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Fiscal Policy in an Estimated DSGE Model of the Japanese Economy: Do Non-Ricardian Households Explain All?

Yasuharu Iwata

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Economic and Social Research Institute
Cabinet Office
Tokyo, Japan

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Abstract

This paper studies how the fiscal authority's financing behavior affects dynamic responses to a government spending shock using an estimated medium-scale dynamic stochastic general equilibrium (DSGE) model of the Japanese economy. The estimated model successfully delivers a positive consumption response regardless of its low share of non-Ricardian households. It points to the importance of the tax rule combination in determining fiscal policy effectiveness, which has been largely omitted in the literature. By conducting some policy experiments, I find that fiscal policy becomes more effective if its finance is allocated lightly on labor-dampening taxes. I also show that a choice of tax rule combination can actually dominate the non-Ricardian share in its effect on fiscal multipliers.

JEL classification: E32, E62.

Keywords: DSGE modeling, fiscal policy, Bayesian estimation, Japanese economy.

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*The Economic and Social Research Institute, Cabinet Office, Government of Japan. E-mail: yasuharu.iwata@cao.go.jp.
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1 Introduction

This paper studies how the fiscal authority's financing behavior affects dynamic responses to a government spending shock using an estimated medium-scale dynamic stochastic general equilibrium (DSGE) model of the Japanese economy. It is well known that an increase in government spending causes a negative wealth effect on intertemporally optimizing households in a dynamic general equilibrium framework, since the increase needs to be financed through future taxation in the end. Accordingly, the macroeconomic effects of a government spending shock in DSGE models crucially depend on how it is financed. The existing literature, however, does not sufficiently explore the consequences under alternative taxing schemes, and relies much on the inclusion of non-Ricardian households to generate a positive response of consumption. By estimating the non-Ricardian household share and tax policy feedback rules of Japan, and by conducting some policy experiments, I found that tax rule combination is an important determinant of fiscal policy effectiveness in Japan; it can be even more important than the non-Ricardian share. To my best knowledge, this is the first paper that estimates a medium-scale DSGE model of the Japanese economy detailed in fiscal policy and also the first that addresses the relationship between tax feedback rules and fiscal policy effectiveness in an estimated DSGE model.

Empirical studies using a standard VAR approach tend to find that private consumption rises after a government spending shock (e.g., see Fatás and Mihov (2001), Blanchard and Perotti (2002), and Perotti (2007)).[1] On the theoretical side, however, a government spending shock is considered to generate a negative wealth effect, which induces households to increase the labor supply and to decrease consumption in a general equilibrium framework, where all households are forward-looking (See Aiyagari et al. (1992) and Baxter and King (1993)[2]). Therefore recently developing DSGE studies on the macroeconomic effects of fiscal policy focus mainly on obtaining the crowding-in effect on consumption in initial periods aiming

[1] On the other hand, studies in the "narrative identification approach" find a fall in consumption following a government spending shock. See, for example, Ramey and Shapiro (1998) and Romer and Romer (2007).

[2] Their analyses are both based on neoclassical models. Linnemann and Schabert (2003) examine fiscal policy effect in a simple New Keynesian DSGE model and find a decisive role for monetary policy. A recent study by Cogan et al. (2009) compares government spending multipliers (defined as the percentage change in output from a *permanent* increase in government spending equal to a one percent of output) in an estimated medium-scale New Keynesian DSGE model with those in an old Keynesian model. They conclude that the multipliers are much smaller in New Keynesian models than in old Keynesian models, mainly due to the assumption of rational expectations. They also show that assumptions about monetary policy considerably affect the magnitude of the multipliers.

at solving this seeming conflict between empirical evidence and the predictions of the model.

Nowadays the most popular way to generate a positive response of consumption is to assume the existence of "rule of thumb" consumers, which is advocated by Campbell and Mankiw (1989) and Mankiw (2000). The rule of thumb consumers, or non-Ricardian households, are usually assumed as liquidity constrained and hence cannot smooth consumption intertemporally[3]. Galí et al. (2007) first introduce the non-Ricardian households to a simple DSGE model and show that it is possible to have the crowding-in effect on consumption in a model with sticky prices, deficit financing, and sufficient share of non-Ricardian households. In these days, non-Ricardian households can be seen in almost every leading DSGE models at policy institutions, such as the Federal Reserve Board's SIGMA, the European Central Bank's New Area-Wide Model (NAWM)[4], the European Commission's QUEST III, and the IMF's newly developed Global Integrated Monetary and Fiscal Model (GIMF).

However, attributing the main cause of fiscal policy effectiveness to sufficient share of non-Ricardian households does not seem to apply well to the Japanese economy. Existing empirical studies on non-Ricardian share do not suggest it is particularly high in Japan[5]. Hatano (2004) reports that Japan's non-Ricardian share stays in the range of 0.2-0.3 throughout the 1980s and the 1990s, applying a Kalman filter technique[6]. On the other hand, a thorough survey on the effectiveness of fiscal policy by Mahfouz et al. (2002) reviews the simulation results of existing macroeconometric models and indicates that fiscal multipliers are larger for Japan than in the United States and European economies.

It has also been recognized that the introduction of non-Ricardian households to a DSGE model by itself is not sufficient to obtain the desired results. It requires an unrealistically high share of non-Ricardian households and a high degree of price stickiness, and an almost counterfactual large increase

[3] For this reason, they are also called as "liquidity-constrained," "hand-to-mouth," and "spenders," interchangably. I call them "non-Ricardian" throughout this paper.

[4] The recently published estimated version of the NAWM (Christoffel et al. (2008)) is simpler in structure than its calibrated version, and does not assume the existence of non-Ricardian households.

[5] The original work by Campbell and Mankiw (1989) estimates the non-Ricardian share of Japan as 0.553 for the period 1959-86, which is higher than their estimate of the U.S., but lower than those of France and Germany. Jappelli and Pagano (1989) estimate it as 0.34-0.52 for the period 1971-83, which is higher than their estimate of the U.S., but lower than those of Italy and Spain.

[6] The non-Ricardian share in Japan is considered higher in the 1970s. Hatano (2004) reports that the non-Ricardian share of Japan rises in the mid-70s to as high as 0.514. Ogawa (1990) is the first paper to adopt a Kalman filter technique to estimate Japan's non-Ricardian share. It reports that the share stays in the range of 0.4-0.5 in the first half of the 80s after a sharp rise starting in 1978.

in real wages to generate the crowding-in effect[7]. Recently several theoretical contributions have been made that seek to fix these problems. Introducing wage stickiness, Colciago (2007) and Furlanetto (2007) both independently show that it is possible to have a positive consumption response with the help of a moderate increase in interest rates while avoiding a large wage increase. Furlanetto and Seneca (2009) introduce habit persistency and some other real rigidities and succeed in reproducing the same consumption multiplier as Galí et al. (2007) with much lower non-Ricardian share and lower price stickiness[8].

The basic question that I address in this paper is whether a standard medium-scale DSGE model, which is rich in both nominal and real rigidities, can account for the seemingly contradictive observation regarding fiscal multipliers and non-Ricardian share in Japan. For that purpose, I introduce non-Ricardian households and three distortionary tax rules to the canonical medium-scale DSGE model of Smets and Wouters (2003) and estimate it utilizing quarterly fiscal data of Japan. As noted above, dynamic responses to a government spending shock in general equilibrium models are considerably affected by the fiscal authority's offsetting financing behavior. Therefore proper identification of tax rules that reflect actual financing behavior is extremely important to compute fiscal multipliers. From this perspective, quantitative fiscal policy analysis should be carried out in a model with distortionary taxation, which is the major financing instrument in the real world. Modeling and estimating the financing behavior are also important from an empirical point of view, as Braun (1994) and McGrattan (1994) have examined in real business cycle models.

Note that introduction of distortionary taxation to a model reduces the households' incentives to work and invest, and creates larger negative effects on output after a government spending shock compared with those created by lump-sum taxation. Baxter and King (1993) study the case in which an increase in

[7] In fact, Coenen and Straub (2005), which introduce non-Ricardian households to the medium-scale DSGE model of Smets and Wouters (2003), conclude that the estimated share of the non-Ricardian households in the euro area is not sufficiently large to deliver a positive response of consumption.

