{t+1}$ , which the regime change arises:

$$\begin{aligned} & \frac{R_{t+1}}{1+\pi_{t+1}} \frac{b_{t+1}}{k_{t+1}} \\ &= \left( \frac{1-\alpha}{(1+\tau)^{1/\alpha}} \right) A \xi^{-(1-\alpha)/\alpha} (1+\pi)^{(1-\alpha)/\alpha} \\ & \left( \bar{\varepsilon}_{t+1} \left( \frac{1}{1+\theta} + \tau \right) - \frac{\lambda(1+\tau)}{(1-\alpha)} \right) \end{aligned} \quad (14)$$

The above defines the threshold  $\bar{\varepsilon}_{t+1}$  implicitly as the function of the interest rate charged on  $b_{t+1}$  as well as the debt-to-capital ratio and demography:  $\bar{\varepsilon}_{t+1} = \bar{\varepsilon}_{t+1}(R_{t+1}, Z_{t+1})$ , where  $Z_{t+1} = (b_{t+1}/k_{t+1}, \pi_{t+1})$ . With  $R_{t+1}$  and  $b_{t+1}/k_{t+1}$ ,  $\bar{\varepsilon}_{t+1}$  increases so that fiscal consolidation is more likely to be in place, whereas it is lowered with  $\pi_{t+1}$ .

**Lemma 2:** Fiscal consolidation must occur at period  $t+1$  when  $\varepsilon_{t+1} \leq \bar{\varepsilon}_{t+1}$

The fiscal consolidation rule involves tax increases, expenditure reductions, and the default on GBs. We denote the state of the economy at period  $t+1$  by  $\mathcal{E}_{t+1} = (\varepsilon_{t+1}, b_{t+1}/k_{t+1}, \pi_{t+1})$ . The fiscal rule is then expressed as  $\Omega_{t+1} \equiv \Omega(\mathcal{E}_{t+1})$  with  $b_{t+1}=0$  that contains

$$\begin{aligned} \tau &\leq \tau_{t+1} = \tau(\mathcal{E}_{t+1}) \leq \bar{\tau}, \lambda \geq \lambda_{t+1} = \lambda(\mathcal{E}_{t+1}), \\ 0 &\leq \zeta_{t+1} = \zeta(\mathcal{E}_{t+1}) \leq 1 \end{aligned}$$

where the default rate ( $\zeta_i = \Delta\pi_{t+1}/(1+\Delta\pi_{t+1})$ ) fulfills<sup>7)</sup>

$$\begin{aligned} & \frac{(1-\zeta_{t+1})R_{t+1}}{1+\pi_{t+1}} \frac{b_{t+1}}{k_{t+1}} \\ &= A \left( \frac{1}{\xi} \right)^{(1-\alpha)/\alpha} \Delta(\tau_{t+1}, \lambda_{t+1}, \varepsilon_{t+1}) \end{aligned} \quad (15)$$

The government cannot fully meet its

obligation but repays its outstanding debt as much as possible out of the primary surplus, as illustrated in (15). Under the consolidation rule, tax rate, expenditure ratio, or default rate deviates from the initial levels. The fiscal rule can take the general form.

In the simulation shown in section 4, we specify the fiscal consolidation rule. Note that it takes only one period to restructure government finance. Given that no GBs are issued, the economy will return to the initial regime in the next period with no debt liability being carried over.

