Estimating Fiscal Multiplier in Japan using a Markov Switching DSGE model with Fiscal and Monetary Policy Regimes*

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1. Introduction

In response to the economic slowdown caused by the COVID-19 pandemic, massive fiscal policies have been implemented worldwide. However, there is no consensus, either theoretically or empirically, on their consequences. As shown in Ramey (2011), most empirical studies using aggregate data report fiscal multipliers in the range of 0.6 to 1.8, though the data do not reject values as low as 0.5 or as high as 2.0. Coenen et al. (2012) and Cogan et al. (2010) estimate standard medium-scale New Keynesian DSGE models and report opposite results, even though their models and data sets are quite similar. Leeper et al. (2017) refer to this situation as "the fiscal multiplier morass." Since governments around the world have been running persistent budget deficits over the past decade, it is difficult to make policy decisions without reliable knowledge of the effects of fiscal policy. For example, the Japanese government implemented large fiscal stimulus packages in the 1990s after the collapse of the bubble economy, yet the economy remained mired in low growth while public debt accumulated. Many governments fear repeating the consequences of Japan's fiscal policies. Nevertheless, few studies estimate fiscal multipliers in Japan using DSGE models.

In this paper, we reevaluate the effects of Japanese fiscal policy by estimating a Markov-switching DSGE (MS-DSGE) model. Leeper et al. (2017) show that the fiscal multiplier varies depending on the regime of fiscal and monetary policy. Following Bianchi (2012), we employ an MS-DSGE model in which fiscal and monetary policy regimes can switch over time. Abe, Fueki, and Kaihatsu (2019) apply the same method to the Japanese economy, but their focus is on the effects of QQE under the zero lower bound (ZLB). By contrast, this paper focuses on fiscal policy before the ZLB period (1970s–1990s). In addition to regime switching in fiscal and monetary policy, we incorporate hand-to-mouth households, as in Gali et al. (2007). Debortoli and Gali (2018) and Bilbiie (2019) show that such two-agent New Keynesian (TANK) models can approximate the implications of heterogeneous-agent New Keynesian (HANK) models regarding the effects of aggregate shocks on macroeconomic variables.

Our estimation results indicate that fiscal policy was relatively active in the late 1970s and during the bubble

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period (late 1980s), and passive in other periods. Conversely, monetary policy was relatively passive in the late 1970s and the bubble period (late 1980s to early 1990s), and active otherwise. The estimated mean of the short-run fiscal multiplier is similar across regimes (about 1.38), but differences emerge in the long run (ranging from 1.40 to 1.55). Moreover, the long-run effects on consumption differ significantly across regimes (ranging from 0.32 to 1.29).

The remainder of this paper is organized as follows. Section 2 presents the model. Section 3 reports the estimation results and simulates fiscal policy under the estimated parameters. Section 4 concludes.

2. The model

Our model is based on the medium-scale New-Keynesian DSGE model developed by Smets and Wouters (2003, 2007), which include various frictions, such as (1) habit formation in consumption, (2) investment adjustment cost (3) variable capital utilization (4) sticky price and wage. Furthermore, we introduce (5) hand-to-mouth households into the model.

2.1 Households

There is a continuum of households indexed by $i \in [0,1]$. A fraction $1-\omega$ of households are Ricardian households who decide consumption and saving in order to maximize its lifetime utility under intertemporal budget constraint and the remaining fraction ω of households are hand-to-mouth households who don't save and fully consume their current disposable income in each period. Only Ricardian households have access to financial market and choose government bond and private capital for saving. It is assumed that there is continuum of members in each households indexed over the same range and each member holds differentiated labor services.

2.1.1 Ricardian households

Suppose that the lifetime utility function of each member of a Ricardian household i is

$$E_0 \sum_{t=0}^{\infty} e^{u_t^c} \beta^t \left[\frac{(C_t^R(i) - hC_{t-1}^R(i))^{1-\theta}}{1-\theta} - \frac{e^{u_t^l} L_t^R(i)^{1+\chi}}{1+\chi} \right] \tag{1}$$

where $C_t^R(i)$ is consumption of Ricardian household i, $L_t^R(i)$ is labor supply of Ricardian household i, C_{t-1}^R is lagged aggregate consumption of Ricardian Households. β is the discount factor, θ is the inverse of intertemporal elasticity of substitution, χ is the inverse of the elasticity of work effort with respect to real wages, h is the degree of external habit formation in consumption. u_t^c and u_t^l represent a preference shock and a labor supply shock, respectively. Both shocks are assumed to follow a first-order autoregressive process with an i.i.d.-normal error term: $u_t^c = \rho_c u_{t-1}^c + \varepsilon_t^c$ and $u_t^l = \rho_l u_{t-1}^l + \varepsilon_t^l$.

Ricardian households maximize its lifetime utility function subject to an intertemporal budget constraint that is given by:

$$\begin{aligned} &P_t C_t^R(i) + P_t I_t^R(i) + \Psi(Z_t(i)) P_t K_{t-1}^R(i) + B_t^R(i) \\ &= W_t^R(i) L_t^R(i) + R_t^k Z_t(i) P_t K_{t-1}^R(i) + R_{t-1} B_{t-1}^R(i) + D_t^R(i) - P_t T_t^R(i) \end{aligned} \tag{2}$$

P_t is aggregate price level (the price of the final good), $K_t^R(i)$ is real private capital stock, $I_t^R(i)$ denote real investment, $B_t^R(i)$ is nominal government bonds, R_t is the gross nominal interest rate, $W_t^R(i)$ is nominal wage rate of

