Comparison of Various Fiscal Policies in the Face of Different Demographic Stages

Naoyuki Yoshino
Keio University

Keigo Kameda
Kwansei Gakuin University

Hiroaki Miyamoto
Hitotsubashi University

Zhenkun Lu*
Kwansei Gakuin University

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* Corresponding author: School of Policy Studies, Kwansei Gakuin University
Gakuen-Uegahara, Sanda, Hyogo 669-1337, Japan, Email: gys53987@kwansei.ac.jp

Abstract

This study examines the impact of aging on the effectiveness of various fiscal expenditures, including government consumption, one-time government transfers to households, public investment, and R&D spending, using a dynamic stochastic general equilibrium model. Our findings reveal that (1) Aging enhances the effects of the transfer on augmenting GDP. (2) Regardless of aging, R&D expenditure consistently stands out over all time spans, with younger society benefiting more. (3) Public investment ranks second among 4 different fiscal policies compare in the long run while younger society shows bigger impact. (4) Government consumption has only a temporary effect and is the least effective in boosting GDP in both young and old societies. (5) Multipliers for public investment and R&D expenditure increase with the accumulation of public capital and TFP. The multipliers of young society is larger than old society because impact on consumption is much more effective.

Keywords: Fiscal Policy Effectiveness, Aging Population, Japan, DSGE Model.

JEL Code: E62, H30, J1

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1. Introduction

Population aging presents a significant challenge for policymakers across both developed and developing countries (Figure 1). Recent studies have thus explored the link between population aging and the effectiveness of fiscal spending. Honda and Miyamoto (2021) found that aging reduces the output-enhancing effects of fiscal expenditure in OECD countries during recessions. Similarly, Basso and Rachedi (2021) identified larger fiscal multipliers in U.S. states characterized by younger populations. Miyamoto and Yoshino (2022) found that aging diminishes the impact of fiscal stimulus on private consumption and employment.[1]

Despite these insights, there remains a significant gap in understanding how aging influences the outcome of various fiscal measures. Moreover, the literature has yet to fully explore the heterogeneity in the effects of different fiscal expenditures. A critical oversight is the lack of detailed analysis regarding in the underlying mechanisms through which population aging impacts these fiscal measures

Addressing these gaps, this paper compares various fiscal policies facing different stages of demography using a dynamic stochastic general equilibrium (DSGE) model that includes both workers and retirees, developed by Yoshino and Miyamoto (2017).[2] We offer three key expansions: First, we thoroughly investigate how aging influences the macroeconomic effectiveness of fiscal expenditures. Second, we compare a wide range of fiscal policies, including (i) government consumption aimed at stimulating aggregate demand, (ii) universal government transfers to all generations, (iii) public investment in infrastructure, and (iv) R&D expenditure fostering technological progress. The first two policies primarily aim to stimulate aggregate demand in the economy, while the

[1] In the context of Japan, Bessho (2021) demonstrated higher fiscal multipliers in regions with younger populations.

[2] As Yoshino and Le (2022) shows, analysis of aging using an overlapping generations (OLG) model is possible, demonstrating the potential for a decline in the effectiveness of fiscal and monetary policies. However, akin to Yoshino and Miyamoto (2017), introducing heterogeneous agents into a DSGE model, accommodating both workers and the elderly simultaneously, allows for an analysis of policy in scenarios where the proportion of the elderly changes. Thus, we argue that the method utilized in this paper is superior to OLG.

latter two contribute to enhancing aggregate supply.

The results of our policy simulation are summarized as follows: Firstly, the GDP-enhancing effect of the three policies (namely, government consumption, government investment and R&D expenditures), other than one-time government transfer, decreases with aging. Aging implies an increase in the share of policy-irrelevant, stable consumption among retirees in aggregate consumption, thereby weakening the demand expansion effect of the three policies other than one-time transfers. Meanwhile, the output multiplier effect of the transfer gives a greater demand expansion effect with aging due to a larger increase in the sum of retirees' consumption. Secondly, regardless of the degree of aging, R&D expenditure consistently emerges as the most effective measure across all time spans due to its considerable impact on aggregate supply. Public investment ranks second in the long run, while government consumption takes this position in the short run. The one-time transfer is the least effective in expanding GDP in any time spans except for the very short term. Thirdly, government consumption multipliers tend to decrease over time after policy implementation, indicating stronger short-term stimuli but weaker long-term effects. These time-dependent changes in fiscal multipliers become more pronounced as aging progresses. Moreover, the rank of fiscal policies' welfare multiplier aligns with the output multiplier. Furthermore, demographic aging significantly diminishes the welfare benefits from policies enhancing aggregate supply, underscoring the need for nuanced policy considerations in the face of shifting demographic structures.

The paper proceeds as follows: Section 2 extends the New Keynesian model with retired workers. Section 3 calibrates the model. Section 4 examines fiscal policies' impacts. Section 5 compares various fiscal policies in face of different demographic stages. Section 6 presents conclusions.

(Figure 1 around here)

2. The Model

Our model consists of four sectors: households, firms, government, and central bank. Households are conceptualized as a continuum distributed over the interval $[0,1]$. Within this framework, a proportion ϕ of households is characterized as workers, while the rest represents retirees. In addition to heterogeneous households, our model incorporates monopolistic competition and price stickiness among firms, following Calvo (1983). The government operates under a budget constraint, collecting revenue through lump-sum taxes and influencing the economy through various fiscal spendings. The central bank balances inflation and economic growth stability by controlling the nominal interest rate.