[8] Linnemann (2006) finds that habit perisitency contributes to a stronger positive response of consumption using a model with a non-additively separable utility function. The nonseparable utility function model allows consumption and labor to move in the same direction and hence can generate the crowding-in effect in DSGE models. See also López-Salido and Rabanal (2006) and Monacelli and Perotti (2008). Bilbiie (2006) discusses the necessary and sufficient conditions to get the desired results in this class of models. There have been other attempts to allow government spending to enter either in production function or utility function. See Kamps (2004), Linnemann and Schabert (2006), and Bouakez and Rebei (2007). Ravn et al. (2006) introduce "deep habit" formulation to the household's preference, in which habits are formed over individual varieties of goods.

government spending leads to output decline if the spending is financed through distortionary taxation in an economy without debt, whereas output rises if it is financed by lump-sum taxation. I also intend to add to the literature by confirming and extending their finding that the effects of government spending crucially depend on the fiscal authority's financing behavior. This point has been recently revisited by Leeper and Yang (2008) in the context of "dynamic scoring" literature. They show how the expansionary effects of a tax cut change under alternative financing schemes in a simple neoclassical model. Although their study focuses on assessing the revenue cost of tax changes, its analytical approach shares much with this paper.

Once we introduce distortionary taxes, delaying taxation through deficit finance affects time paths of economic variables, such as consumption, labor, investment, and output. In addition, if we consider multiple tax rules, financing allocation across tax instruments also affects the time paths of economic variables. Some early works based on neoclassical models are worth mentioning. Trostel (1993) examines an allocative effect of deficit financed fiscal policy, and shows that the longer the delay in taxation, the greater the initial increase in economic variables, although the larger the decrease after the taxation, since the debt to be repaid becomes larger. Ludvigson (1996) finds that a purely deficit-financed government spending increases labor and output especially when the labor supply is elastic, whereas tax-financed spending leads to decreases in these. Jones (2002) shows that labor income taxation decreases labor hours and output more than capital income taxation does in a model without debt.

There has been not much work that addresses the relationship between distortionary taxes and fiscal policy effectiveness in the context of DSGE models. Bilbiie and Straub (2004) stress the importance of analyzing distortionary taxation in DSGE models, arguing that a lump-sum tax is just unrealistic. They show that it is more difficult to obtain a positive response of consumption after a government spending shock under distortionary taxation, which lowers after-tax wages. On the other hand, Linnemann (2004) shows that it is possible to have the crowding-in effect even in the presence of distortionary taxation, with the help of elastic labor supply and under the premise that unemployment benefits help to widen the tax base. It should be noted that both studies find a critical role in labor supply, which is in line with the findings of Ludvigson (1996) and Jones (2002). This is hardly surprising because fiscal policy effects in general equilibrium models are basically obtained through labor hour increases, as addressed in Aiyagari et al. (1992) and Baxter and King (1993).

A recent study by Forni et al. (2009) (FMS, hereafter) is the first and only attempt so far to examine the effects of fiscal policy in an estimated medium-scale DSGE model augmented with non-Ricardian households and multiple distortionary tax rules. The model is estimated by applying Bayesian estimation technique, and by utilizing fiscal data of the euro area. In this regard, FMS's study is the most relevant work to this paper, although their interest is mainly centered on the role of the estimated value of non-Ricardian share. After the success of Smets and Wouters (2003), the Bayesian estimation technique has become the standard tool for the quantitative evaluation of DSGE models. Coenen and Straub (2005), López-Salido and Rabanal (2006), and Ratto et al. (2009) apply the technique to estimate the non-Ricardian share with a view toward quantitative assessment of fiscal policy effectiveness[9]. As for the application to the Japanese economy, studies on Bayesian estimation of DSGE models are growing, but almost no attention has been paid to its fiscal aspects (See e.g., Iiboshi et al. (2008), Sugo and Ueda (2008), Fujiwara et al. (2008), and Ichiue et al. (2008)). Moreover, no study has been done yet that estimates non-Ricardian share in a DSGE framework.

In this paper I contribute to the debate on fiscal policy effectiveness by estimating a medium-scale DSGE model detailed in fiscal policy for the Japanese economy. The results are largely consistent with those of previous studies. The estimated non-Ricardian household share is relatively low. The model exhibits rather strong positive responses to a government spending shock, successfully delivering the crowding-in effect on consumption in initial periods. This paper then explores the causes of the fiscal policy effectiveness in addition to the estimated non-Ricardian share. Simulating the model under various tax rule combinations, it is shown that initial output increases after a government spending shock become greater if its finance is allocated lightly on consumption and labor income taxes, which dampen labor hour increases after the shock. The paper also shows that a choice of tax rule combination can actually dominate the non-Ricardian share in its effect on fiscal multipliers. I believe that this paper sheds light on the importance of proper modeling of the government's financing behavior to assess the quantitative effects of fiscal policy.

The remainder of this paper is organized as follows. In the next section, I set out the model in detail. Section 3 presents the estimation results. Section 4 reports the results of the simulations under alternative tax rule combinations. Section 5 offers some conclusions and suggests a few directions for future research.

[9] Bilbiie et al. (2008) estimate non-Ricardian share of the U.S. in a simple DSGE model applying the minimum-distance strategy.

2 The Model

The model is an extended variant of the medium-scale estimated DSGE model developed by Smets and Wouters (2003). The Smets and Wouters (2003) model features various real and nominal rigidities: habit formation, investment adjustment cost, variable capital utilization, sticky price and wage á la Calvo (1983), and indexation in prices and wages. Coenen and Straub (2005) also introduce non-Ricardian households and distortionary taxes to the Smets and Wouters (2003) model, but they model distortionary taxes in a time-invariant manner and the model is estimated without using fiscal data. Therefore their model essentially captures the dynamics of the hypothetical lump-sum tax only. Below I introduce three distortionary taxes (consumption, labor and capital income taxes) and feedback policy rules for each, in addition to the non-Ricardian households. I also introduce a feedback rule for a government spending. I believe that these settings contribute to the proper identification of the fiscal authority's behavior with the help of fiscal data in estimation.

2.1 Households

There is a continuum of households indexed by $n \in [0, 1]$. A fraction $1-\omega$ of this continuum of households indexed by $i \in [0, 1-\omega)$ has access to financial markets and acts *Ricardian*, i.e., the households maximize their lifetime utilities by choosing consumption, investment, financial assets in the form of government bonds, capital stock, and utilization rate of capital stock. The remaining households, indexed by $j \in [1-\omega, 1]$ do not have access to financial markets and simply consume all of their current disposable income. The latter households are dubbed *non-Ricardian*. Modeling these two extremely different households in their time horizon is rather ad-hoc but it is considered parsimonious, since the model has been proven to provide a better description of aggregate consumption behavior (See Mankiw (2000) and Galí et al. (2007)). Recall that the international evidence reported in the original work by Campbell and Mankiw (1989) includes that from Japan.

2.1.1 Ricardian households

Each member of Ricardian households i maximizes its lifetime utility by choosing consumption $C_t^R(i)$, investment $I_t(i)$, government bonds $B_t(i)$, next period's capital stock $K_t(i)$, and intensity of the capital stock utilization $z_t(i)$, given the following lifetime utility function that is additively separable between consumption and labor:

$$E_t \sum_{t=0}^{\infty} \beta^t \varepsilon_t^b \left(\frac{1}{1-\sigma_c} \left(C_t^R(i) - hC_{t-1}^R \right)^{1-\sigma_c} - \frac{\varepsilon_t^l}{1+\sigma_l} L_t^R(i)^{1+\sigma_l} \right),$$

where, β is the discount factor, σ_c denotes the inverse of of the intertemporal elasticity of substitution and σ_l is the inverse of the elasticity of work effort with respect to real wages. $L_t^R(i)$ represents the labor supply of the Ricardian household i. h measures the degree of habit formation in consumption. C_{t-1}^R is lagged aggregate per capita Ricardian consumption. Two serially correlated shocks, a preference shock ε_t^b and a labor supply shock ε_t^l are considered and are assumed to follow a first-order autoregressive process with an i.i.d.-normal error term: $\varepsilon_t^b = \rho_b \varepsilon_{t-1}^b + \eta_t^b$ and $\varepsilon_t^l = \rho_l \varepsilon_{t-1}^l + \eta_t^l$.