Ricardian household i, R_t^k is real rental rate of private capital, $D_t^R(i)$ is the nominal dividend income from firms, $T_t^R(i)$ is lump-sum taxes (or transfers, if negative) paid by Ricardian household i, $Z_t(i)$ is the capital utilization rate, and $\Psi\,(Z_t(i))$ is the utilization cost function. It is assumed that the utilization cost function $\Psi(Z_t(i))$ is increasing and convex function $\Psi' > 0$, $\Psi'' > 0$), and the utilization cost is zero $\Psi(1) = 0$ when the capital utilization rate is at the steady state $\overline{Z} = 1$

The Ricardian household accumulates the private capital stock according to the following capital accumulation equation:

$$K_t^R(i) = (1-\delta_p)K_{t-1}^R(i) + \left[1 - S\left(\frac{e^{u_t^{inv}} I_t^R(i)}{I_{t-1}^R(i)}\right)\right] I_t^R(i) \tag{3}$$

where δ_p is depreciation rate of private capital, $S(\bullet)$ represents the adjustment cost function in investment. Assume that $S' > 0$, $S'' \leq 0$, $S(1) = S' = 0$, and we define $\zeta \equiv \frac{1}{S''}$. u_t^{inv} represents investment shock and is assumed to follow a first-order autoregressive process with an i.i.d.-normal error term:
$u_t^{inv} = \rho_{inv} u_{t-1}^{inv} + \varepsilon_t^{inv}$.

Letting Λ_t and $\Lambda_t Q_t$ stand for the Lagrange multipliers associated with the budget constraint (2) and the capital accumulation equation (3), respectively, the first-order conditions with respect to $C_t^R(i)$, $B_t^R(i)$, $Z_t(i)$, $I_t^R(i)$, $K_t^R(i)$ are expressed as follows:

$$\Lambda_t = e^{u_t^c}(C_t^R(i) - hC_{t-1}^R)^{-\theta} \tag{4}$$

$$\Lambda_t = \beta R_t \frac{P_t}{P_{t+1}} \Lambda_{t+1} \tag{5}$$

$$R_t^k = \Psi'(Z_t(i)) \tag{6}$$

$$\begin{aligned} 1 =& Q_t \left[1 - S\left(\frac{e^{u_t^{inv}} I_t^R(i)}{I_{t-1}^R(i)}\right) - S'\left(\frac{e^{u_t^{inv}} I_t^R(i)}{I_{t-1}^R(i)}\right) \frac{e^{u_t^{inv}} I_t^R(i)}{I_{t-1}^R(i)}\right] \\ &+ \beta E_t Q_{t+1} \left[\frac{\Lambda_{t+1}}{\Lambda_t} S'\left(\frac{e^{u_{t+1}^{inv}} I_{t+1}^R(i)}{I_t^R(i)}\right) \left(\frac{e^{u_{t+1}^{inv}} I_{t+1}^R(i)}{I_t^R(i)}\right) \frac{I_{t+1}^R(i)}{I_t^R(i)}\right] \end{aligned} \tag{7}$$

$$Q_t = \beta E_t \frac{\Lambda_{t+1}}{\Lambda_t}[Q_{t+1}(1-\delta_p) + R_{t+1}^k Z_{t+1}(i) - \Psi(Z_{t+1}(i))] \tag{8}$$

2.1.2 Hand-to-mouth households

Hand-to-mouth households fully consume their current disposable income in each period. Thus, the budget constraint of the hand-to-mouth household is given by:

$$P_t C_t^{NR}(i) = W_t^{NR}(i) L_t^{NR}(i) - P_t T_t^{NR}(i) \tag{9}$$

where $C_t^{NR}(i)$ is consumption of hand-to-mouth household i, $L_t^{NR}(i)$ is labor supply of hand-to-mouth household i, $W_t^{NR}(i)$ is nominal wage rate of handto-mouth household i, $T_t^{NR}(i)$ is lump-sum taxes (or transfers, if negative) paid by hand-to-mouth household i.

2.1.3 Wage setting and labor supply

Each Ricardian household i supplies a differentiated type of labor and decides to choose the amount of labor supply $L_t^R(i)$ monopolistically in the labor market. The nominal wages for differentiated labor services, $W_t^R(i)$, are determined by staggered fashion, according to the stochastic time dependent rule proposed by Calvo (1983). On the other hand, each hand-to-mouth household i are assumed to set their wages, $W_t^{NR}(i)$, for their differentiated labour services, $L_t^{NR}(i)$, to be equal to the Ricardian households i who has same labor type. Then, both wages and labor hours will be equal between Ricardian and hand-to-mouth households, that is, $W_t^R(i) = W_t^{NR}(i) = W_t(i)$, $L_t^R(i) = L_t^{NR}(i) = L_t(i)$.

An independent and perfectly competitive employment agency bundles differentiated labor, $L_t(i)$, into an aggregate labor input, L_t, using the following Dixit-Stiglitz-type aggregator function:

$$L_t = \left[\int_0^1 L_t(i)^{\frac{1}{1+\lambda_{wt}}} di \right]^{1+\lambda_{wt}} \tag{10}$$

where λ_{wt} is the wage markup shock and is assumed to follow i.i.d.-normal around a constant: $\lambda_{wt} = \lambda_w + \varepsilon_t^w$.

The demand for $L_t(i)$ is given by

$$L_t(i) = \left(\frac{W_t(i)}{W_t} \right)^{\frac{1+\lambda_{wt}}{\lambda_{wt}}} L_t \tag{11}$$

where W_t is the aggregate nominal wage rate. From equations (11) and (10), we get

$$W_t = \left[\int_0^1 W_t(i)^{-\frac{1}{\lambda_{wt}}} di \right]^{-\lambda_{wt}} \tag{12}$$

Each Ricardian household i takes L_t and W_t as given.

With probability $1 - \xi_w$, a Ricardian household is assumed to be able to reoptimize its nominal wage. If a Ricardian household cannot reoptimize its wage, it adjusts $W_t(i)$ according to the following indexation scheme:

$$W_t(i) = \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} W_{t-1}(i) \tag{13}$$

where γ_w is the degree of wage indexation.