### 3.3 Nominal Interest Rate

Let us now turn to the nominal interest rate of GBs  $R_{t+1}$  that is settled at period  $t$ , accounting for the fiscal consolidation in the event of  $\varepsilon_{t+1} \leq \bar{\varepsilon}_{t+1}$ . Recall the arbitrage condition (5.3) that equates return on GB and capital in the expected term. Manipulating this using (6.2) and (15) establishes the following:

$$\begin{aligned} & (1-F(\bar{\varepsilon}_{t+1}))R_{t+1} \\ &= A(1+\tau_{t+1}) \left( \frac{1}{\xi} \right)^{(1-\alpha)/\alpha} \left\{ \alpha\Phi(\bar{\varepsilon}_{t+1}) - \frac{k_{t+1}}{b_{t+1}} \right. \\ & \left. \int^{\bar{\varepsilon}_{t+1}} (\Delta(\bar{\varepsilon}_{t+1}, \bar{\tau}_{t+1}, \bar{\lambda}_{t+1}, \tau)) dF(\bar{\varepsilon}_{t+1}) \right\} \end{aligned} \quad (16)$$

where

$$\begin{aligned} & \Phi(\bar{\varepsilon}_{t+1}) \\ &= \left( \int^{\bar{\varepsilon}_{t+1}} \bar{\varepsilon}_{t+1} \left( \frac{1+\bar{\pi}_{t+1}}{1+\bar{\tau}_{t+1}} \right)^{(1-\alpha)/\alpha} dF(\bar{\varepsilon}_{t+1}) \right. \\ & \left. + \left( \frac{1+\pi_{t+1}}{1+\tau} \right)^{(1-\alpha)/\alpha} \int_{\bar{\varepsilon}_{t+1}} (\bar{\varepsilon}_{t+1}) dF(\bar{\varepsilon}_{t+1}) \right) \\ & \Delta(\varepsilon_{t+1}, \tau_{t+1}, \lambda_{t+1}, \tau) \\ &= (1+\pi_{t+1})^{(1-\alpha)/\alpha} \left( \frac{\tau_{t+1}}{(1+\tau_{t+1})^{1/\alpha}} (1-\alpha)\varepsilon_{t+1} \right. \\ & \left. - \lambda_{t+1} \left( \frac{1}{(1+\tau)} \right)^{(1-\alpha)/\alpha} \right) \end{aligned}$$

Note that  $\Phi_t$  reflects the expected return on private capital. It is clear to see that this is non-increasing with the threshold level given that  $\tau \leq \tau_{t+1}$ . Eq. (16) yields the nominal interest rate of GBs as a function of the threshold, the debt-to-capital ratio, and the

population:  $R_{t+1} = R_{t+1}(\bar{\varepsilon}_{t+1}, Z_{t+1})$ .

### 3.4 Interaction

There exists interaction between the threshold of fiscal consolidation  $\bar{\varepsilon}_{t+1}$  and the nominal interest rate of GBs  $R_{t+1}$  defined by (14) and (16), respectively. By solving these equations, their equilibrium values can be obtained. Note that these are assessed from period  $t$  or an ex ante perspective when  $\varepsilon_{t+1}$  is not known and fiscal consolidation is not yet in place.

**Proposition 1:** Denoted by  $R_{t+1}^*$  and  $\bar{\varepsilon}_{t+1}^*$  are the equilibrium levels of the nominal interest rate of GBs and the threshold of fiscal consolidation conditional upon  $b_{t+1}/k_{t+1}$  and the consolidation rule  $\Omega_{t+1} = \Omega(\mathcal{E}_{t+1})$ . These are given as solutions to the following equations:

$$\begin{aligned} & \frac{R_{t+1}}{1 + \pi_{t+1}} \frac{b_{t+1}}{k_{t+1}} \\ &= \left( \frac{1 - \alpha}{(1 + \tau)^{1/\alpha}} \right) A \xi^{\varepsilon - (1 - \alpha)/\alpha} (1 + \pi)^{(1 - \alpha)/\alpha} \\ & \quad \left( \bar{\varepsilon}_{t+1} \left( \frac{1}{1 + \theta} + \tau \right) - \frac{\lambda(1 + \tau)}{(1 - \alpha)} \right) \\ & (1 - F(\bar{\varepsilon}_{t+1})) R_{t+1} \\ &= A (1 + \tau_{t+1}) \left( \frac{1}{\xi} \right)^{(1 - \alpha)/\alpha} \left\{ \alpha \Phi(\bar{\varepsilon}_{t+1}) - \frac{k_{t+1}}{b_{t+1}} \right. \\ & \quad \left. \int^{\bar{\varepsilon}_{t+1}} (\Delta(\bar{\varepsilon}_{t+1}, \bar{\tau}_{t+1}, \tilde{\lambda}_{t+1}, \tau) dF(\bar{\varepsilon}_{t+1})) \right\} \end{aligned}$$