The Ricardian household faces a flow budget constraint (expressed in real terms):

$$\begin{aligned} &(1+\tau_t^c)C_t^R(i) + I_t(i) + \Psi(z_t(i))K_{t-1}(i) + \frac{B_t(i)}{R_t P_t} \\ &= (1-\tau_t^d)w_t(i)L_t^R(i) + (1-\tau_t^k)r_t^k z_t(i)K_{t-1}(i) + (1-\tau_t^k)\frac{D_t(i)}{P_t} + \frac{B_{t-1}(i)}{P_t}, \end{aligned} \tag{1}$$

where $\Psi(z_t(i))$ is the cost associated with variations in the degree of capital utilization $z_t(i)$. τ_t^c, τ_t^d, τ_t^k denote consumption, labor and capital income tax rates, respectively. $D_t(i)$ denotes dividends distributed by firms to the Ricardian household i. P_t is aggregate price level, R_t is riskless return on government bonds, $w_t(i)$ is real wage income, and r_t^k is real rental rate of capital. Notice that capital stock and government bonds of the current period are denoted here as $K_{t-1}(i)$ and $B_{t-1}(i)$ meaning that their decisions are made at time $t-1$. For simplicity, I assume that a consumption tax is levied on private consumption expenditure alone, following Coenen and Straub (2005). A lump-sum tax or transfer is omitted since my interest focuses on examining the role of distortionary tax rule combination in fiscal policy effectiveness.

The physical capital accumulation law for the Ricardian household is expressed as:

$$K_t(i) = (1-\delta)K_{t-1}(i) + \left[1 - S\left(\frac{\varepsilon_t^i I_t(i)}{I_{t-1}(i)}\right)\right] I_t(i), \tag{2}$$

where δ is the depreciation rate, $S(\cdot)$ represents the adjustment cost function in investment. ε_t^i is a shock to investment cost function and is assumed to follow a first-order autoregressive process with an i.i.d.-normal error term: $\varepsilon_t^i = \rho_i \varepsilon_{t-1}^i + \eta_t^i$. Following Smets and Wouters (2003), I assume the capital utilization rate in steady state as $\bar{z} = 1$, and the corresponding cost as $\Psi(\bar{z}) = 0$. Moreover, the investment adjustment cost function is assumed to satisfy $S(1) = S^{'}(1) = 0$.

Letting Λ_t and $\Lambda_t Q_t$ denote the Lagrange multipliers, the first-order conditions with respect to $C_t^R(i)$, $B_t(i)$, $I_t(i)$, $K_t(i)$, and $z_t(i)$ are expressed as follows:

$$(1+\tau_t^c)\Lambda_t = \varepsilon_t^b \left(C_t^R(i) - hC_{t-1}^R\right)^{-\sigma_c}, \tag{3}$$

$$\beta R_t E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t}\frac{P_t}{P_{t+1}}\right] = 1, \tag{4}$$

$$\begin{aligned} & Q_t \left[1 - S\left(\frac{\varepsilon_t^i I_t(i)}{I_{t-1}(i)}\right)\right] - Q_t S^{'}\left(\frac{\varepsilon_t^i I_t(i)}{I_{t-1}(i)}\right)\frac{\varepsilon_t^i}{I_{t-1}(i)} I_t(i) \\ = \; & -\beta E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t} Q_{t+1} S^{'}\left(\frac{\varepsilon_{t+1}^i I_{t+1}(i)}{I_t(i)}\right)\frac{\varepsilon_{t+1}^i I_{t+1}(i)}{I_t(i)^2} I_{t+1}(i)\right] + 1, \end{aligned} \tag{5}$$

$$Q_t = \beta E_t \left[\frac{\Lambda_{t+1}}{\Lambda_t}\left((1-\delta)\, Q_{t+1} + (1-\tau_{t+1}^k) r_{t+1}^k z_{t+1}(i) - \Psi(z_{t+1}(i))\right)\right] + \eta_t^q, \tag{6}$$

$$\left(1-\tau_t^k\right) r_t^k = \Psi^{'}(z_t(i)). \tag{7}$$

Here, Q_t represents the shadow price of additional unit of capital. Letting an over-bar denote a steady-state value, it can be shown that $1/\beta = \bar{R} = 1 - \delta + \left(1 - \bar{\tau}^k\right)\bar{r}^k + \delta\bar{\tau}^k$ and $\bar{Q} = 1$.

2.1.2 Non-Ricardian households

Non-Ricardian households are modeled as non-optimizing agents following the original assumption in Campbell and Mankiw (1989) and Galí et al. (2007). Since the members of non-Ricardian households j do not have access to financial markets, they simply consume all of their after-tax disposable income. Denoting consumption and labor input of non-Ricardian households as $C_t^{NR}(j)$ and $L_t^{NR}(j)$, the period-by-period budget constraint they face is given by (expressed in real terms):

$$(1+\tau_t^c)C_t^{NR}(j) = (1-\tau_t^d) w_t(j) L_t^{NR}(j). \tag{8}$$

2.1.3 Wage setting

Following Erceg et al. (2006), FMS, and essentially Coenen and Straub (2005), I assume that the members of Ricardian households act as wage setters for their differentiated labor services $L_t^R(i)$ in monopolistically competitive markets. The nominal wages for differentiated labor services $W_t^R(i)$ are determined by staggered contracts á la Calvo (1983). On the other hand, the members of non-Ricardian households are assumed to set their wages $W_t^{NR}(j)$ for their differentiated labor services $L_t^{NR}(j)$ to be equal to the average wage of Ricardian households. Because all households face the same labor demand schedule, both wages and labor hours will be equal for every household, i.e., $W_t^R(i) = W_t^{NR}(j) = W_t(n)$ and $L_t^R(i) = L_t^{NR}(j) = L_t(n)$. Notice that this assumption implies that labor hour response to a government spending shock in this economy is the same as those in an economy in which all households are Ricardian.

An independent and perfectly competitive employment agency bundles differentiated labor $L_t(n)$ into a single type of effective labor input L_t using the following technology:

$$L_t = \left[\int_0^1 L_t(n)^{\frac{1}{1+\lambda_{w,t}}} dn\right]^{1+\lambda_{w,t}},$$

where an i.i.d.-normal shock η_t^w is assumed for the wage markup $\lambda_{w,t} = \lambda_w + \eta_t^w$. The employment agency solves:

$$\max_{L_t(n)} W_t \left[\int_0^1 L_t(n)^{\frac{1}{1+\lambda_{w,t}}} dn\right]^{1+\lambda_{w,t}} - \int_0^1 W_t(n) L_t(n) dn,$$

where $W_t \equiv w_t P_t$ is aggregate nominal wage index. The labor demand schedule for each differentiated labor service is then expressed as:

$$L_t(n) = \left(\frac{W_t(n)}{W_t}\right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t.$$

Putting the labor demand to the bundler technology of the employment agency gives:

$$W_t = \left[\int_0^1 W_t(n)^{-\frac{1}{\lambda_{w,t}}} dn\right]^{-\lambda_{w,t}}.$$