As our model's household and firm settings are similar to those of Yoshino and Miyamoto (2017), we focus on describing the main modifications here. By changing elderly ratio we can analyze the impact of various fiscal policies in young economy.

2.1 Household's Problem

We begin with the worker's problem. In the standard New Keynesian model, government consumption is wasteful expenditure, crowding out private consumption through a negative wealth effect. However, many empirical studies on macro-data in Japan have ascertained that an increase in government consumption positively influences private consumption (see, for instance, Kameda, 2014; Morita, 2015). To better reconcile with this finding, Yoshino and Miyamoto (2017) introduces imperfect substitutability between private and government consumption in households' utility function. Consequently, the expected lifetime utility function of a worker is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{1-\sigma} \left[\left\{ \omega c_{w,t}^{\frac{\zeta-1}{\zeta}} + (1-\omega) g_t^{\frac{\zeta-1}{\zeta}} \right\}^{\frac{\zeta}{\zeta-1}} \right]^{1-\sigma} - \frac{h_{w,t}^{1+\mu}}{1+\mu} \right\} \tag{1}$$

where $\beta \in (0,1)$ is subjective discount factor, $c_{w,t}$ is one worker's consumption, g_t is government consumption of such services as hospital service, free public transportation, etc., and $h_{w,t}$ is work hours. The parameter $1/\sigma$ is intertemporal elasticity of substitution, and $1/\mu$ is the Frisch elasticity of labor supply. The parameter ζ is the elasticity of substitution between private and government consumption, and the share parameter ω determines how much government consumption affects utility.

The budget constraint of a worker is as follows:

$$c_{w,t}+i_{w,t}+b_{w,t}=w_t h_{w,t}+r_t k_{w,t-1}+R_{t-1}\frac{b_{w,t-1}}{\pi_t}+d_{w,t}-\tau_{w,t}+TR_{w,t} \quad (2)$$

where w_t is real wages, r_t is the real interest rate, R_t is the gross nominal interest rate, $d_{w,t}$ is the dividend that the worker receives from the firm sector, $\tau_{w,t}$ is the lump-sum tax, $TR_{w,t}$ is the one-time transfer received by workers, and $\pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate.

The accumulation of one worker's capital stock is given by

$$k_{w,t}=(1-\delta)k_{w,t-1}+i_{w,t} \quad (3)$$

where δ is the depreciation rate and $i_{w,t}$ is investment of one worker.

The worker chooses consumption $c_{w,t}$, capital stock $k_{w,t}$, and government bonds $b_{w,t}$ to maximize the above expected lifetime utility subject to the budget constraint and capital accumulation equation. The first-order conditions are as follows:

$$\left(\omega c_{w,t}^{\frac{\zeta-1}{\zeta}}+(1-\omega)g_t^{\frac{\zeta-1}{\zeta}}\right)^{\frac{1-\sigma\zeta}{\zeta-1}}\omega c_{w,t}^{\frac{-1}{\zeta}}=\lambda_t \quad (4)$$

$$h_{w,t}^{\mu}=\lambda_t w_t \quad (5)$$

$$\beta\mathbb{E}_t\lambda_{t+1}[r_{t+1}+1-\delta]=\lambda_t \quad (6)$$

$$\beta\mathbb{E}_t\frac{\lambda_{t+1}R_t}{\pi_{t+1}}=\lambda_t \quad (7)$$

where λ_t is the Lagrange multiplier on the budget constraint, which also represents the worker's marginal utility of income.

The remaining measure of $1-\phi$ households is retired. The lifetime utility function of a retiree is given by

$$\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\frac{1}{1-\sigma}\left[\left\{\omega c_{r,t}^{\frac{\zeta-1}{\zeta}}+(1-\omega)g_t^{\frac{\zeta-1}{\zeta}}\right\}^{\frac{\zeta}{\zeta-1}}\right]^{1-\sigma} \quad (8)$$

where $c_{r,t}$ is one retiree's consumption.

Following Yoshino and Miyamoto (2017), retirees are not confronted with the trade-off between saving and consumption. Nevertheless, considering the uniformity of pension disbursements over time and anchored in the principle of consumption smoothing, it follows logically that a retiree's optimal consumption mirrors the pension they receive. Thus, the consumption of one retiree $c_{r,t}$ is

$$c_{r,t} = s \times \bar{w} + TR_{r,t} \tag{9}$$

where $s \times \bar{w}$ is the pension related to the steady state value of real wages. Moreover, $TR_{r,t}$ is the one-time transfer received by retirees.

2.2 Firm's Problem

As we explained earlier, there are two types of firms: a perfectly competitive final good firm and monopolistic competitive intermediate goods firms indexed by j∈ [0,1]. No corporate tax is considered for simplicity.

The final good Y_t is produced by combining a continuum of differentiated intermediate goods $y_{j,t}$. The production function is given by

$$Y_t = \left(\int_0^1 y_{j,t}^{\frac{\epsilon-1}{\epsilon}} d\mathrm{j} \right)^{\frac{\epsilon}{\epsilon-1}} \tag{10}$$

where ε governs the degree of substitution between different inputs.