In the above proposition, we do not preclude the case that there arise multiple equilibria, the two equations intersecting more than twice or the equilibrium diverges,  $\bar{\varepsilon}_{t+1}^*$  reaching  $\bar{\varepsilon}$  as shown by Oguro and Sato (2011). In addition, by inserting the solution into (15) and taking the expectation, we can obtain the following proposition:

**Proposition 2:** With the debt-to-capital ratio  $b_{t+1}/k_{t+1}$  and the consolidation rule  $\Omega_{t+1} = \Omega(\mathcal{E}_{t+1})$ , fiscal inflation that is calculated in the expected term is given as follows:

$$E_t[1 + \Delta\pi_{t+1}]$$

$$\begin{aligned} &= \frac{R_{t+1}}{1 + \pi_{t+1}} \frac{b_{t+1}}{k_{t+1}} \\ &= \frac{R_{t+1}}{1 + \pi_{t+1}} \frac{b_{t+1}}{k_{t+1}} \int^{\bar{\varepsilon}_{t+1}} \frac{dF(\bar{\varepsilon}_{t+1})}{\Delta(\bar{\tau}_{t+1}, \tilde{\lambda}_{t+1}, \bar{\varepsilon}_{t+1})} \\ & \quad + 1 - F(\bar{\varepsilon}_{t+1}) \end{aligned} \quad (17)$$

## 4. Simulation

### 4.1 Parameter Setting and Scenarios

By using the simulation developed in section 3, the aim of this section is to analyze the impacts of deflation and inflation on the real interest rate of GBs and the threshold that the consolidation occurs given  $b_t/k_t$  at period  $t$ . Moreover, we calculate the fiscal inflation of (17) and the threshold that the consolidation occurs given  $b_t/k_t$  at period  $t$ . Our quantitative analysis does not intend to replicate any practice of economy. Rather, it aims to supplement our theoretical model, resolve the ambiguity of its results, and clarify its policy implications.

The parameters are specified in Table 1.  $\varepsilon_t$  distributes over [0.5-1.5] according to the inverse U-shaped density function with a mean of one. We set the tax rate to be relatively low (10%) and the expenditure rate at 10% of potential output as well. This implies that a primary deficit is likely to result unless  $\varepsilon_t$  is larger than the mean of one, so there exists the possibility that public debt is accumulated as consolidation risk is enhanced. The fiscal consolidation rule demands that expenditure be cut to  $\lambda_{t+1} = 0.035$ . The wage tax rate under consolidation is assumed to be increasing in  $\varepsilon_{t+1}$ , whereas it increases with  $b_{t+1}/k_{t+1}$ . This is specified as in Table 1. The consolidation rule relies on more tax increases for large debt-to-capital ratios, whereas the default rate ( $\zeta(\mathcal{E}_{t+1}) = \Delta\pi_{t+1}/(1 + \Delta\pi_{t+1})$ ) is raised when  $\varepsilon_{t+1}$  is small and so the economy is depressed. Such a presumption should be plausible.