The Ricardian household i, which is allowed to reoptimize its wage, sets the optimal wage $W_t^*(i)$ to maximize its lifetime utility. The optimal wage is obtained by the result of the maximization problem as below.

$$E_t \sum_{k=0}^{\infty} \xi_w^k \beta^k L_{t+k}(i) \left[\frac{W_t^*(i)}{P_{t+k}} \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^{\gamma_w} (C_{t+k}^R(i) - hC_{t+k-1}^R)^{-\theta} - (1+\lambda_{wt}) e^{u_{t+k}^l} (L_{t+k}(i))^{\chi} \right] = 0 \tag{14}$$

According to equations (12), (13), (14), the evolution of the aggregate nominal wage rate is determined by the following expression:

$$W_t = \left[(1-\xi_w)(W_t^*(i))^{-\frac{1}{\lambda_{wt}}} + \xi_w \left(\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} W_{t-1}(i) \right)^{-\frac{1}{\lambda_{wt}}} \right]^{-\lambda_{wt}} \tag{15}$$

2.1.4 Aggregation

Aggregate consumption C_t and labor input L_t are given by a weighted average of Ricardian households and hand-to-mouth households.

$$C_t \equiv \omega C_t^{NR}(i) + (1-\omega)C_t^R(i) \tag{16}$$

$$L_t \equiv \omega L_t^{NR}(i) + (1-\omega)L_t^R(i) \tag{17}$$

As only Ricardian households have access to financial markets, we obtain the following condition for aggregate investment I_t, private capital K_t, government bonds B_t:

$$I_t \equiv (1-\omega)I_t^R(i) \tag{18}$$

$$K_t \equiv (1-\omega)K_t^R(i) \tag{19}$$

$$B_t \equiv (1-\omega)B_t^R(i) \tag{20}$$

2.2 Firms

There are two types of firms. A continuum of monopolistically competitive intermediate good firms indexed $j \in [0,1]$, each of which makes differentiated intermediate good $Y_t(j)$, and perfectly competitive final goods firms, which bundles these intermediate goods into a final good Y_t. Furthermore, there is public capital in the economy and intermediate good firms can use public capital without costs.

2.2.1 Final good firm

The production function of final good firm is given by:

$$Y_t = \left[\int_0^\infty Y_t(j)^{\frac{1}{1+\lambda_{pt}}} dj\right]^{1+\lambda_{pt}} \tag{21}$$

where λ_{pt} is the price markup shock and is assumed to follow i.i.d.-normal around a constant: $\lambda_{pt} = \lambda_p + \varepsilon_t^p$.

Profit maximization yields the demand for the differentiated intermediate goods and the price of the final good P_t:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\frac{1+\lambda_{pt}}{\lambda_{pt}}} \tag{22}$$

$$P_t = \left[\int_0^1 P_t(j)^{\frac{1}{\lambda_{pt}}} dj\right]^{-\lambda_{pt}} \tag{23}$$

where $P_t(j)$ is the price of intermediate good j.

2.2.2 Intermediate goods firms

Each intermediate-goods firm j produces its differentiated output using the following Cobb-Douglas production function including public capital

$$Y_t(j) = e_{u_{at}} (Z_t K_{t-1}(j)) \alpha (L_t(j))_{1-\alpha} K_{Gtv} - \Phi \tag{24}$$

where $K_{t-1}(j)$ and $L_t(j)$ represent the private capital and labor services hired by firm j. $K_{G_{t-1}}$ is public capital, Φ is fixed cost of production. u_t^a is the technology shock assumed to follow a process: $u_t^a = \rho_a u_{t-1}^a + \varepsilon_t^a$.

Accumulation process of public capital is as follows.

$$K_{Gt} = (1 - \delta_g) K_{Gt} + I_{Gt} \tag{25}$$

I_{Gt} is public investment, δ_g is depreciation rate of public capital.

Taking the aggregate real wage rate $\hat{W}_t \equiv \frac{W_t}{P_t}$ and the rental cost of private capital R_t^k as given, cost minimization implies:

$$\frac{\hat{W}_t}{R_t^k} = \frac{1-\alpha}{\alpha} \frac{Z_t K_{t-1}(j)}{L_t(j)} \tag{26}$$

$$MC_t = \frac{\hat{W}}{(1-\alpha) e^{u_t^a} K_{Gt}^{\nu}} \left[\frac{(1-\alpha) R_t^k}{\alpha \hat{W}_t} \right] \tag{27}$$

where MC_t is marginal cost of intermediate goods firms. For all intermediate goods firms, the aggregate real wage rate $\hat{W}_t$ and the capital rental rate R_t^k are given for all intermediate goods firms. Since all intermediate goods firms can access to public capital, the marginal costs of all intermediate goods firms are equal.

As in the case of wage setting, a fraction $1 - \xi_p$ of intermediate goods firms can reoptimize their prices, unless otherwise they follow the price indexation scheme:

$$P_t(j) = \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} \tag{28}$$

where γ_p is the degree of price indexation.