With probability $1 - \xi_w$, each Ricardian household i is assumed to be allowed to reset its wage optimally, unless otherwise it adjusts its wage partially according to the following indexation scheme:

$$W_t^R(i) = \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma_w} W_{t-1}^R(i),$$

where γ_w measures the degree of indexation. The Ricardian household i, which is allowed to optimally reset its wage, is assumed to maximize its lifetime utility taking aggregate nominal wage W_t and effective labor L_t as given. Since the household knows the probability ξ_w^s that the wage it chooses in this period will still be in effect s periods in the future, the optimal wage $W_t^{R*}(i)$ is given by:

$$W_t^{R*}(i) \equiv \arg\max_{W^*(i)} E_t \sum_{s=0}^{\infty} (\beta\xi_w)^s \left[\frac{1}{1-\sigma_c} \left(C_{t+s}^R(i) - hC_{t+s-1}^R \right)^{1-\sigma_c} - \frac{\varepsilon_t^l}{1+\sigma_l} \left(\left(\frac{W_t^{R*}(i)}{W_{t+s}} \right)^{-\frac{1+\lambda_{w,t+s}}{\lambda_{w,t+s}}} L_{t+s} \right)^{1+\sigma_l} \right],$$

subject to

$$(1+\tau_{t+s}^c) C_{t+s}^R(i) + I_{t+s}(i) + \Psi(z_{t+s}(i)) K_{t+s-1}(i) + \frac{B_{t+s}(i)}{R_{t+s} P_{t+s}}$$

$$= (1-\tau_{t+s}^d) \frac{W_t^{R*}(i)}{P_{t+s}} \left(\frac{W_t^{R*}(i)}{W_{t+s}} \right)^{-\frac{1+\lambda_{w,t+s}}{\lambda_{w,t+s}}} L_{t+s} + (1-\tau_{t+s}^k) r_{t+s}^k z_{t+s}(i) K_{t+s-1}(i) + (1-\tau_{t+s}^k) \frac{D_{t+s}(i)}{P_{t+s}} + \frac{B_{t+s-1}(i)}{P_{t+s}}.$$

Since we know that $W_t^R(i) = W_t^{NR}(j) = W_t(n)$, aggregate nominal wage law of motion is then expressed as:

$$W_t = \left[(1-\xi_w) \left(W_t^*(n) \right)^{-\frac{1}{\lambda_{w,t}}} + \xi_w \left(\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} W_{t-1}(n) \right)^{-\frac{1}{\lambda_{w,t}}} \right]^{-\lambda_{w,t}}, \tag{9}$$

where $W_t^*(n) = W_t^{R*}(i)$.

2.2 Firms

There are two types of firms: perfectly competitive final-good firms and monopolistically competitive intermediate-good firms indexed by $f \in [0,1]$. The final-good firm produces the good Y_t combining the differentiated intermediate goods $y_t(f)$ produced by the firm f.

2.2.1 Final-good firms

The final-good producing firm combines intermediate goods using the following bundler technology:

$$Y_t = \left[\int_0^1 y_t(f)^{\frac{1}{1+\lambda_{p,t}}} df \right]^{1+\lambda_{p,t}},$$

where an i.i.d.-normal shock η_t^p is assumed for the price markup $\lambda_{p,t} = \lambda_p + \eta_t^p$. The final-good firm solves:

$$\max_{y(f)} P_t \left[\int_0^1 y_t(f)^{\frac{1}{1+\lambda_{p,t}}} df \right]^{1+\lambda_{p,t}} - \int_0^1 p_t(f) y_t(f) df,$$

where $p_t(f)$ is the price of the intermediate good $y_t(f)$. Then, the demand function for the intermediate good is expressed as:

$$y_t(f) = \left(\frac{p_t(f)}{P_t} \right)^{-\frac{1+\lambda_{p,t}}{\lambda_{p,t}}} Y_t.$$

Putting this demand to the bundler technology of the final-good firm gives a pricing rule:

$$P_t = \left[\int_0^1 p_t(f)^{-\frac{1}{\lambda_{p,t}}} df \right]^{-\lambda_{p,t}}.$$

2.2.2 Intermediate-good firms

Each intermediate-good firm f produces its differentiated output using an increasing-returns-to-scale Cobb-Douglas technology:

$$y_t(f) = \varepsilon_t^a \tilde{k}_{t-1}(f)^\alpha l_t(f)^{1-\alpha} - \Phi,$$

where $\tilde{k}_{t-1}(f)$ is the effective capital stock at time t given by $\tilde{k}_{t-1}(f) = z_t k_{t-1}(f)$. $l_t(f)$ is the effective labor input bundled by the employment agency, and Φ represents a fixed cost. ε_t^a is a technology shock assumed to follow a first-order autoregressive process with an i.i.d.-normal error term: $\varepsilon_t^a = \rho_a \varepsilon_{t-1}^a + \eta_t^a$.

Taking the real rental cost of capital r_t^k and aggregate real wage w_t as given, cost minimization subject to the production technology yields marginal cost and labor demand:

$$mc_t = \frac{w_t^{1-\alpha} \left(r_t^k \right)^\alpha}{\varepsilon_t^a \alpha^\alpha (1-\alpha)^{1-\alpha}}, \tag{10}$$

$$\frac{w_t}{r_t^k} = \frac{1-\alpha}{\alpha} \frac{z_t k_{t-1}(f)}{l_t(f)}.$$

The latter immediately gives the labor demand function at the aggregate level:

$$L_t = \frac{1-\alpha}{\alpha} \frac{r_t^k}{w_t} z_t K_{t-1}. \tag{11}$$

Nominal profits $d_t(f)$ for the intermediate-good firm are given by:

$$d_t(f) = p_t(f) y_t(f) - P_t mc_t (y_t(f) + \Phi),$$

which are distributed to Ricardian households as dividends. Aggregation gives:

$$D_t = P_t Y_t - P_t mc_t (Y_t + \Phi). \tag{12}$$

2.2.3 Price setting

As in the case of wage setting, I assume sluggish price adjustment due to the staggered price contracts á la Calvo (1983). A fraction $1-\xi_p$ of intermediate-good firms can re-optimize their prices, unless otherwise they follow the price indexation scheme:

$$p_t(f) = \left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma_p} p_{t-1}(f),$$

where γ_p measures the degree of indexation.

An intermediate-good firm f, which is allowed to re-optimize, knows the probability ξ_w^s that the price it chooses in this period will still be in effect s periods in the future. Taking aggregate nominal price index P_t and output Y_t as given, the optimal price $p_t^*(f)$ is chosen as:

$$p_t^*(f) \equiv \arg\max_{p^*(f)} E_t \sum_{s=0}^{\infty} (\beta\xi_p)^s \left[(p_t^*(f) - P_{t+s} mc_{t+s}) \left(\frac{p_t^*(f)}{P_{t+s}}\right)^{-\frac{1+\lambda_{p,t+s}}{\lambda_{p,t+s}}} Y_{t+s} - P_{t+s} mc_{t+s} \Phi \right].$$

Aggregate price law of motion is then expressed as:

$$P_t = \left[\left(1-\xi_p\right) \left(p_t^*(f)\right)^{-\frac{1}{\lambda_{p,t}}} + \xi_p \left(\left(\frac{P_{t-1}}{P_{t-2}}\right)^{\gamma_p} p_{t-1}(f) \right)^{-\frac{1}{\lambda_{p,t}}} \right]^{-\lambda_{p,t}}. \tag{13}$$

2.3 Fiscal and Monetary Authorities

2.3.1 Fiscal policy

The fiscal authority purchases final goods G_t, issues bonds B_t, and levies a consumption tax, a labor income tax, and a capital income tax at rates τ_t^c, τ_t^d, and τ_t^k, respectively. The real flow budget constraint for the fiscal authority is expressed as follows:

$$G_t + \frac{B_{t-1}}{P_t} = \tau_t^c C_t + \tau_t^d w_t L_t + \tau_t^k r_t^k z_t K_{t-1} + \tau_t^k \frac{D_t}{P_t} + \frac{1}{R_t}\frac{B_t}{P_t}. \tag{14}$$

Notice that the budget constraint itself is a fiscal rule. Since we have five fiscal policy instruments τ_t^c, τ_t^d, τ_t^k, G_t, and B_t, we need as many as four fiscal rules other than the budget constraint[10]. Although