The parameter  $g$  in the tax function refers to the extent of the required tax increase. The simulation sets two values for  $g$ :  $g=2$  and  $g=5$ . A higher  $g$  value implies



Table 1. Parameters

Parameters	Values
$\xi$	1.0
$\alpha$	0.3
$\theta$	1.333
$A$	7.0
$\Omega^0 = \{\tau, \lambda, \zeta\}$	$\tau = 0.1$ $\lambda = 0.1$
$\Omega_{t+1} \equiv \Omega(\Xi_{t+1})$	$\tau(\varepsilon_{t+1}, b_{t+1}/k_{t+1}) = \text{Min}\left(g \times \tau, \tau + 3.8 \frac{b_{t+1}}{k_{t+1}} \varepsilon_{t+1}\right)$ $\lambda(\varepsilon_{t+1}, b_{t+1}/k_{t+1}) = 0.035$

Table 2. Scenarios

Scenarios	The extent of the required tax increase	Price dynamics
1	$g=2$	$\pi_{t+1}=0$
2	$g=2$	$\pi_{t+1}=-0.139$
3	$g=2$	$\pi_{t+1}=0.161$
4	$g=5$	$\pi_{t+1}=0$
5	$g=5$	$\pi_{t+1}=-0.139$
6	$g=5$	$\pi_{t+1}=0.161$

larger tax increases in fiscal consolidation, which in turn implies lower fiscal inflation. This is defined as residual by (17). By comparing the results of different levels of  $g$ , we can assess the effect of the fiscal rule on  $R_{t+1}^*$  and  $\varepsilon_{t+1}^*$  as well as the transition of the debt-to-capital ratio. In order to examine the impacts of deflation and inflation, we consider three cases: 1) zero inflation ( $\pi_{t+1}=0$ ), 2) 0.5% deflation per annum ( $\pi_{t+1}=(1-0.005)^{30}-1=-0.139$ ), and 3) 0.5% inflation per annum ( $\pi_{t+1}=(1+0.005)^{30}-1=0.161$ ). Here, we take one period in our model to represent 30years. Distinguished by the parameter  $g$  and the price dynamics, six scenarios are presented in Table 2.

## 4.2 Results

In this section, we focus on the interior equilibrium in the simulation. The real interest rate of GBs for the six scenarios are shown as in Figures 2 and 3, where  $b_{t+1}/k_{t+1}$  is treated parametrically on horizontal axis.<sup>8)</sup> Figure 2 is related to Scenarios 1 to 3 with  $g=2$  and Figure 3 related to Scenarios 4 to 6 with  $g=5$ .

In Figure 2 with  $g=2$ , we take Scenario 1 with zero inflation ( $\pi_{t+1}=0$ ). The real

interest rate of GBs is gradually increasing with  $b_{t+1}/k_{t+1}$ . At  $b_{t+1}/k_{t+1}=0.615$ , the stable interior level of the real interest rate of GBs disappears. Scenario 1 is compared with Scenarios 2 and 3 in order to assess the impacts of deflation and inflation. The real interest rate of GBs in Scenario 2 with  $\pi_{t+1}=-0.139$  and that in Scenario 3 with  $\pi_{t+1}=0.161$  differ from that in Scenario 1. At the same level of  $b_{t+1}/k_{t+1}$ , the real interest rate of GBs in Scenario 2 is lower and that in Scenario 3 higher than that in Scenario 1. In Scenario 2, the stable interior level of the real interest rate of GBs disappears at  $b_{t+1}/k_{t+1}=0.585$  and in Scenario 3 it disappears at  $b_{t+1}/k_{t+1}=0.645$ .