A firm resetting its price chooses the optimal price $P_t^*(j)$ so as to satisfy following condition that is obtained by the optimization problem:

$$E_t \sum_{k=0}^{\infty} \xi_p^k \beta^k Y_{t+k}(j) \left[\frac{P_t^*(j)}{P_{t+k}} \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^{\gamma_p} - (1 + \lambda_{pt}) MC_t \right] = 0 \tag{29}$$

From equations (23), (28), (29), the aggregate price law of motion is expressed as follows:

$$P_t = \left[(1 - \xi_p)(P_t^*(j))^{-\frac{1}{\lambda_{pt}}} + \xi_p \left(\left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p} P_{t-1}(j) \right)^{-\frac{1}{\lambda_{pt}}} \right]^{-\lambda_{pt}} \tag{30}$$

2.3 Government and Central Bank

2.3.1 Monetary policy

Following Bianchi (2012), we assume that the monetary authority sets the nominal interest rate as follows:

$$r_t = \rho_r r_{t-1} + (1-\rho_r)(\phi_{\pi,\xi_t^{mp}}\pi_{t-1} + \phi_y y_t) + \varepsilon_t^r \tag{31}$$

where $\pi_t \equiv \ln \frac{P_t}{P_{t-1}}$, $r_t \equiv \ln \frac{R_t}{R}$, $y_t \equiv \ln \frac{Y_t}{Y}$. R and Y denote nominal interest rate and aggregate output in the steady state. ε_t^r is an i.i.d.-normal shock to the interest rate. The parameter $\phi_{\pi,\xi_t^{mp}}$ may be switched. ξ_t^{mp} represent the monetary policy regime that is in place at t. As same in Abe, Fueki and Kaihatsu (2019), there are four combinations of fiscal/monetary policy regimes. We will discuss these policy regimes in the next section.

2.3.2 Fiscal policy

The fiscal authority spends government consumption G_t and public investment I_{G_t}. Revenue is generated through rump-sum taxes and by issuing bonds B_t to finance its expenditures. The flow government budget constraint is:

$$B_t = R_{t-1}B_{t-1} + P_tG_t + P_tI_{G_t} - P_tT_t \tag{32}$$

where $T_t \equiv \omega T_t^{NR}(i) + (1-\omega)T_t^R(i)$.

Following Leeper (1991), we assume the fiscal authority adjusts lumpsum taxes in response to the government debt to GDP ratio:

$$t_t = \phi_{b,\xi_t^{fp}} b_t + \varepsilon_t^t \tag{33}$$

where we define $t_t \equiv \frac{T_t - T}{Y}$, $b_t \equiv \frac{B_t/P_t - B/P}{Y}$. ε_t^t is an i.i.d.-normal shock to the tax. $\phi_{b,\xi_t^{fp}}$ can also be switched, and ξ_t^{fp} represent the fiscal policy regime that is in place at t.

Public investment and government consumption are assumed to follow the following stochastic process:

$$i_{gt} = \rho_{ig} i_{gt-1} + \varepsilon_{igt} \tag{34}$$

$$g_t = \rho_g g_{t-1} + \varepsilon_{gt} \tag{35}$$

where $i_{gt} \equiv \frac{I_{Gt} - I_G}{Y}$, $g_t \equiv \frac{G_t - G}{Y}$. ε_t^{ig} and ε_t^g are i.i.d.-normal shock to the government consumption and public investment.

2.3.3 Market Clearing

Lastly, the equilibrium condition of final good market is given by:

$$Y_t = C_t + I_t + \Psi(Z_t)K_{t-1} + I_{G_t} + G_t \tag{36}$$

3. Log-linearized Equations

Next, we log-linearize the model in the previous section around the steady state. We define capital letters without any subscripts X as the steady state value of the variable X_t and small letters with time subscripts $x_t \equiv \ln \frac{X_t}{X}$ as log-deviations from the steady state. Following Gali et al. (2007), the consumption levels of Ricardian and Hand-to-

Mouth households are assumed to be equal in the steady state ($C^R = C^{NR} = C$). The log-linearized equations are as follows.

$$c_t^R = \frac{h}{1+h}c_{t-1}^R + \frac{1}{1+h}E_t c_{t+1}^R - \frac{1-h}{(1+h)\theta}(r_t - E_t\pi_{t+1}) + \frac{1-h}{(1+h)\theta}(u_t^c - E_t u_{t+1}^c) \tag{37}$$

$$c_t^{NR} = \left(\frac{\hat{W}N}{C}\right)(\hat{w}_t + n_t) - \left(\frac{Y}{C}\right)t_t^{NR} \tag{38}$$

$$c_t = \omega c_t^{NR} + (1-\omega)c_t^R \tag{39}$$

$$i_t = \frac{1}{1-\beta}i_{t-1} + \frac{\beta}{1+\beta}E_t i_{t+1} + \frac{\zeta}{1+\beta}q_t + \frac{\beta}{1+\beta}(E_t u_{t+1}^{inv} - u_t^{inv}) \tag{40}$$

$$q_t = -(r_t - E_t\pi_{t+1}) + \frac{1-\delta_p}{1-\delta_p+R^k}q_{t+1} + \frac{R^k}{1-\delta_p+R^k}E_t r_{t+1}^k + \varepsilon_t^q \tag{41}$$

where, ε_t^q is a equity premium shock and is assumed to be i.i.d. normal.

$$\begin{aligned}\hat{w}_t =& \frac{\beta}{1+\beta}E_t\hat{w}_{t+1} + \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}\pi_{t+1} - \frac{1+\beta\gamma_w}{1+\beta}\pi_t + \frac{\gamma_w}{1+\beta}\pi_{t-1} \\ &- \frac{1}{1+\beta}\frac{\lambda_w(1-\beta\xi_w)(1-\xi_w)}{(\lambda_w+(1+\lambda_w)\chi)\xi_w}\left[\hat{w}_t - \chi l_t - \frac{\theta}{1-h}(c_t^R - hc_{t-1}^R) - u_t^l - \varepsilon_t^w\right]\end{aligned} \tag{42}$$

$$z_t = \psi r_t^k \tag{43}$$

where, $\Psi \equiv \frac{\Psi'(1)}{\Psi''(1)}$.