[10] If we consider only one type of tax, fiscal rules are to be formulated for the tax and government spending other than the budget constraint. See, for example, Bilbiie and Straub (2004) and Galí et al. (2007). Although Coenen and Straub

little consensus exists in the literature on the formulation of fiscal rules, the rules in practice are typically designed to guarantee fiscal solvency in the model. Imposing feedback from government debt to taxes is quite popular in medium-scale DSGE models, especially in those at policy institutions such as SIGMA, NAWM, and QUEST III. Here, I consider three feedback rules for each tax and a government spending rule in log-linearized form following FMS. The tax rates[11] are supposed to positively respond to a debt-to-output ratio[12]:

$$\hat{\tau}_t^c = \rho_{tc}\hat{\tau}_{t-1}^c + (1-\rho_{tc})\,\phi_{tcb}(\hat{b}_{t-1} - \hat{Y}_{t-1}) + \eta_t^{tc}, \tag{15}$$

$$\hat{\tau}_t^d = \rho_{td}\hat{\tau}_{t-1}^d + (1-\rho_{td})\,\phi_{tdb}(\hat{b}_{t-1} - \hat{Y}_{t-1}) + \eta_t^{td}, \tag{16}$$

$$\hat{\tau}_t^k = \rho_{tk}\hat{\tau}_{t-1}^k + (1-\rho_{tk})\,\phi_{tkb}(\hat{b}_{t-1} - \hat{Y}_{t-1}) + \eta_t^{tk}, \tag{17}$$

where the hats above variables denote log-deviations from steady state. $b_t \equiv B_t/P_t$ denotes government bonds in real terms. η_t^g, η_t^{tc}, η_t^{td}, and η_t^{tk} are i.i.d.-normal errors. It should be noted that the fiscal policy rules described here allow partial debt finance, while the debt is to be repaid through tax revenue over time. The speed of repayment is determined by a combination of the coefficients on the debt-to-output ratio of the tax rules, namely by the set of parameters ρ_{tc}, ϕ_{tcb}, ρ_{td}, ϕ_{tdb}, ρ_{tk}, and ϕ_{tkb}.

Government spending is assumed to follow a feedback rule that responds to output gap in log-linearized form:

$$\hat{G}_t = \rho_g\hat{G}_{t-1} + \left(1-\rho_g\right)\phi_{gy}\hat{Y}_{t-1} + \eta_t^g. \tag{18}$$

(2005) introduce multiple distortionary taxes to the Smets and Wouters (2003) model, the taxes are assumed to be fixed over time. Therefore fiscal policy instruments in their model are essentially three: government spending, lump-sum tax, and debt. Accordingly, their tax policy rule is formulated only for the lump-sum tax, following Galí et al. (2007).

[11] The aggregate tax rates faced by the representative agent in macroeconomics can be appropriately approximated by the aggregate effective tax rates, which are computed using macroeconomic data, such as national accounts and revenue statistics. The method for computing the effective tax rates was originally proposed by Lucas (1990), and was successfully extended by Mendoza et al. (1994).

[12] Although no formal budget rule has been legislated in Japan, fiscal consolidation has been a major priority for the government. The government is hence assumed to follow "passive fiscal policy" in the sense of Leeper (1991). Leeper and Yang (2008) also employ similar tax rules in log-linearized form for three different taxes (labor and capital income taxes, and a lump-sum tax) with positive coefficients on debt-to-output ratio.

2.3.2 Monetary policy

The monetary authority sets nominal interest rates according to a simple feedback rule in log-linearized form:

$$\hat{R}_t = \rho_r \hat{R}_{t-1} + (1-\rho_r)\,\phi_{r\pi}\hat{\pi}_{t-1} + (1-\rho_r)\,\phi_{ry}\hat{Y}_t + \eta_t^R, \tag{19}$$

where $\pi_{t-1} \equiv \log(P_{t-1}/P_{t-2})$ denotes inflation rate. An i.i.d.-normal shock η_t^R to the interest rate is assumed.

2.4 Aggregation and Market Clearing

Aggregate consumption C_t and labor hour L_t in per-capita term are given by a weighted average of the corresponding variables for each consumer type:

$$C_t = (1-\omega)C_t^R(i) + \omega C_t^{NR}(j), \tag{20}$$

$$L_t = (1-\omega)L_t^R(i) + \omega L^{NR}(j),$$

and again, since all households supply the same amount of labor by assumption, aggregate labor hour is given by:

$$L_t = L_t^R(i) = L_t^{NR}(j).$$

Because only Ricardian households have access to financial markets, aggregate government bonds B_t, investment I_t, physical capital K_t, and dividends D_t distributed by firms are expressed as:

$$B_t = (1-\omega)B_t^R(i),$$

$$I_t = (1-\omega)I_t^R(i),$$

$$K_t = (1-\omega)K_t^R(i),$$

$$D_t = (1-\omega) D_t^R(i).$$

Finally, aggregate production equation and the final-goods market equilibrium condition are given by:

$$Y_t = \varepsilon_t^a z_t {K_{t-1}}^{\alpha} {L_t}^{1-\alpha} - \Phi, \tag{21}$$

$$Y_t = C_t + I_t + G_t + \Psi(z_t) K_{t-1}. \tag{22}$$

Notice that equation (22) can be derived from the budget constraints of Ricardian households (1), non-Ricardian households (8), and the government (14). It follows that one of them is redundant.

3 Bayesian Estimation of the Model

In estimating the model parameters, I first log-linearize the model around the deterministic steady state and conduct Bayesian inference using a Markov Chain Monte Carlo (MCMC) method, which is now a standard technique in estimating DSGE models. The log-linearized form of the model is reported in Appendix B.

3.1 Preliminary Setting

The model parameters are estimated on the Japanese data for the period starting from 1980:Q1 to 1998:Q4. The end period is determined following Iiboshi et al. (2008) not to include the period during which the zero-interest-rate policy was adopted. In estimating the model, I use fiscal data on government spending (calculated as a sum of government consumption and investment) and aggregate effective tax rates on consumption and labor income, in addition to the ordinary seven series in the literature, i.e., output, private consumption, investment, labor hour, wage, inflation rate, and interest rate. The aggregate effective tax rates are calculated following the method of Mendoza et al. (1994) as FMS. In contrast with FMS, only quarterly data are utilized for the tax rate calculation, which is available from the *National Accounts of Japan* from 1980:Q1. The series of effective tax rates on capital income is also calculated. However, the obtained data series is too volatile and hence is discarded in the estimation. Appendix A gives the details of the calculation.

All the variables are detrended using the Hodrick-Prescott filter. Since the model is an extended variant of Smets and Wouters (2003) and accordingly of its application to the Japanese economy of Iiboshi et al. (2008) and Sugo and Ueda (2008), I largely follow these studies in choosing prior distributions and in fixing several parameters that are difficult to identify. Specifically, I set the capital share $\alpha = 0.3$, the discount rate $\beta = 0.99$, the depreciation rate $\delta = 0.06$, and the wage markup $\lambda_w = 0.5$. As for the steady state values, I take sample period averages except for the capital-output ratio and debt-to-output ratio, which are set $\bar{K}/\bar{Y} = 2.2$ and $\bar{B}/\bar{P}\bar{Y} = 0.6$, following Iiboshi et al. (2008) and Broda and Weinstein (2004) respectively. I set the steady state consumption-to-output ratio $\bar{C}/\bar{Y} = 0.56$ and assume $\bar{C}^R/\bar{Y} = \bar{C}^{NR}/\bar{Y} = \bar{C}/\bar{Y}$. The steady state values for government spending-to-output ratio, and consumption, labor and capital income tax rates are set $\bar{G}/\bar{Y} = 0.16$, $\bar{\tau}^c = 0.08$, $\bar{\tau}^d = 0.32$, and $\bar{\tau}^k = 0.61$, respectively. Note that I utilize the discarded data series mentioned above for the calculation of $\bar{\tau}^k$. Other steady state values, $\bar{L}/\bar{Y}$, $\bar{w}$, $\bar{r}^k$, and $\overline{mc}$ are all set to be consistent with the steady state conditions implied by the model.

3.2 Estimation Results

In conducting Bayesian MCMC estimation, I use the DYNARE software for MATLAB. The draws from the posterior distribution have been obtained by taking two parallel chains of 1,000,000 replications for Metropolis-Hastings algorithm. Tables 1-2 report prior distributions, posterior means, and 90% credible intervals (or Bayesian confidence intervals) of the parameters. Prior and posterior distributions are also shown in Figures 1-5. Most parameters are well identified, but some are not. It should be noted that parameters related to investment show poor identifiability. For that reason, I choose to calibrate the parameter for the elasticity of investment on the price of capital adjustment cost $\varsigma \equiv 1/\bar{S}''$ to the posterior mean estimate of Sugo and Ueda (2008). Nonetheless, the persistence parameter of the shock to investment cost function could not be identified.