We now turn to Figure 3 with  $g=5$ . In Scenarios 4 to 6, there exists a range in which the real interest rate of GBs shows downward sloping, confirming the theoretical hypothesis of Oguro and Sato (2011). Figure 3 has two vertical scales. The left-hand scale of the figure shows the level of the real interest rate of GBs and the right-hand scale the difference between the real interest rate of GBs at  $b_{t+1}/k_{t+1}$  and that at  $b_t/k_t$ . Take Scenario 4 with zero inflation ( $\pi_{t+1}=0$ ). The real interest rate of GBs initially declines with  $b_{t+1}/k_{t+1}$ . Its moderate downward trend continues until  $b_{t+1}/k_{t+1}=1.32$  where the real interest rate of GBs takes its minimum value. The slope is then reversed, further increasing the debt-to-capital ratio and rapidly raising the real interest rate. At  $b_{t+1}/k_{t+1}=1.44$ , the stable interior level of the real interest rate of GBs disappears. Scenario 4 is also compared with Scenarios 5 and 6 in order to assess the impacts of deflation and inflation. At the same level of  $b_{t+1}/k_{t+1}$ , the real interest rate of GBs in Scenario 5 is lower and that in Scenario 6 higher than that in Scenario 4. In Scenario 5, the stable interior level of the real interest rate of GBs disappears at  $b_{t+1}/k_{t+1}=1.335$ , and in Scenario 6 at  $b_{t+1}/k_{t+1}=1.485$ . Inflation can sustain the interior equilibrium for larger  $b_{t+1}/k_{t+1}$  compared with deflation. It can be thus concluded that deflation lowers the real

Figure 2. The Real Interest Rate of GBs in Scenarios 1 to 3 ( $g=2$ )

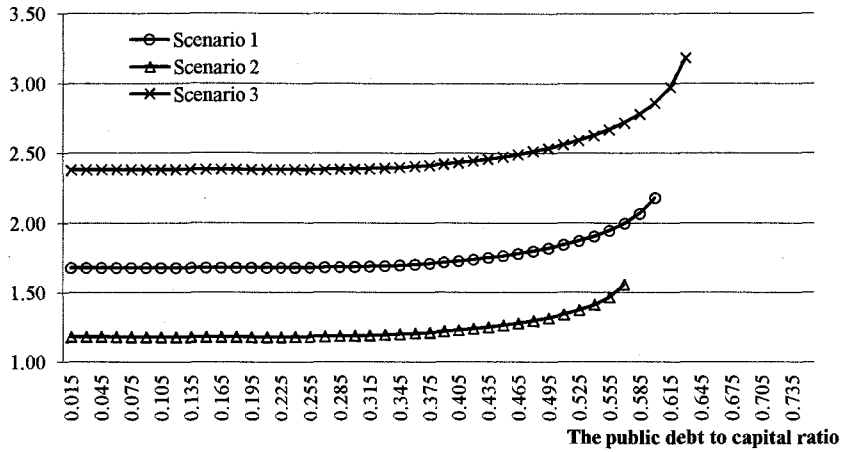


Figure 3. The Real Interest Rate of GBs in Scenarios 4 to 6 ( $g=5$ )

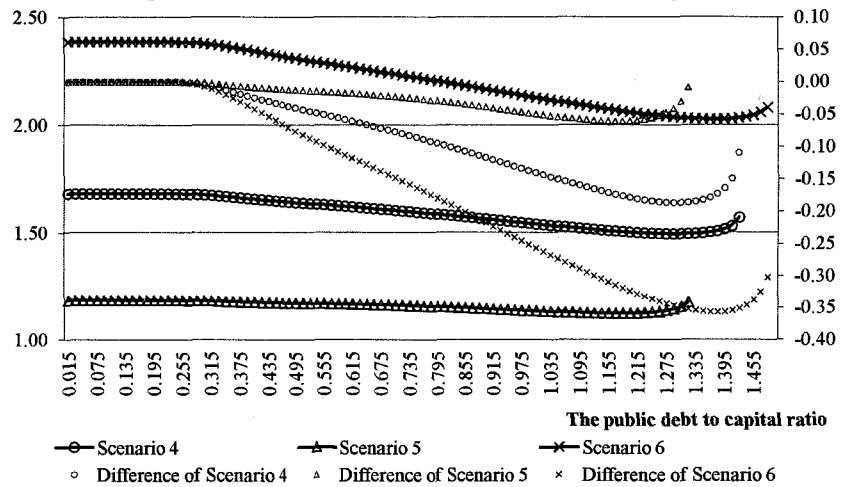
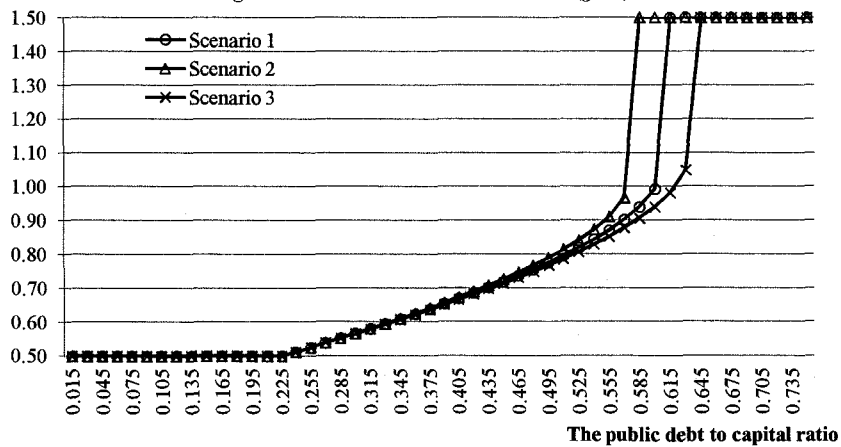