The final good producer is perfectly competitive and maximizes real profits subject to (10). Thus, the problem of the final good producer is

$$\max_{y_{j,t}} P_t Y_t - \int_0^1 P_{j,t} y_{j,t} dj \tag{11}$$

This yields the demand for intermediate goods:

$$y_{j,t} = \left(\frac{P_{j,t}}{P_t} \right)^{-\epsilon} Y_t \tag{12}$$

Substituting (12) into (10), we have the following relationship between the aggregate price level and the prices of intermediate goods:

$$P_t^{1-\epsilon} = \int_0^1 (P_{j,t})^{1-\epsilon} d\mathrm{j} \tag{13}$$

The production function of intermediate goods firm j is given by

$$y_{j,t} = A_t (k_{j,t-1})^{\alpha} (h_{j,t})^{1-\alpha} k_{g,t}^{\alpha_g}\ ,0 < \alpha < 1,\ \ 0 < \alpha_g < 1 \tag{14}$$

where $k_{j,t-1}$, $k_{g,t}$ and $h_{j,t}$ represent private capital, aggregate public capital and labor services hired by firm j, and A_t denotes the TFP. Public capital is treated as exogenous for simplicity.

Cost minimization implies

$$\frac{k_{j,t-1}}{h_{j,t}} = \frac{\alpha w_t}{(1-\alpha) r_t} \tag{15}$$

This equation implies that the capital-labor ratio is equalized across intermediate goods producers. Then, the marginal costs of firms are given by

$$mc_t = \frac{{r_t}^{\alpha} {w_t}^{1-\alpha}}{A_t k_{g,t}^{\alpha_g}} \tag{16}$$

We assume that intermediate goods firms are subject to price setting frictions à la Calvo (1983). Thus, an intermediate goods firm can set its price optimally with probability 1–ξ, and with probability ξ, it must keep its price unchanged relative to what it was in the previous period:

$$P_{j,t} = P_{j,t-1}. \tag{17}$$

A firm optimizing its price maximizes

$$\max_{P_{j,t}^*} \mathbb{E}_t \sum_{i=0}^{\infty} (\beta\xi)^i \lambda_{t+i} \{P_{j,t}^* - P_{t+i} mc_{t+i}\} y_{j,t+i} \tag{18}$$

subject to the demand function

$$y_{j,t+i} = \left(\frac{P_{j,t}^*}{P_{t+i}}\right)^{-\epsilon} Y_{t+i}, \tag{19}$$

and where P_t^* is the optimal nominal price.

The profit maximization problem yields

$$P_{j,t}^* = \frac{\epsilon}{\epsilon - 1} \frac{\mathbb{E}_t \sum_{i=0}^{\infty} (\beta\xi)^i \lambda_{t+i} mc_{t+i} y_{j,t+i}}{\mathbb{E}_t \sum_{i=0}^{\infty} (\beta\xi)^i \lambda_{t+i} \frac{y_{j,t+i}}{P_{t+i}}} \tag{20}$$

Finally, combine with Eq. (13), the law of motion for the aggregate price level is given by

$$P_t = [\xi P_{t-1}^{1-\epsilon} + (1-\xi) P_{j,t}^{*1-\epsilon}]^{\frac{1}{1-\epsilon}}. \tag{21}$$

2.3 Aggregation of the economy

The aggregate level of any consumer-specific variables $x_{i,t}$ where $i \in \{w, r\}$ is given by $x_t = \int_0^1 x_{i,t} di = \phi x_{w,t} + (1-\phi) x_{r,t}$, as households in each of the two groups are identical. Hence, aggregate consumption c_t is given by

$$c_t = \phi c_{w,t} + (1-\phi) c_{r,t}. \tag{22}$$

Since only workers provide labor services and retirees keep constant real deposits (capital stock), the aggregate hours of worker h_t, aggregate capital supply k_t, and aggregate investment i_t are given by

$$h_t = \phi h_{w,t} \tag{23}$$

$$k_t = \phi k_{w,t} \tag{24}$$

$$i_t = \phi i_{w,t} \tag{25}$$

We assume that the one-time transfer payments for retirees and workers are identical. Consequently, the aggregated transfer payments can be expressed as:

$$TR_t = \phi TR_{w,t} + (1-\phi) TR_{r,t},\ TR_{w,t} = TR_{r,t} \tag{26}$$

Similarly, only workers hold financial assets, receive dividends from firms, and pay the lump-sum tax. Thus, we have

$$b_t = \phi b_{w,t} \tag{27}$$

$$d_t = \phi d_{w,t}, \tag{28}$$

$$\tau_t = \phi \tau_{w,t}. \tag{29}$$

In this paper, policy effects in different aging economy will be compared by changing the value of ϕ in Section 5.