$$k_{t+1} = (1-\delta_p)k_t + \delta_p i_t \tag{44}$$

$$l_t = -\hat{w} + r_t^k + z_t + k_{t-1} \tag{45}$$

$$y_t = \phi[u_t^a + \alpha k_t + \alpha z_t + (1-\alpha)l_t + \nu k_{gt}] \tag{46}$$

where, $\phi \equiv 1 + \frac{\Psi}{Y}$.

$$\pi_t = \frac{\beta}{1+\beta\gamma_p}E_t\pi_{t+1} + \frac{\gamma_p}{1+\beta\gamma_p}\pi_{t-1} + \frac{(1-\beta\xi_p)(1-\xi_p)}{(1+\beta\gamma_p)\xi_p}[\alpha r_t^k + (1-\alpha)\hat{w} - u_t^a - \nu k_{gt} + \varepsilon_t^p] \tag{47}$$

$$y_t = \frac{C}{Y}c_t + \frac{I}{Y}i_t + i_{gt} + g_t + R^k\frac{K}{Y}z_t \tag{48}$$

$$b_t = Rb_{t-1} + R\frac{B}{PY}r_t - R\frac{B}{PY}\pi_t + i_{gt} + g_t - t_t \tag{49}$$

$$k_{gt} = (1-\delta_G)k_{gt-1} + \delta_G\frac{Y}{G}i_{gt} \tag{50}$$

$$r_t = \rho_r r_{t-1} + (1-\rho_{r,})(\phi_{\pi,\xi_t^{mp}}\pi_{t-1} + \phi_y y_t) + \varepsilon_t^r \tag{51}$$

$$t_t = \phi_{b,\xi_t^{fp}}b_t + \varepsilon_{tt} \tag{52}$$

$$i_{gt} = \rho_{ig} i_{gt-1} + \varepsilon_{igt} \tag{53}$$

$$g_t = \rho_{ggt-1} + \varepsilon_{gt} \tag{54}$$

$$u_t^a = \rho_a u_{t-1}^a + \varepsilon_t^a \tag{55}$$

$$u_t^c = \rho_c u_{t-1}^c + \varepsilon_t^c \tag{56}$$

$$u_{lt} = \rho_l u_{lt-1} + \varepsilon_{lt} \tag{57}$$

$$u_t^{inv} = \rho_{inv} u_{t-1}^{inv} + \varepsilon_t^{inv} \tag{58}$$

4. Policy regimes

4.1 Types of regimes

According to Leeper (1991), we call monetary policy is “active” when Taylor’s principle is satisfied. This means the coefficient of the monetary policy rule to inflation is greater than one (i.e. $\phi_\pi > 1$). On the contrary, monetary policy is called “passive” when Taylor’s principle is not satisfied (i.e. $\phi_\pi < 1$). Taylor’s principle is a condition that prevents explosive path of inflation rate. Similarly, fiscal policy is “passive” when fiscal authority stabilizes government debt (or prevents explosive path of government debt). This means the coefficient of the tax rule to government debt is greater than the steady state real interest rate (i.e. $\phi_b > \beta^{-1} - 1$). On the other hand, fiscal policy is “active” when fiscal authority does not stabilizes government debt (i.e. $\phi_b < \beta^{-1} - 1$). Passive fiscal policy can be considered as “non-Ricardian fiscal policy” Woodford (1995) calls. ”non-Ricardian fiscal policy” does not adjusts the path of primary surpluses to hold the present value of current and future surpluses equal to the real value of outstanding government debt. This means that without changes in prices, the real government debt will diverge to infinity (not stabilized). There are four combinations of fiscal and monetary policy regimes.

- Regime I: Active monetary and passive fiscal policy (AM/PF).
- Regime II: Passive monetary and passive fiscal policy (PM/PF).
- Regime III: Active monetary and Active fiscal policy (AM/AF)
- Regime IV: Passive monetary and active fiscal policy (PM/AF).

The standard New-Keynesian literature usually assume Regime I (AM/PF), and Regime IV (PM/AF) corresponds to the FTPL regime in Leeper (1991).

4.2 Transition Matrix

The transition matrices that determine the probability of transition from one regime to another is given as follows.

$$H^{mp} = \begin{bmatrix} H_{11}^{mp} & 1 - H_{22}^{mp} \\ 1 - H_{11}^{mp} & H_{22}^{mp} \end{bmatrix} \tag{59}$$

$$H^{fp} = \begin{bmatrix} H_{11}^{fp} & 1 - H_{22}^{fp} \\ 1 - H_{11}^{fp} & H_{22}^{fp} \end{bmatrix} \tag{60}$$

H_{ij}^{mp} represents the probability of monetary policy transitioning from regime i to regime j. We set "active" as regime 1 and "passive" as regime 2 for monetary policy. H_{ij}^{fp} represents the probability of fiscal policy transitioning from regime i to regime j. We set "passive" as regime 1 and "active" as regime 2 for fiscal policy.

5. Estimation

5.1 Fixed parameters and prior distributions

We estimate our model using Bayesian inference methods. Following Iibishi et al. (2006), Sugo and Ueda (2008), and Iwata (2011), we fix some parameters as below. The discount factor $\beta = 0.996$, the private capital share $\alpha = 0.362$, the private capital depreciation rate $\delta_p = 0.06$, the steadystate output share of consumption ${}_{Y}{}^{C} = 0.6$, and price and wage markup $\lambda_p = \lambda_w = 0.2$. Additionally, the steady-state output share of public investment $\frac{I_G}{Y} = 0.07$, output share of government debt $\frac{B}{P}/Y = 2$, and the ratio of public capital to private capital ${}^{K}{}_{K}{}^{G} = 0.6$. These are rough average value in the sample period. The rate of depletion of social capital is generally smaller than the rate of depletion of private capital [1)], we set $\delta_G = 0.04$. We also fix the probability of transition matrix $H_{11} = H_{22} = 0.75$ for each policy.