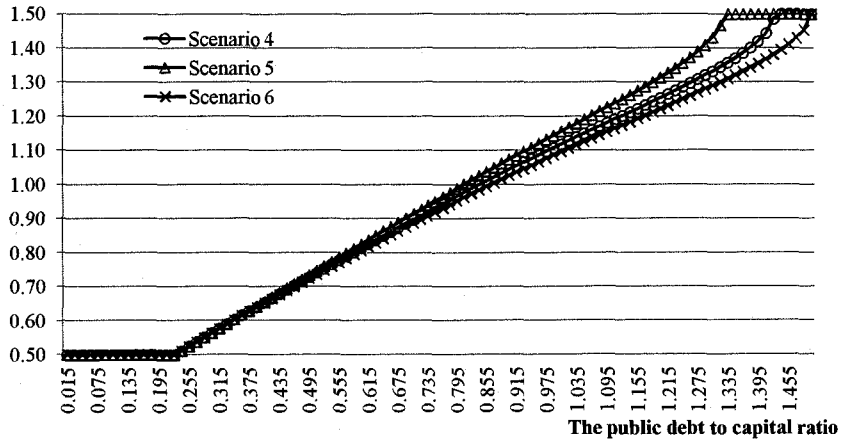
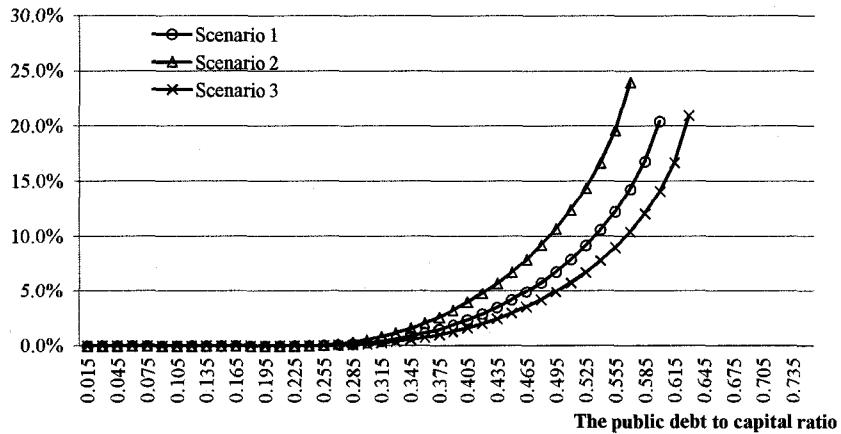
Figure 4. Threshold in Scenarios 1 to 3 ( $g=2$ )



interest rate of GBs, but does not sustain the interior equilibrium.