2.4 Fiscal and Monetary Authorities

The government purchases goods for consumption g_t, public investment purpose $i_{g,t}$, R&D expenditure for technology RD_t, social security benefits $(1-\phi)s\overline{w}$, and one-time transfer TR_t. It finances them by levying the lump-sum tax and issuing government bonds. Hence, the government budget constraint in real terms is given by

$$b_t + \tau_t = g_t + i_{g,t} + R_{t-1}\frac{b_{t-1}}{\pi_t} + (1-\phi)s \times \overline{w} + TR_t + RD_t. \tag{30}$$

The accumulation of public capital follows:

$$k_{g,t} = i_{g,t} + (1-\delta)k_{g,t-1} \tag{31}$$

Public investment $i_{g,t}$ follows a stochastic process:

$$\log(i_{g,t}) = (1-\rho_{ig})\log\left(\overline{i_g}\right) + \rho_{ig}\log(i_{g,t-1}) + \epsilon_{ig,t},\ \epsilon_{ig,t} \sim N(0, \sigma_{ig}^2). \tag{32}$$

Government consumption g_t follows a stochastic process:

$$\log(g_t) = (1-\rho_g)\log(\overline{g}) + \rho_g \log(g_{t-1}) + \epsilon_{g,t},\ \epsilon_{g,t} \sim N(0,\sigma_g^2). \tag{33}$$

Similarly, the one-time transfer follows:

$$\log(TR_t) = (1-\rho_{tr})\log\left(\overline{TR}\right) + \rho_{tr}\log(TR_{t-1}) + \epsilon_{tr,t},\ \epsilon_{tr,t} \sim N(0,\sigma_{tr}^2). \tag{34}$$

For representing the effect of R&D expenditure RD_t, we specify that the TFP follows the stochastic process below[3].

$$log(A_t) = \rho_a log(A_{t-1}) + \rho_{ag}\left(\frac{RD_t}{Y_t} - \frac{\overline{RD}}{\overline{Y}}\right) + \epsilon_{a,t}, \epsilon_{a,t} \sim N(0,\sigma_a^2) \tag{35}$$

Moreover, the R&D expenditure shock takes the following form:

$$\log(RD_t) = \rho_{RD}\log(RD_{t-1}) + (1-\rho_{RD})\log\left(\overline{RD}\right) + \epsilon_{RD,t}, \epsilon_{RD,t} \sim N(0,\sigma_{RD}^2) \tag{36}$$

where ρ_{RD} is the persistency of R&D expenditure shock.

Furthermore, we allow for debt financing but assume a tax rule exists to keep the level of real debt constant in the long run. Thus, the tax rule is

$$\frac{\tau_t}{\overline{\tau}} = \left(\frac{b_{t-1}}{\overline{b}}\right)^{\psi}, \tag{37}$$

where ψ is the feedback parameter from debt to taxes. The monetary policy follows a Taylor rule,

$$\frac{R_t}{\overline{R}} = \left(\frac{\pi_t}{\overline{\pi}}\right)^{\varphi_\pi}\left(\frac{Y_t}{\overline{Y}}\right)^{\varphi_Y}\exp(\nu_t), \tag{38}$$

[3] In the second term of equation (33), we adjust the ratio of R&D expenditure to GDP by subtracting its steady-state value, ensuring that TFP eventually converges to its steady-state level. This adjustment is crucial for ensuring that the model possesses a well-defined steady state without growth trend, following Minford and Meenagh (2019).

where any variable without a time subscript denotes the corresponding steady-state value of the variable, φ_{π} Indicates how strongly the monetary authority responds to deviations of inflation from target, φ_Y is the response to the output gap, and v_t follows a stochastic process:

$$\nu_t = \rho_\nu \nu_{t-1} + \varepsilon_{\nu,t}, \varepsilon_{\nu,t} \sim N(0, \sigma_\nu^2). \tag{39}$$

2.5 Market Clearing Conditions

The labor market is in equilibrium when the labor demand by the intermediate goods firms $h_t \equiv \int_0^1 h_{j,t}\, dj$ is equal to the labor services supplied by workers. Similarly, the capital rental market is in equilibrium when the demand for capital by the intermediate goods firms $k_t \equiv \int_0^1 k_{j,t} dj$ equals to the capital supply. The monetary policy rule determines the nominal interest rate. In order to maintain money market equilibrium, the money supply adjusts endogenously to meet the money demand at those interest rates. The final good market is in equilibrium when the supply by the final good firms (Eq. 10) equals the demand by consumers and the government:

$$Y_t = c_t + i_t + g_t + RD_t + i_{g,t} \tag{40}$$

3. Calibration for quarterly macroeconomic data

Calibrating the model, we utilize Japanese data, which reflects the most pronounced aging trends worldwide, as summarized in Table 1. The model period is set to one quarter, with a subjective discount factor of $\beta = 0.99$, implying a 4% per year steady-state real interest rate.

Following existing studies, we calibrate parameters in the consumer utility function. We set the risk aversion parameter $\sigma = 1.0$ following the estimation of Sugo and Ueda (2008). In addition, μ is set at 2.0 indicating a Frisch elasticity of $1/\mu = 0.5$, in line with micro evidence (Kuroda and Yamamoto, 2008). We set the share parameter of public and private goods $\omega = 0.6$ and elasticity of substitution $\zeta = 0.4$ based on Hamori and Asako (1999) and Brückner and

Pappa (2012).

Turning to the production function, we target capital share with α=1/3 and normalize the steady state of technology level to $\bar{A} = 1$. Based on the estimation of Kameda et al. (2022), we set the elasticity of output with respect to public capital $\alpha_g = 0.2$. We set the deprecation rate $\delta = 0.028$ following Esteban-Pretel et al. (2010).