The prior distribution is summarized in Table 1. In this paper, the parameters do not present in the standard New-Keynesian model are the parameter about productivity of public capital v and the share of hand-tomouth households ω. We set the prior distribution of ω based on Hatano (2004) and Iwata (2011). The prior distribution

Table 1: Estimated Parameters

	Prior distribution			Posterior	
Parameter	Distribution	Mean	S.D	Mean	90% interval
h	Beta	0.7	0.15	0.887	[0.819, 0.958]
θ	Beta	1	0.375	1.178	[0.670, 1.696]
χ	Gamma	2	0.75	2.280	[1.215, 3.324]
$1/\zeta$	Gamma	4	1.5	7.308	[5.480, 9.105]
$\phi - 1$	Gamma	0.075	0.0125	0.079	[0.057, 0.101]
ψ	Normal	1	0.1	0.971	[0.807, 1.138]
ω	Beta	0.3	0.1	0.223	[0.114, 0.331]
ξp	Beta	0.375	0.1	0.727	[0.663, 0.791]
ξw	Beta	0.375	0.1	0.385	[0.271, 0.496]
γ_p	Beta	0.5	0.25	0.537	[0.170, 0.906]
γw	Beta	0.5	0.25	0.575	[0.288, 0.903]
$\phi\pi,1$	Normal	1.5	0.1	1.363	[1.161, 1.580]
$\phi\pi,2$	Normal	0.05	0.1	0.039	[0.001, 0.059]
$\phi b,1$	Gamma	0.001	0.1	0.001	[0.000, 0.0013]
$\phi b,2$	Gamma	0.03	0.1	0.022	[0.014, 0.032]
ϕ_y	Normal	0	0.1	0.055	[-0.126, 0.232]
ρ_r	Beta	0.8	0.1	0.637	[0.554, 0.717]
ρig	Beta	0.5	0.2	0.826	[0.725, 0.935]
ρ_g	Beta	0.5	0.2	0.709	[0.535, 0.893]
ρ_a	Beta	0.5	0.2	0.518	[0.337, 0.698]
ρ_c	Beta	0.5	0.2	0.541	[0.231, 0.842]
ρn	Beta	0.5	0.2	0.588	[0.424, 0.757]
ρinv	Beta	0.5	0.2	0.644	[0.500, 0.794]

1） See, Otto and Voss (1998)

of v is based on many studies analyzing the productivity effects of public capital in Japan, including Murata and Ohno (2001), Hayashi (2003), and Iwamoto (2005). For other parameters, we refer mainly to Sugo and Ueda (2008) and Kaihatsu and Kurozumi (2014).

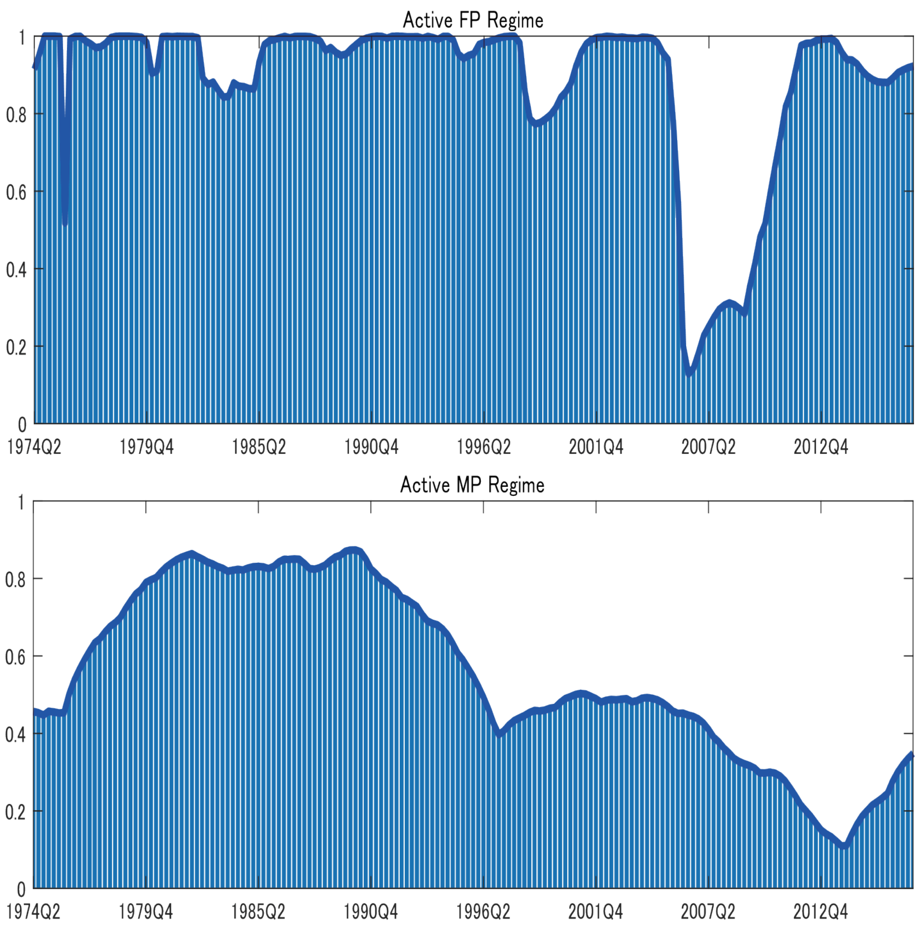
5.2 Data

We use quarterly Japanese data over the period from 1973:1Q to 1998:4Q for estimation. We exclude the data after 1999 due to the issue of ZLB. We use eight quarterly Japanese time series as observable variables. Seven of them are the same as used in Iiboshi, Nishiyama and Watanabe, Sugo and Ueda (2008). literature, which includes output, private consumption and investment, labour hours, wages, the inflation rate and the interest rate. All of the variables are detrended using the Hodrick-Prescott filter.