Consider the threshold of the regime change  $\tilde{\epsilon}_{t+1}^*$ . In all scenarios, this monotonical-

ly increases in  $b_{t+1}/k_{t+1}$ , as shown in Figures 4 and 5. By comparing these figures with different consolidation rules,  $\tilde{\epsilon}_{t+1}^*$  stays lower when the tax increase in the consideration is

Figure 5. Threshold in Scenarios 4 to 6 ( $g=5$ )Figure 6. Fiscal inflation in Scenarios 1 to 3 ( $g=2$ )

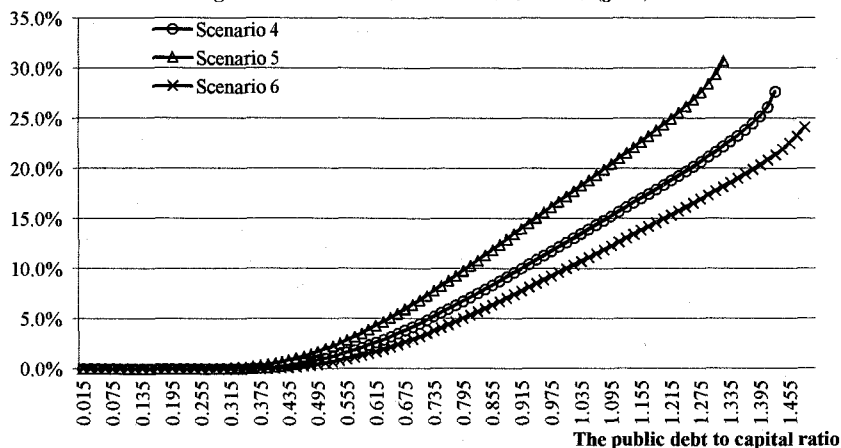
larger (i.e.,  $g$  is high), reflecting a lower interest rate. The prospect for large tax increases in the event of fiscal restructuring, which contributes to lowering the default rate, only serves to mitigate consolidation risk, which should be intuitive. The risk is reflected in the GB premium, which is defined as the difference between the real interest rate of GBs and the expected real return on capital. The premium remains negligible when risk is low: according to consolidation risk, the revenue deficiency is largely filled by tax increases and expenditure reductions. The default rate in the event of consolidation is raised as the debt-to-capital ratio increases, which in turn augments the premium.

To see the effect of deflation and inflation on  $\tilde{\varepsilon}_{t+1}^*$ , we compare Scenario 1 (Scenario 4) with Scenarios 2 and 3 (Scenarios 5 and 6).

The simulation establishes that the threshold is lowered in the case of inflation and rises in the case of deflation.

We now turn to fiscal inflation, which is calculated in the expected term as in (17). The expected fiscal inflation is lowered as the tax increase in the consolidation grows (i.e.,  $g$  is high). Figures 6 and 7 show fiscal inflation from the perspective of period  $t+1$ .<sup>9)</sup>

In Figure 6, for  $b_{t+1}/k_{t+1} < 0.35$ , fiscal inflation is low in Scenarios 1 to 3. However, after that, it monotonically increases in  $b_{t+1}/k_{t+1}$  as shown in the figure. At the near points of  $b_{t+1}/k_{t+1} = 0.60$  in Scenario 1, it reaches over 20%. At the near points of  $b_{t+1}/k_{t+1} = 0.57$  in Scenario 2, it reaches over 24%. This indicates the impact of fiscal inflation (i.e., monetizing all parts of the default using monetary policy).