Next, we calibrate nominal rigidity parameters based on existing studies. Specifically, demand elasticity is set to $\epsilon = 11$, implying a steady-state markup of 10%. Considering estimates from Iiboshi et al. (2006), Sugo and Ueda (2008), Ichiue et al. (2013), and Kuo and Miyamoto (2016), we set the Calvo parameter to $\xi = 0.8$, indicating an average contract duration of approximately five quarters.

We determine the fraction of workers ϕ based on the ratio of the population aged 20–64 to those aged 20 or older, setting $\phi = 0.85$ according to the National Institute of Population and Social Security Research.

As for policy parameters, to maintain comparability with existing studies (Clarida et al. 1998; Fujiwara et al. 2007; Fujiwara et al. 2008) we set $\varphi_\pi = 1.5$ and $\varphi_Y = 0.1$ for the Taylor rule.

Based on relevant surveys, Explanation of the Statistical Survey of Actual Status for Salary in the Private Sector conducted by the National Tax Agency, and the Annual Report on the Public Pension System conducted by the Ministry of Health, Labour and Welfare, we set the ratio of average pensions to average salary s to 0.4. Additionally, we establish steady-state values for the government spending to GDP ratio ($\bar{g}/\bar{Y} = 0.16$), one-time transfer to GDP ratio ($\overline{TR}/\bar{Y} = 0.03$), public investment to GDP ratio ($\bar{\iota_g}/\bar{Y} = 0.06$) and debt to GDP ratio ($\bar{b}/\bar{Y} = 1.7$), following Yoshino and Miyamoto (2017). The steady-state value for R&D expenditure to GDP ratio $\overline{RD}/\bar{Y}$ is set to 0.04 based on data of Chun et al. (2012). Following Kato and Miyamoto (2013), we set government spending autoregressive parameters $\rho_g = \rho_{RD} = \rho_{tr} = 0.9$, the same as each other for comparison. Lastly, following Gali et al. (2007), we consider a moderately persistent monetary shock and set $\rho_v = 0.5$.

Furthermore, we calibrate the persistency parameter of TFP, ρ_a, and the elasticity of TFP with respect to R&D expenditure ρ_{ag} through an empirical study for Japan as follows. Chun et al. (2012) estimates the relationship between the growth rate of TFP and R&D expenditure as follows:

$$d\log(A_t) = \beta_1 \frac{RD_t}{Y_t} + \beta_2 \log(A_{t-1})$$

where β_1 and β_2 is estimated as 0.61 and -0.13, respectively. We can re-write this regression equation as follows:

$$\log(A_t) = \beta_1 \frac{RD_t}{Y_t} + (1+\beta_2)\log(A_{t-1})$$

Therefore, we can calibrate the values of ρ_a and ρ_{ag} to match the stochastic process of TFP in Eq. (33) with this regression equation.

$$\begin{cases} \rho_a = 1 + \beta_2 = 0.87 \\ \rho_{ag} = \beta_1 = 0.61 \end{cases}$$

Overall, our calibration is based on existing studies and statistical data, and we believe it provides a reasonable representation of the Japanese economy.

Finally, drawing on the approach used by Yoshino and Miyamoto (2017), we set the labor participation rates ϕ at 0.85 and 0.55 respectively, to simulate the effects on fiscal policy. This method allows for a nuanced understanding of how changes in population structure can influence macroeconomic dynamics after the implication of fiscal policies. With a labor participation rate $\phi = 0.85$, we set the debt-to-taxes feedback parameter ψ to 0.1 following Mayer et al. (2010). To maintain consistent tax revenues across different population structures, we adjust ψ to 0.067 when $\phi = 0.55$. This change only affects the dynamics of lump-sum taxes and national debt, with no impact on other variables.

Table 1: Parameter values (quarterly basis)

Parameter	Description	Value	Source/Target
β	Discount factor	0.99	Data
σ	Relative risk aversion parameter	1.0	Sugo and Ueda (2008)
μ	The inverse of Frisch elasticity	2.0	Kuroda and Yamamoto (2008)
ω	Share parameter of government consumption	0.6	Hamori and Asako (1999)
ζ	Elasticity of utility function	0.4	Brückner and Pappa (2012)
α	Capital share	1/3	Data
α_g	Elasticity of output with respect to public capital	0.2	Kameda et al. (2022)
$\bar{A}$	Steady state of aggregate	1.0	Normalization