5.3 Estimation Results

Estimated results are summarized in Table 1. Here, the fraction of hand-tomouth households ω is estimated to be 0.223 in posterior mean. This value is consistent with previous studies. Figure 1 report the smoothed probabilities

Figure 1: The smoothed probabilities for fiscal and monetary policy regime

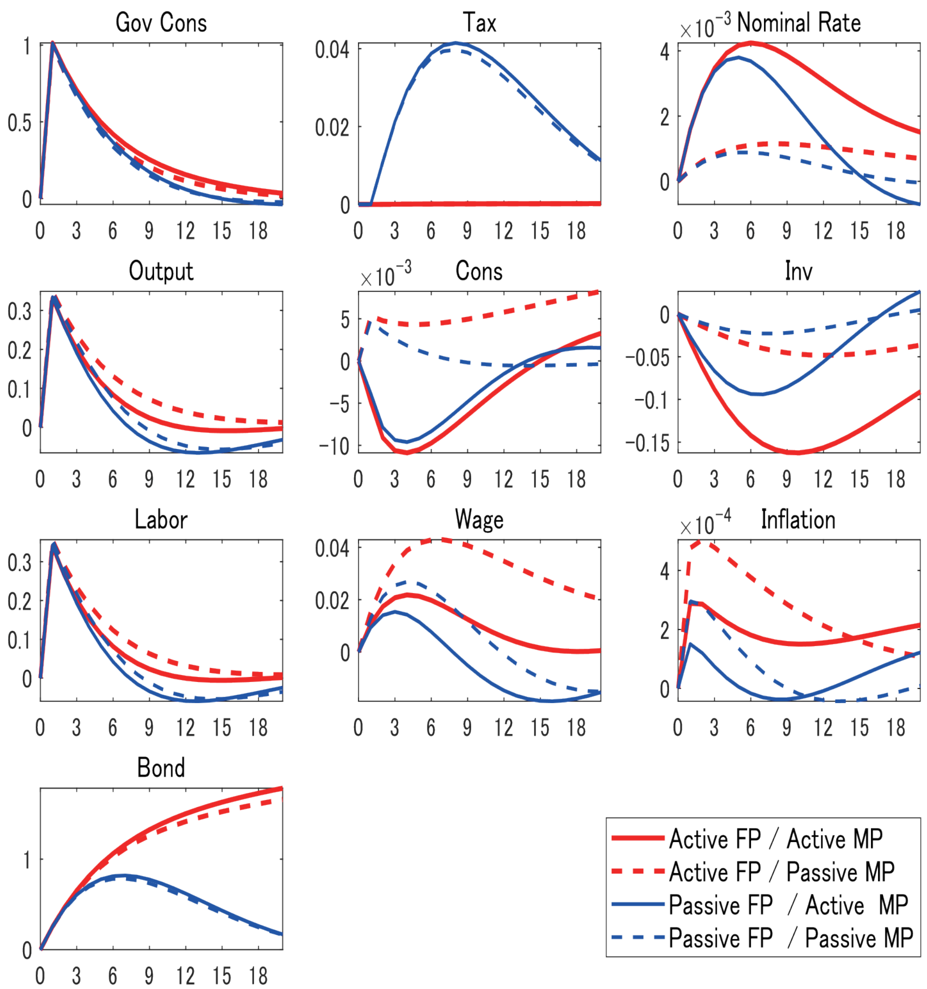


for fiscal and monetary regime. The top panel of Figure 1 shows the fiscal policy regime, while the bottom panel shows the monetary policy regime. Figure 1 show that fiscal policy is relatively active in the late 1970s and the bubble period (late 1980s), and passive in the rest of periods. On the other hand, monetary policy is also relatively passive in the late 1970s and the bubble period (late 1980s and early 1990s), and active in the rest of periods.

5.4 Fiscal Multiplier

Figure 2 shows the impulse response function to 0.1 increase in government spending shock for each regime combination. There are four regimes, Active monetary policy/ Passive fiscal policy (AM/PF), Passive monetary policy/ Passive fiscal policy (PM/PF), Active monetary policy/ Active fiscal policy (AM/AF), and Passive monetary policy/ Active fiscal policy (PM/AF).

Figure 2: IRFs to 0.1 increase in government spending shock



Since there are hand-to-mouth households in our model, consumption responds positively to the increase in government spending. Following Leeper et al. (2017), we define the Present Value Fiscal Multiplier (PVFM) as follows:

$$PVFM(k) = \frac{E_t \sum_{j=0}^{k} (\prod_{i=0}^{k} (1 + \bar{r}_t)^{-1}) \Delta Y_{t+j}}{E_t \sum_{j=0}^{k} (\prod_{i=0}^{k} (1 + \bar{r}_t)^{-1}) \Delta G_{t+j}} \tag{61}$$

where $\bar{r}_{t+i}$ is the model-implied real interest rate. Consumption multiplier can be defined analogously. At $k = 0$, PVFM equals the impact multiplier. Because a PVFM is cumulative, its value at $t+k$ reports the total effect over k periods of a change in spending at time t. The impact fiscal multiplier (PVFM(0)) is not different among regimes, at about 1.38.

On the other hand, 5 years fiscal multiplier (PVFM(20)) vary slightly among regimes. The smallest value of PVFM(20) is 1.4 for PM/PF regime, and the largest value is 1.55 for AM/AF regime. Similarly, we can calculate the present value consumption multiplier (PVCM). The impact consumption multiplier (PVCM(0)) is the same for any regime (0.42), but the multiplier for the five years (PVCM(20)) is much different. The smallest value of PVCM(20) is 0.32 for PM/PF regime, and the largest value is 1.29 for AM/AF regime. Thus, we find that the AM/AF regime yields the largest multiplier for both production and consumption.