Figure 7. Fiscal inflation in Scenarios 4 to 6 ( $g=5$ )

In Figure 7, the expected fiscal inflation also monotonically increases in  $b_{t+1}/k_{t+1}$ . At the same level of  $b_{t+1}/k_{t+1}$ , it is lower than that in Figure 6 because of the larger tax increase in the consolidation (i.e., higher  $g$ ). For  $b_{t+1}/k_{t+1} > 0.375$ , the disparity becomes prominent. At the same level of  $b_{t+1}/k_{t+1}$ , fiscal inflation in Scenario 6 with  $\pi_{t+1} = 0.161$  stays lower than that in Scenario 4 with zero inflation and that in Scenario 5 with  $\pi_{t+1} = -0.139$  is higher than in Scenario 4. It can be thus concluded that initial inflation ( $\pi_{t+1}$ ) reduces the expected fiscal inflation when the default rate in the event of consolidation is raised.

In addition, the fiscal inflation in Scenario 4 reaches 27.7% at  $b_{t+1}/k_{t+1} = 1.425$ , that in Scenario 5 30.8% at  $b_{t+1}/k_{t+1} = 1.32$ , and that in Scenario 6 24.1% at  $b_{t+1}/k_{t+1} = 1.485$ .

## 5. Conclusion

In this paper, we analyze the impact of deflation and inflation on the real interest rate of GBs, using an overlapping generations model with the relationship between the real interest rate of GBs and the fiscal consolidation rule. Our key findings are summarized as follows. Deflation may lower the real interest rate of GBs to the same level of public debt to capital, even if the fiscal consolidation rule is same, as opposed to the conventional view that the real interest rate of GBs is determined independent of deflation if the classical

dichotomy equation holds. Our results are consistent with how the real interest rate of Japanese GBs reacts in situations of deflation.

This paper also addresses the impact of fiscal inflation (i.e., monetizing all parts of the GB's default using monetary policy). We calculate the expected fiscal inflation when the default rate in the event of fiscal consolidation is raised. The fiscal inflation may be high if the extent of the required tax increase in fiscal consolidation is low.

Our model is highly stylized and highlights certain issues that should be examined in future research. These issues include (1) the search for the "actual" threshold of regime change and the limitation of using the public debt-to-GDP ratio in the Japanese economy, (2) the effect on our model of the financial crisis, especially the bank runs (Diamond & Dybvig 1983; Diamond & Rajan 2001; Allen & Gale 1998; Uhlig 2010) caused by the default of GBs, and (3) the analysis of the threshold of regime change and the limitation of the public debt-to-GDP ratio in an open economy.

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## Notes

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1) If the labor market is in full employment,  $l_t=1$ .

2) In (4.2), we abstract idiosyncratic risk including the bankruptcy of the private capital. This presumes that the household can fully diversify such risk and that only the aggregate shock remains.

3) In this paper, we assume that although monetary policy determines price level, it passively follows active fiscal policy.

4) In the case, we obtain  $\tilde{P}_{t+1}c_{t+1}^0=q_t P_t s_t R_{t+1}+(1-q_t)\tilde{P}_{t+1}s_t\tilde{r}_{t+1}$  from (4.2).

5) We consider only a single period bond in order to abstract issues of bond maturity composition.

6) However, return on private capital remains positive with the revenue maximizing tax rate being bounded by less than 100%.

7) Note that with fiscal inflation

$$\begin{aligned}\frac{\tilde{P}_{t+1}}{P_t} &= \frac{P_{t+1}}{P_t}(1+\Delta\tilde{\pi}_{t+1}) = (1+\pi_{t+1})(1+\Delta\tilde{\pi}_{t+1}) \\ &= \left(1-\frac{\pi_{t+1}}{1+\pi_{t+1}}\right)^{-1}(1-\zeta_{t+1})^{-1}.\end{aligned}$$

8) The real interest rate of GBs is calculated from the nominal interest rate of GBs ( $R_{t+1}^*$ ) and price dynamics ( $\pi_{t+1}$ ).

9) In this paper, although one period in our model is 30years, we assume that fiscal inflation finishes after three years. Therefore, the expected fiscal inflation in Figures 6 and 7 are calculated as  $(E_t[1+\Delta\pi_{t+1}])^{1/3}-1$ .

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