Tables 3-4 compare the estimated mean parameter values with those of previous DSGE studies: Smets and Wouters (2003) (SW), Coenen and Straub (2005) (CS), and FMS for the euro area, Levin et al. (2006) (LOWW) for the United States, and Iiboshi et al. (2008) (INW) and Sugo and Ueda (2008) (SU) for Japan. Studies listed here except FMS are all variants of the Smets and Wouters (2003) model. Although FMS employ adjustment cost functions for sticky price and wage mechanism, FMS's other features, such as real rigidities, shocks, and functional forms share much in common with these studies listed here.

Overall, the values of posterior mean estimates are not so different from those reported in previous studies. From the viewpoint of fiscal policy effectiveness, structural parameters for non-Ricardian share, price and wage stickiness, habit persistency, and labor supply elasticity are of particular interest. Although there has been no other study that estimates non-Ricardian share in a DSGE framework for the Japanese economy, the estimated mean value of non-Ricardian share 0.25 is very much consistent with the Kalman filter estimates of Hatano (2004). Compared with other DSGE-based estimates for the euro area and the U.S. on the other hand, the value is somewhat smaller[13]. The Calvo parameter for wage stickiness is considerably higher, while that for price is considerably lower than the estimates of INW and SU. However, they are largely in line with the results of Koga and Nishizaki (2005). They estimate Japanese Calvo parameters for wage and price are in the range of 0.7-0.75 and 0.5-0.55 respectively[14], based on the method of Galí and Gertler (1999). Parameter values for habit persistency and labor supply elasticity are in between INW and SU. All in all, posterior means of structural parameters do not suggest large fiscal multipliers in this economy.

Turning to the policy parameters, the estimated response of monetary policy to inflation is weak while that to output gap is strong compared with those of INW. This may reflect the difference in the sample periods. The estimation period of INW is 1970:Q1 to 1998:Q4, while that is 1980:Q1 to 1998:Q4 in this paper. In fact, a recent study by Ichiue et al. (2008) employs the same formulation of monetary policy and reports a set of estimated mean parameter values $\rho_r = 0.85$, $\phi_{r\pi} = 1.49$, and $\phi_{ry} = 0.16$ for a sample period 1981:Q1 to 1995:Q4[15], which are close to my estimates. Regarding fiscal policy, it is indicated that government spending was neither countercyclical nor procyclical during the estimation period. Although posterior mean estimates of tax rule parameters that govern their responses to debt-to-output ratio are all positive, those of consumption and labor income tax rules are not reliably different from zero. The results suggest that capital income taxation played a central role in stabilizing the government debt in Japan during the estimation period. This is not hardly surprising, considering that the debt-to-output ratio and corporate income tax rate show largely correlated movements throughout the 1980s in Japan. Both have increased in the first half of 80s and have decreased in the second half[16], while the individual

[13] As for the euro area, Coenen and Straub (2005) report 0.246, 0.249, and 0.370 for different tax specifications. FMS report 0.37 and 0.34 for the cases with and without unions, respectively. Ratto et al. (2009) report 0.35. As regards the U.S., Bilbiie et al. (2008) estimate 0.35 and 0.51 for different sample periods.

[14] They assume a partial wage indexation scheme indexed to past aggregate wage inflation instead of general price inflation. The same specification can be seen in Erceg et al. (2006).

[15] They also report $\rho_r = 0.88$, $\phi_{r\pi} = 1.48$, and $\phi_{ry} = 0.24$ for a case in which firms are assumed to adjust labor input through employment.

[16] The co-movement reflects fiscal consolidation efforts in Japan during the 1980s. The statutory corporate tax rate was

income tax burden has increased in the 80s and has decreased in the 90s, and the indirect tax burden has largely been stable over the period. One more thing to be noted is that the estimated persistence parameters are all substantially smaller than those of FMS. This may be attributable to the difference in data sources used for the tax rate calculation, since only quarterly series are used in this paper, while FMS use some annual series and transform them into quarterly.

4 Assessing the Role of Tax Policy Rules

In this section, I first illustrate basic properties of the estimated model after a government spending shock. I then proceed to examine attributes of fiscal policy effectiveness with particular emphasis on exploring the role of tax feedback rules. To facilitate the assessment, I specify alternative tax rule combinations and conduct some simulations employing them in the estimated model. In the following analysis, all the parameters are calibrated to the estimated means of the posterior distributions for the parameters unless otherwise noted.

4.1 Responses to a Government Spending Shock

4.1.1 Impulse responses

Figures 6-7 depict selected dynamic responses to a government spending shock equal to one standard error under the estimated parameterization. All dynamic responses are shown as percentage deviations from steady state. Along with previous DSGE studies on fiscal policy effectiveness, I mainly focus on the initial responses to a government spending shock. As seen in the upper middle panel of Figure 6, the model successfully delivers the crowding-in effect on consumption. This is somewhat surprising since none of the estimated values of key structural parameters for fiscal policy effectiveness, such as non-Ricardian share, price and wage stickiness, habit persistency, and labor supply elasticity show significance to generate the crowding-in effect. In particular, the estimated share of non-Ricardian households in Japan seems to be too small to predict the crowding-in effect according to previous studies (e.g., see Coenen and Straub (2005)[17]).

Investment, which typically responds negatively to a government spending shock in a New Keynesian

raised in 1981 and 1984, and reduced in 1987, 1989, and 1990.

[17] They argue that the value of non-Ricardian share needs to exceed 0.35 to obtain the crowding-in effect in their estimated model of the euro area.

DSGE setting, also shows positive responses in initial periods. The initial responses probably reflect a relatively moderate increase in interest rates and a strong increase in labor. Recall that an increase in labor supply induced by the negative wealth effect on leisure shifts up the marginal product schedule for capital and hence increases investment in neoclassical models, while a sharp rise in interest rates drags down investment in DSGE models (e.g., see Baxter and King (1993) and Linnemann and Schabert (2003)).

As can be seen in the lower left panel of Figure 6, real wages decline after a government spending shock. This contrasts sharply with the results of Galí et al. (2007), in which a positive consumption response is obtained through a large wage increase. The high wage stickiness and distortionary taxation of the model may explain this. In general, real wage response after a government spending shock is rather complicated both theoretically and empirically. It has been known that real wages decline after a government spending shock to meet the labor supply increase in basic neoclassical models. Recent studies on DSGE models find that both price stickiness and inclusion of non-Ricardian households induce a real wage increase after a government spending shock, whereas wage stickiness and distortionary taxation reduce the wage increase[18]. The eventual reaction of the real wage is the sum of these effects. Turning to empirical studies, the response of real wage is also ambiguous as Fatás and Mihov (2001) and Blanchard and Perotti (2002) support a limited positive response while Burnside et al. (2004) support a negative response.

An increase in government spending is to be financed either through debt or through taxes, and the debt repayment needs to be financed by a split among consumption, labor and capital income taxes eventually. The upper left panel of Figure 7 confirms that fiscal solvency is guaranteed in the estimated model, although it is indicated that the debt stabilization takes a rather long time. The other three panels of Figure 7 show that three taxes all contribute to the stabilization[19] and that a capital income tax plays a central role.

The tax responses to a government spending increase in turn affect the households' decisions and accordingly the time paths of economic variables. Therefore it is also important to see the effects of a tax increase to understand the consequences after a government spending shock. Figures 8-10 portray

[18] See Linnemann and Schabert (2003), Bilbiie and Straub (2004), Colciago (2007), Galí et al. (2007), and Furlanetto (2007).

[19] This is of course due to the parameter values that are calibrated to the estimated posterior means. Notice that those of consumption and labor income taxes are not reliably positive.

the dynamic responses to tax increases of which each equals to one standard error. As can be seen in the figures, response patterns to consumption and labor income tax shocks are largely the same. By contrast, initial responses of real wages and labor hours to a capital income tax shock exhibit particular differences with those to consumption and labor income tax shocks. It also should be noted that investment shows a large decline following a capital income tax shock.