6. Conclusion

In this paper, we evaluated the fiscal multiplier in Japan by estimating a Markov-switching DSGE model that allows for changes in fiscal and monetary policy regimes. It is well established that the fiscal multiplier can vary significantly depending on the prevailing policy configuration. To address this, we developed a two-agent New Keynesian (TANK) model with hand-to-mouth households and incorporated the possibility of regime switches in fiscal and monetary policy between active and passive stances. In general, the fiscal multiplier is larger when fiscal policy is active (non-Ricardian) and monetary policy is passive (not stabilizing inflation).

Using Japanese data from the 1970s to the 1990s, excluding the zero nominal interest rate period, we found that fiscal policy was relatively active in the late 1970s and during the bubble period (late 1980s), but passive in other periods. Conversely, monetary policy was relatively passive in the late 1970s and the bubble period (late 1980s to early 1990s), and active otherwise. The estimated mean short-run fiscal multiplier is similar across regimes (about 1.38), but differences emerge in the long run (ranging from 1.40 to 1.55). Moreover, the long-run effects on consumption differ substantially across regimes (ranging from 0.32 to 1.29).

As a direction for future research, we intend to extend the model to include the zero interest rate period, which is particularly relevant for understanding Japan's more recent economic experience.

References

[1] Abe, N., T. Fueki, and S. Kaihatsu (2019), "Estimating a Markov Switching DSGE Model with Macroeconomic Policy Interaction ," *Bank of Japan Working Paper Series* 19-E-3.

[2] Bilbiie, F. (2019), "The New Keynesian cross," forthcoming in *Journal of Monetary Economics.*

[3] Bianchi, F. (2012), "Evolving Monetary/Fiscal Policy Mix in the United States," *American Economic Review* 102,

pp.167-172.

[4] Coenen, G., C. Erceg, C. Freedman, D. Furceri, M. Kumhof, R. Lalonde, D. Laxton, J. Linde, A. Mourougane, D. Muir, S. Mursula, C. de Resende, J. Roberts, W. Roeger, S. Snudden, M. Trabandt, and J. in't Veld (2012), "Effects of Fiscal Stimulus in Structural Models," *American Economic Journal: Macroeconomics 4*, pp.22 - 68.

[5] Coenen, G. and R. Straub (2005), "Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Erea," *International Finance 8,* pp.435-470.

[6] Cogan, J. F., T. Cwik, J. B. Taylor, and V. Wieland (2010), "New Keynesian versus Old Keynesian Government Spending Multipliers," *Journal of Economic Dynamics and Control,* 34, pp.281-295.

[7] Debortoli, D. and J. Gali (2018), "Monetary Policy with Heterogeneous Agents: Insights from TANK," Economics Working Papers 1686, Department of Economics and Business, Universitat Pompeu Fabra.

[8] Forni,L., M. Monteforte, and L. Sessa (2009), "The General Equilibrium Effects of Fiscal Policy: Estimates for Euro Erea," *Journal of Public Economics* 93, pp.559-585.

[9] Gali,J.J., D. Lopez-Salido, and J. Valles (2007), "Understanding the Effects of Government Spending on Consumption," *Journal of the European Economic Association* 5, pp.227-270.

[10] Hatano, T. (2004), "The Macroeconomic Effects of Fiscal Deficits: An Examination of the Kalman-Filter Neutral Proposition," Financial Review, No. 74, pp. 65-91, Ministry of Finance Policy Research Institute. (in Japanese)

[11] Hayashi, M. (2003), "Production Effects and Simultaneity of Social Capital, " Economic Analysis, No. 169, pp.97-119, Economic and Social Research Institute, Cabinet Office. (in Japanese)

[12] Iiboshi,H., S. Nishiyama and T. Watanabe (2006), "An Estimated Dynamic Stochastic General Equilibrium Model of the Japanese Economy: A Bayesian Analysis," mimeo.

[13] Iwata,Y.(2011), "The Government Spending Multiplier and Fiscal Financing: Insights from Japan," *International Finance* 14, pp.231-264.

[14] Iwamoto, Y. (2005), "Is Public Investment Useful?" in Otake, F. (ed.), *An Invitation to Applied Economics*, pp.115-136, NIPPON HYORON SHA. (in Japanese)

[15] Kaihatsu,S. and Kurozumi,T.(2014), "Sources of Business Fluctuations: Financial or Technology Shocks?," *Review of Economic Dynamics* 17, pp.224-242.

[16] Leeper,E., N. Traum, and T. B. Walker (2017), "Clearing Up the Fiscal Multiplier Morass," *America Economic Review* 107, pp.2409-2054.

[17] Murata, O. and Y. Ohno (2001), "Productivity Effects of Social Capital: A Survey of Empirical Analysis," in Nagamine, J. and Y. Katayama (eds.), *Public Investment and Road Policy,* pp.173-207, NIPPON HYORON SHA. (in Japanese)

[18] Otto,G.D. and Voss,G.M.(1998), "Is Public Capital Provision Efficient?," *Journal of Monetary Economics* 42, pp.47-66.

[19] Ramey, V. A. (2011), "Can Government Purchases Stimulate the Economy?," *Journal of Economic Literature* 49, pp.673-685.

[20] Smets,F. and S. Wouters (2003),"An Estimated Dynamic General Equilibrium Model of the Euro Area," *Journal of European Economic Association* 1, pp.1123-1175.

[21] Smets,F. and S. Wouters (2007), "Shocks and Frictions in US Business Cycles A Bayesian DSGE Approach," *American Economic Review* 97, pp.586-606.

[22] Sugo,T. and K. Ueda (2008), "Estimating a DSGE Model for Japan: Evaluating and Modifying a CEE/SW/LOWW Model," *Journal of the Japanese and International Economies* 22, pp.476-502.