	productivity		
δ	Depreciation rate	0.028	Esteban-Pretel et al. (2010)
ϵ	Elasticity of demand	11	10% steady-state markup rate
ξ	Calvo parameter	0.8	Kuo and Miyamoto (2016)
ϕ	Fraction of workers	0.85	Data
φ_y	Taylor rule coefficient for output	0.1	Fujiwara et al. (2008)
φ_π	Taylor rule coefficient for inflation	1.5	Fujiwara et al. (2008)
ψ	Feedback parameter in the tax rule	0.1 and 0.067	Mayer et al. (2010)
s	Social security benefits to wage ratio	0.4	Annual Report on the Public Pension System
$\bar{g}/\bar{Y}$	Government spending to GDP ratio	0.16	Yoshino and Miyamoto (2017)
$\overline{TR}/\bar{Y}$	One-time transfer to GDP ratio	0.03	Yoshino and Miyamoto (2017)
$\bar{\iota_g}/\bar{Y}$	Public investment to GDP ratio	0.06	Yoshino and Miyamoto (2017)
$\bar{b}/\bar{Y}$	Debt to GDP ratio	1.7	Yoshino and Miyamoto (2017)
$\overline{RD}/\bar{Y}$	R&D expenditure to GDP ratio	0.06	Chun et al. (2012)
ρ_g	Persistency of gov. consumption shock	0.9	Kato and Miyamoto (2013)
ρ_v	Persistency of monetary policy shock	0.5	Gali et al. (2007)
ρ_{tr}	Persistency of one-time transfer	0.9	Kato and Miyamoto (2013)
ρ_{RD}	Persistency of gov. R&D expenditure shock	0.9	Kato and Miyamoto (2013)
ρ_a	Persistency of TFP	0.87	Chun et al. (2012)
ρ_{ag}	Elasticity of TFP with respect to R&D expenditure	0.61	Chun et al. (2012)
ϕ	Labor participant ratio	0.85 and 0.55	Yoshino and Miyamoto (2017)

4. Quantitative Analysis

This section will consider how aging change the macroeconomic effects of the four types of government fiscal policies, i.e., government consumption on public goods, g_t, universal one-time government transfers to all generations, TR_t, public investment in infrastructure $i_{g,t}$, and the R&D expenditure augmenting TFP, RD_t.

In the steady state, the ratios of the four fiscal expenditures to GDP vary, as shown in Table 1. When applying a 1% policy shock to each, the actual increase in expenditure differs for each type. For example, a 1% shock in government consumption leads to a 0.16% rise in the GDP's steady state value. In contrast, a 1% one-time transfer shock results in only a 0.03% rise. So, it's not accurate to compare these policies by just using a 1% shock. To make a fair comparison, we adjust the shock size so that the initial increase in each expenditure type is equal to 0.01% of the GDP's steady-state value.

Before the comparison, we show the impulse responses to a 0.01% GDP increase in government consumption, assuming no complement effects with private consumption in Figure 2 as a benchmark.[4] These responses, as expected, closely resemble the outcomes in the standard Real Business Cycle model. The anticipated future tax burden on workers triggers a negative wealth effect, leading to a reduction in their consumption. This effect, in turn, raises labor supply and savings. However, the rise in government consumption outweighs the decrease in private consumption, thereby boosting aggregate demand. In the capital market, the additional national debt absorbs households' savings, diminishing the supply of productive capital. Despite this, the expansion of aggregate demand increases capital demand, overwhelming the supply. Consequently, the real interest rate rises, and private investment is crowded out. In the labor market, the increase in labor supply exceeds the heightened labor demand, causing a decline in real wages. In a parameter setting reflecting the Japanese economy, the increased real interest rate and decreased real wage lead to a rise in the marginal cost of intermediate goods for firms, resulting in an increase in the inflation rate. Furthermore, the central bank raises the nominal interest rate through the Taylor rule.

Following the initial shock, the increment of government consumption declines. However, the accumulation of debt continued, leading to a sustained rise in real interest rate. Consequently, the marginal costs and inflation rates also increases, along with nominal interest rates. Also, this increase in real interest rate decreases the labor supply through factor substitution, which makes wage recovers to its steady state.

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[4] In this case, we set the share parameter, ω, for private consumption in the utility function to 1. Consequently, government consumption does not augment the marginal utility of private consumption and becomes a kind of 'wasteful expenditure'.

Let us now examine the effects of aging on this fiscal spending, comparing macroeconomic responses under two different demographic structures, $\phi = 0.85$ and 0.55. Given the complexity of causal mechanisms involved, we categorize these effects into two components: the demand-side aging effect and the supply-side aging effect.

On the demand-side, aging works to weaken the policy effects. Aggregate consumption consists of the weighted sum of workers' and retirees' consumption. An increase in government expenditure decreases workers' consumption through the negative wealth effects. Meanwhile, aging means a decrease in the share of workers in total population. Under our parameter settings, this decreased share effects overwhelms the negative wealth effects. Therefore, aging reduces the increase in aggregate consumption that government aims to expand. We call this mitigation effect of aging "the demand-side aging effect." Note that retirees are characterized by their Rule-of-Thumb behavior but shielded from the volatility of labor income due to their stable pension incomes. [5]

On the other hand, aging concentrates the tax burden on a smaller amount of workers. Therefore, when the government increases fiscal expenditure in the aging economy, the resultant reduction in workers' lifetime income amplifies the increase in factor supply: labor supply and saving. We refer to this factor-increasing effects as "the supply-side aging effect."