4.1.2 Fiscal multipliers

To evaluate the quantitative effects of a government spending shock, I go on to examine the traditional fiscal multipliers. Table 5 compares fiscal multipliers[20] of the model with those of other DSGE models of which multipliers are available; FMS, the ECB's NAWM (cf. Straub and Tchakarov (2007)[21]), and the QUEST III of the European Commission (cf. Ratto et al. (2009)). Since this is the first attempt to estimate a medium-scale DSGE model of the Japanese economy with a detailed role of fiscal policy, the multipliers of the Japanese government's traditional large-scale econometric model (the ESRI model, hereafter) are also reported as reference[22].

Table 5 shows that the output multiplier in the first period is larger than those of other DSGE models for the euro area, reflecting the strong increase in investment and successfully crowded-in consumption. Furthermore, the yearly averages of the multipliers are not so different from those of the ESRI model, regardless of DSGE model structure. In later periods, however, the model exhibits large decreases in consumption, investment, and, hence, in output. One possible attribute of the large swings is the allocative effect examined by Trostel (1993). If government spending is debt-financed initially, the debt repayment needs to be financed by taxes in later periods and a large decline occurs subsequently. The timing of taxation is determined by the tax rule coefficients of the model. As we have seen in the previous subsection, debt stabilization takes a rather long time, and the estimated tax rule combination resorts its main financing source to a capital income tax. Naturally, the decline in later periods is significant

[20] The multipliers are defined as the percent deviation from steady state in response to a *temporary* increase in government spending equal to a one percent of steady state output.

[21] Note that their verison of NAWM takes government consumption and investment separately, and assumes that public capital constitutes an important factor in the production function.

[22] The ESRI model is an IS-LM based quarterly model in which persistency in government spending is not assumed. See ESRI (2009) for details. Since the total amount of cumulative increase in government spending following its initial shock in the estimated model is nearly equal to that of the initial shock multiplied by four, I take the case for one year-long increase in the ESRI model as a comparable case in Table 5.

in investment. Another possible explanation is that the negative effects of taxation is large because the model considers only distortionary taxes. Burnside et al. (2004) study dynamic responses to a government spending shock in a neoclassical model without debt under two different tax schemes, in which all taxes are either lump-sum or distortionary. Their calibration exercise shows that labor hour increases are less persistent and that investment declines in later periods are larger under a distortionary tax scheme. Recall that distortionary taxation reduces the households' incentives to work and invest, and creates a larger negative effect on output after a government spending shock compared with lump-sum taxation.

4.2 Policy Experiments

4.2.1 Properties of the estimated tax rules

To examine the role of tax rules in fiscal policy effectiveness, I consider the sensitivity of fiscal multipliers to changes in tax policy parameters. I begin by comparing the simulation results under the estimated tax policy parameters with those under parameters that replicate tax rules estimated in FMS. Fixing the persistence parameters, I adjust the policy parameters ϕ_{tcb}, ϕ_{tdb}, and ϕ_{tkb} of each tax rule so that the coefficients on debt-to-output ratio become equal to those of FMS estimates for the euro area[23]. The adjusted policy parameters and the coefficients are reported in Table 6 with those of my estimates and of FMS's original estimates. The coefficients suggest that debt in Japan is mainly financed through capital income taxation while its finance in the euro area is allocated nearly evenly across three taxes.

Figure 11 illustrates the dynamic responses of output to a government spending shock equal to a one percent of steady state output under the estimated tax rules (referred to as *baseline specification*, solid line) and those under the adjusted tax rules (referred to as *FMS specification*, dotted line). The dynamic responses are depicted as percentage deviations from steady state, and hence correspond to the fiscal multipliers examined in the previous subsection. The multipliers of baseline specification are larger in initial periods than those of FMS specification, while showing more declines in later periods. Figure 12 reveals that the greater multipliers of baseline specification in initial periods can be attributable both to dynamic responses of consumption and to those of investment, which are also depicted as percentage deviations from steady state. A closer look at the patterns of output, consumption, and investment responses indicates that investment serves as a major driving force for the stronger output response of

[23] I assume that tax rates respond to the debt-to-output ratio of the previous period, while FMS assume that of the present period instead. Nonetheless, the difference does not affect the overall results of this paper.

baseline specification. Furthermore, investment seems to start recovering first and consumption seems to follow. Indeed, consumption of Ricardian households, which are by definition asset holders, supports this view, showing a similar pattern to investment as can be seen in Figure 13. The smaller decline in investment under FMS specification in later periods is probably due to its relatively weak responsiveness of a capital income tax to a debt-to-output ratio compared with baseline specification.

Before turning to further analysis on tax rule combination, it is worth addressing briefly the role of the estimated monetary policy since it generally plays a decisive role in responses after a government shock by reducing both investment and Ricardian consumption (See Linnemann and Schabert (2003) and Cogan et al. (2009)). For that purpose, I consider a reference case in which more anti-inflationary monetary policy is employed by setting $\phi_{r\pi} = 1.7$ (referred to as *anti-inflationary monetary policy case*), which seems to be a kind of consensus value for the euro area (cf. SW, CS, and FMS). Figure 13 shows that the initial decline of Ricardian consumption in the anti-inflationary monetary policy case (dash-dotted line) is bigger than that of baseline specification as expected, but it is smaller than that of FMS specification. Given that FMS specification allocates its financing source nearly evenly among three taxes, the results suggest that the rather greater fiscal multipliers of the estimated model owe much to its tax rule combination, which resorts its main financing source to capital income taxation.

I close this subsection by making some general remarks on the role of tax rules after a government spending shock. An increase in government spending needs to be financed through taxation in the end whether or not it is partially (or all) debt-financed for some time. The size of a coefficient on a debt-to-output ratio of a tax rule determines the timing of the taxation and accordingly affects the time paths of economic variables such as output, consumption, and investment after a government spending shock. Even more importantly, when analyzing an economy with multiple distortionary taxes, the relative size of the coefficient compared with those of other tax rules also affects the time paths, since different distortionary taxes differ in their disincentive effects on the households' decisions. Thus, both absolute and relative sizes of the coefficients are important to investigate the role of different tax rule combinations in fiscal policy effectiveness. To make this point clear, I consider a case in which responsiveness of each tax rule to a debt-to-output ratio is equally strong ($\phi_{tcb} = \phi_{tdb} = \phi_{tkb} = 0.2$, referred to as *specification 1* (SP1)), keeping the values of the estimated persistence parameters. The coefficients of specification 1 indicate that consumption, labor and capital income are all taxed more heavily than in the case of baseline and FMS specification for a given debt-to-output ratio. However, Figure 13 shows that the initial decline of Ricardian consumption after a government spending shock in specification 1 (dashed line) is smaller than that in FMS specification. It follows that the difference between fiscal multipliers under baseline and those under FMS specification cannot be explained only by absolute sizes of the coefficients. Therefore we will examine next how responses to a government spending shock differ by changing the relative degrees of responsiveness to the debt-to-output ratio across the tax rules.

4.2.2 Illustrative simulations under alternative tax rule combinations

We now move to an exploration of the role of tax rule combination, with an emphasis on the relative size of coefficients on the responsiveness to the debt-to-output ratio. To this end, I consider three alternative specifications, which employ different parameter values that govern the responsiveness, referring to them as *specification 2* (SP2), *specification 3* (SP3), and *specification 4* (SP4). Each resorts its main financing source to a consumption tax ($\phi_{tcb} = 0.2$, $\phi_{tdb} = \phi_{tkb} = 0.01$), a labor income tax ($\phi_{tdb} = 0.2$, $\phi_{tcb} = \phi_{tkb} = 0.01$), and a capital income tax ($\phi_{tkb} = 0.2$, $\phi_{tcb} = \phi_{tdb} = 0.01$), respectively. The policy parameters and corresponding coefficients are reported again in Table 6. Figures 14-15 portray investment and Ricardian consumption responses to a government spending shock under these specifications with those under specification 1 (solid line). The responses under specification 4 (dash-dotted line), which resorts its main financing source to capital income taxation, show similar patterns to those under baseline specification as expected, while those under specification 2 (dotted line) and specification 3 (dashed line) show similar patterns to those under FMS specification. As in the case of baseline specification, investment rises initially after a government spending shock and shows a large decline in later periods under specification 4. Again, a similar pattern of Ricardian consumption is also observed.