Based on these two-side effects, let us consider the total aging effect. When the government expands their consumption in an aging economy ($\phi = 0.55$), aging works to mitigate the policy effect through the demand-side aging effects, resulting in a smaller decrease in aggregate consumption. As evident, this leads to a greater increase in aggregate demand, and subsequently, in labor and capital

[5] This setting is different from Gali et al. (2007), which also introduced a segment of households—those adhering to the Rule-of-Thumb consumption behavior—into their model. These households do not save and thus their consumption is equal to their labor income. Gali et al. (2007) reported that an increase in government consumption not only elevates the labor income of these Rule-of-Thumb households but also intensifies the positive repercussions on aggregate consumption and output.

demand. On the other hand, the supply-side effects are amplified by aging, resulting in a greater increase in factor supply. In the labor market, the supply overwhelms the demand; therefore, the real wage is lower than in the case of $\phi = 0.85$. In contrast, real interest rates become higher in the capital market. Under our parameter setting, the changes in factor prices does not change the marginal cost of intermediate good for firms, thereby have a little influence in the inflation rate and nominal interest rate

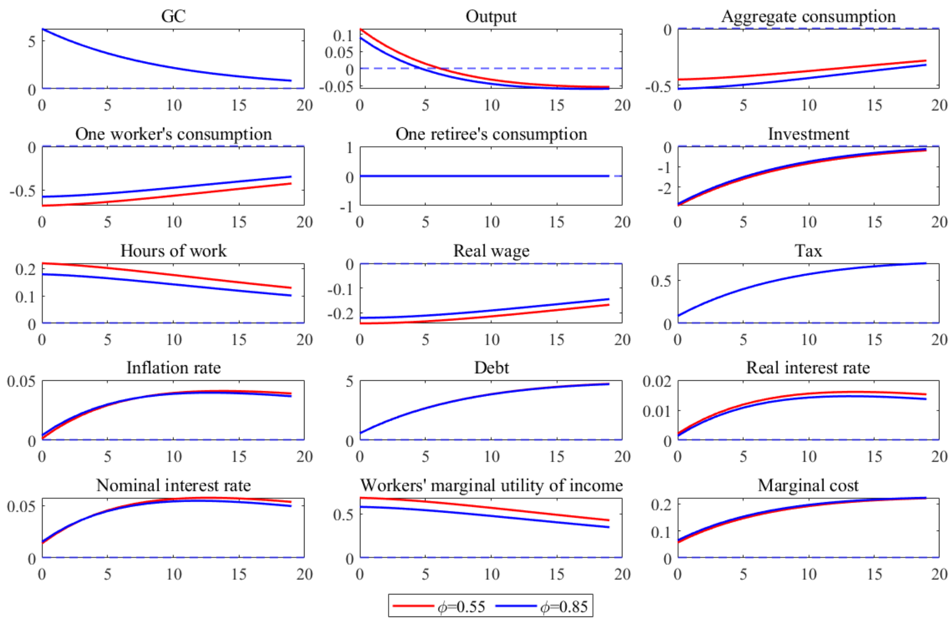


Figure 2: Impulse responses to a 0.01% increase of GDP in government consumption without complimentary effect
(Basis point deviation from steady state values)

Note: Impulse responses reflect basis point deviations from steady-state values. Red lines labeled "ϕ=0.85" show responses from the model with higher labor participation, while blue lines labeled "ϕ=0.55" show responses from the model with lower labor participation.

4.1 Case 1: Effects of an increase in government consumption with complimentary effect on private consumption

Figure 3 shows the impulse responses to a 0.01% GDP increase in government consumption that has the complement effects as shown in Eq. (4). In this case, since the government consumption raises the marginal utility of consumption of workers, it bolsters aggregate consumption to large extent. Therefore, aggregate demand increases more than in the benchmark case, leading to higher demand of labor and capital. However, to compensate the increased consumption, workers supply both factors more than in the benchmark case, causing a greater drop in real factor prices. Similar to the benchmark case, changes in factor prices result in a rise in the marginal costs under our parameter settings, causing an increase in the inflation rate.

After this initial shock, government consumption declines gradually. As a result, the marginal utility of private consumption drops down, resulting in a decline in private consumption and the factor supply of workers. As a result, real wages slightly recover, real interest rates rise, and so do nominal interest rates and inflation rates.

As seen in the benchmark case, in the aging economy with ϕ=0.55, the tax burden concentrates on a smaller number of workers, leading to a greater reduction in their consumption. However, since the effect of government consumption on increasing the marginal utility of consumption is stronger when consumption levels are lower, per capita consumption of workers in the aging economy increases more than in the younger economy with ϕ=0.85, in contrast with the benchmark case. This, in turn, through equations (4) and (5), moderates the increase in labor supply in the aging economy and consequently results in a moderate decrease in wages.

Having said that, since there are more workers in the younger economy, aggregate consumption increases more than in the aging economy. Therefore, the impact on output at the initial stage becomes more significant in the younger economy. However, this expansion of consumption through equations (4) and (5), implies a decrease in savings, and the resulting decrease in capital accumulation shrinks production. Thus, the long-term policy effects are smaller in the younger economy.