What is the economic rationale behind these patterns? Recall that the initial output increase after a government spending shock in a general equilibrium model is brought about by a labor hour increase and following an investment rise. An increase in government spending needs to be financed by a corresponding increase in taxation; it is inevitable to have the negative wealth effect, which decreases consumption and the leisure of Ricardian households. The decrease in leisure is the flipside of the labor hour increase. The labor hour increase induces capital accumulation to rise since it has a positive impact on the marginal product of capital, making investment more attractive. These are the basic mechanisms discussed in Aiyagari et al. (1992) and Baxter and King (1993). Beyond this, the model we have studied here considers three distortionary taxes, and each affects the households' decisions in different ways. Therefore, in the presence of multiple distortionary taxation, it is possible to affect the results by changing the allocation of government finance across the taxes. Notice that both consumption and labor income taxes have dampening effects on labor, since the labor supply schedule is related to the utility-maximizing choice between consumption and labor on an after-tax basis. Hence, tax rule combinations such as specifications 2 and 3 limit initial increases in labor after a government spending shock more than specifications 1 and 4, which in turn partly offset the investment and output rises. Thus, initial declines in Ricardian consumption are larger in specifications 2 and 3 than in specifications 1 and 4. In later periods, however, specifications 1 and 4 show larger declines in investment and subsequently in Ricardian consumption, reflecting a capital income tax increase. This interpretation accords well with the model's impulse responses to tax shocks. As we have seen in Figures 8-10, consumption and labor income tax shocks both raise real wages and decrease labor hours, whereas the capital income tax shock decreases real wages and increases labor hours in the very initial period. The result here is largely in line with Jones (2002), which finds that labor income taxation decreases labor hours and output more than capital income taxation does.

Figure 16 illustrates the labor-dampening effects of consumption and labor income taxes. As expected, labor hour increases are prevented to a larger extent in specification 2 (dotted line) and specification 3 (dashed line), rather than in specification 1 (solid line) and specification 4 (dash-dotted line). These patterns correspond to those of investment and Ricardian consumption as shown in Figures 14-15. The resulting output responses to a government spending shock is depicted in Figure 17. It shows that initial output increase becomes greater if the government finance is allocated lightly on labor-dampening taxes, such as consumption and labor income taxes. One might wonder why labor hour increases are smaller in specifications 2 and 3 than in specification 1, which assumes the same value for ϕ_{tcb} and ϕ_{tdb} as specification 2 and specification 3, respectively. The reason is that the increases in consumption and labor income taxation under specification 1 are actually less than those under specifications 2 and 3, since government finance is nearly evenly allocated across three tax instruments under specification 1.

As discussed above, the increase in labor supply is definitely the main channel of fiscal policy transmission. However, it is not clear whether the change of its elasticity increases fiscal multipliers or not in the presence of distortionary taxation. Although Baxter and King (1993) find that it is possible to have a fiscal multiplier greater than one if the labor supply is highly elastic, the analysis essentially focuses on the case of lump-sum taxation[24]. In contrast, Kamps (2004) shows that an increase in government

[24] The distortionary tax rates are held fixed and debt is not considered in the analysis. See also Aiyagari et al. (1992).

investment financed by distortionary taxes reduces labor more in later periods as the elasticity of labor becomes larger in a neoclassical model with productive public capital. As already noted by Ludvigson (1996), distortionary tax finance has two different effects on labor in the opposite direction. The disincentive effects of distortionary taxes reduce the labor supply, while the negative wealth effect increases it. Since both effects are amplified as the elasticity becomes higher, its net influence on fiscal multipliers depends on their respective magnitude. It is interesting to consider an "indivisible labor" case (in which infinite elasticity $\sigma_l = 0$ is assumed) for baseline specification (referred to as *infinitely elastic labor supply case*). Figure 18 reports the consumption and investment responses of the infinitely elastic labor supply case after a government spending shock (dotted line, and dash-dotted line, respectively) compared with those of baseline (solid line, and dashed line, respectively). The multipliers in initial periods are actually smaller in the infinitely elastic labor supply case.

Finally, I provide a brief assessment on the relative importance of non-Ricardian share and tax rule combination in determining fiscal policy effectiveness by conducting some sensitivity analyses. Table 7 reports fiscal multipliers under specification 4 with non-Ricardian shares $\omega = 0.0$, 0.1, 0.2, 0.3, and those under specifications 1-3 with $\omega = 0.3$. Interestingly, the model under specification 4 generates a positive (although small) response of consumption in the first period even in the case in which all households are Ricardian ($\omega = 0.0$). Moreover, specification 4 with $\omega = 0.1$ exhibits larger output multipliers than specifications 1-3 with $\omega = 0.3$ until the fourth period. These results lead to the conclusion that a choice of tax rule combination can alter the consequences of fiscal policy anticipated by the given non-Ricardian share.

5 Concluding Remarks

In this paper, I have made essentially two contributions: I have presented an estimated medium-scale DSGE model of the Japanese economy detailed in fiscal policy, and I have shown that tax rule combination plays a decisive role in determining fiscal policy effectiveness, which has been largely omitted in the literature. To this end, I introduced multiple distortionary tax rules and estimated them utilizing quarterly government expenditure and tax data on the Japanese economy. My main findings are as

Linnemann (2004) obtains a similar result using a DSGE model with labor income taxation, arguing that it is possible to have the crowding-in effect on consumption as long as the labor supply is sufficiently elastic. However, the result rests on its assumption of unemployment benefits, which makes government spending automatically countercyclical.

follows. First, non-Ricardian share in Japan is somewhat smaller than those in the euro area and the United States. Second, the estimated model successfully delivers the crowding-in effect on consumption regardless of its low share of non-Ricardian households. Third, fiscal policy becomes more effective if its finance is allocated lightly on labor-dampening taxes. This applies to Japan for the period 1980:Q1 to 1998:Q4. Fourth, a choice of tax rule combination can actually dominate the non-Ricardian share in its effect on fiscal multipliers. Furthermore, there may be cases that the model can generate the crowding-in effect in an economy where all households are Ricardian, depending on its choice of tax rule combination. I believe that this paper adds a new dimension to the recent debate about fiscal multipliers in New Keynesian models (e.g., see Cogan et al. (2009)).

Differently from monetary policy, there seems to be little consensus in the literature with respect to modeling fiscal policy rules. Most previous studies often abstract distortionary taxes and debt from models, or occasionally treat them as time-invariant. However, as we have confirmed, formulation of tax rules affects the magnitude of fiscal multipliers considerably. Given this, it should be stressed that proper modeling of the government's financing behavior is fairly important to assess the quantitative effects of fiscal policy. More broadly, the same applies to the modeling of the spending side. Allowing for a productive role for public capital is one possible extension (e.g., see Kamps (2004) and Linnemann and Schabert (2006)). This paper is the first step toward estimating the government behavior based on quarterly fiscal data. In future research on estimating a DSGE model of the Japanese economy, the fiscal policy rule specification may need to be further reexamined to see whether it best describes actual government behavior. Empirical evaluation of the model, such as a comparison with VAR models, is an important task I left out. It will be also necessary to explore proper procedures to obtain an appropriate capital income tax series for estimation. Another avenue worth pursuing is to consider the possibility that policy rules may change over time, since there is some indication in my result that policy parameters are sensitive to the estimation period. If that is the case, estimation techniques for models with time-varying parameters (e.g., see Fernández-Villaverde and Rubio-Ramírez (2008)) or models with Markov-switching rules (e.g., see Davig and Leeper (2007)) would be necessary. These techniques are also useful in dealing with the zero-interest-rate period of Japan (See Yano (2009))[25].

[25] See also Fujiwara (2006) for an application of a Markov-switching VAR framework to the analysis of Japanese monetary policy during the zero-interest-rate period.

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