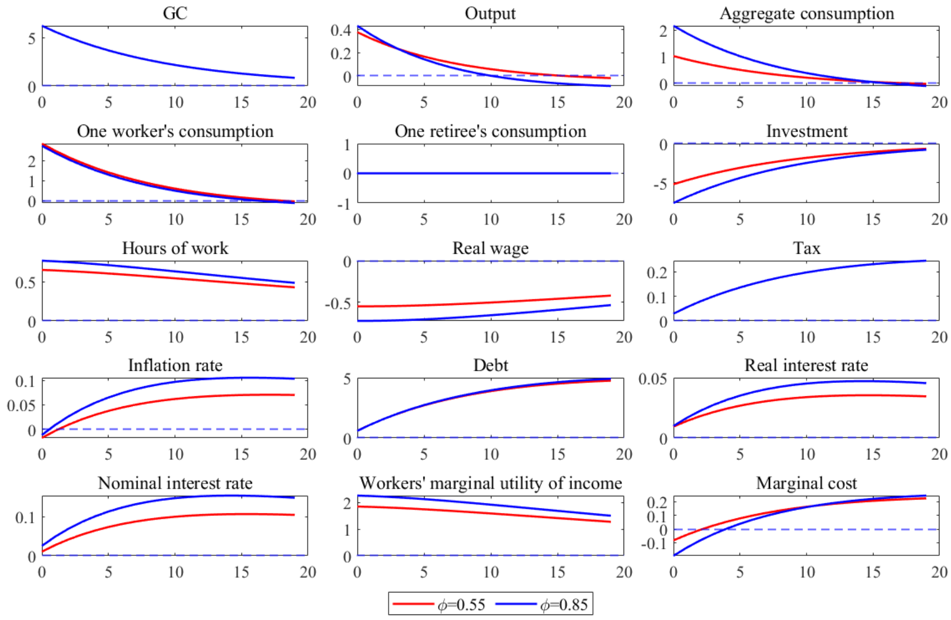


Figure 3: Impulse responses to a 0.01% increase of GDP in government. consumption (Basis point deviation from steady state values)

Note: Impulse responses reflect basis point deviations from steady-state values. Red lines labeled "ϕ=0.85" show responses from the model with higher labor participation (i.e. younger economy), while blue lines labeled "ϕ=0.55" show responses from the model with lower labor participation (i.e. aging economy).

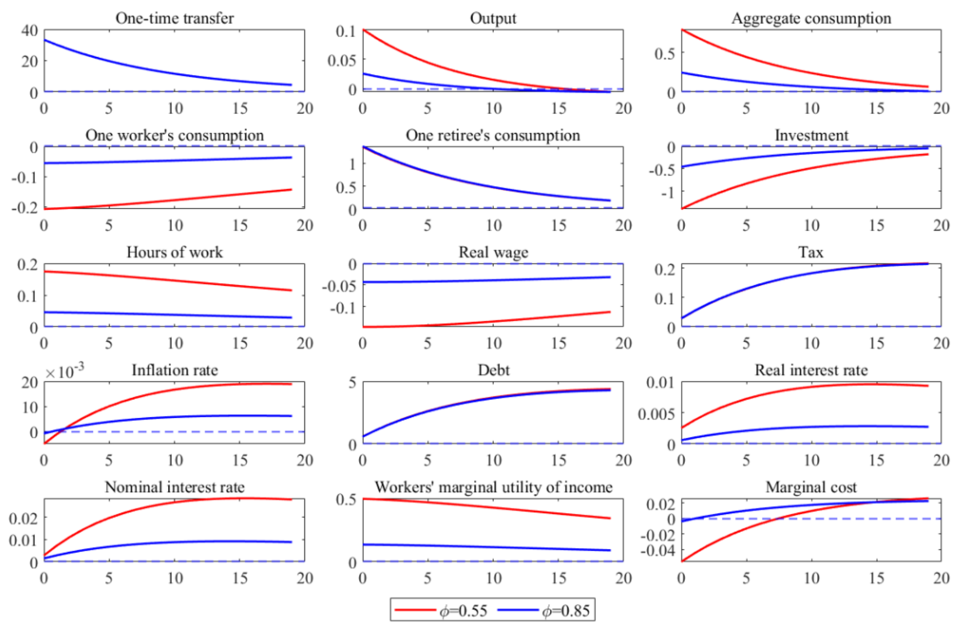
4.2 Case 2: Effects of an increase in one-time transfer to all generations

Figure 4 shows the impulse responses to a 0.01% increase of GDP in one-time government transfer to all generations. Increased transfers can be interpreted as a combination of increased taxes on workers and increased income to retirees and workers, given that this transfer is financed exclusively by future lump-sum taxes collected from workers. Note that the fact that the complemental effects of government consumption don't work for one-time transfer.

The mechanism of one-time transfer operates as follows: On one hand, the negative wealth effect from tax hikes leads to a decline in consumption of workers. Meanwhile, retirees consume all of the transfers from the government due to their rule-of-thumb behavior. As a result, aggregate consumption increases. The same factor price mechanism explained in the benchmark case, which increases real interest rates and decreases real wages, is at play here as well, resulting in a decline in a decrease in inflation rates and nominal interest rates[6].

In examining the impact of aging on the effectiveness of a one-time transfer policy under ϕ=0.55, a crucial observation is that retirees deplete the entire transfer amount. Consequently, despite the presence of the demand-side aging effect, aggregate consumption experiences a more pronounced increase in an aging economy with ϕ=0.55. The supply-side aging effect leads to a marked increase in their factor supply, subsequently resulting in a notable decrease in real wages in the aging economy. Because the effects of real wages on the marginal cost of intermediate goods surpass those of real interest rates in the initial period, the marginal costs and inflation rates become negative initially, then increases along with a rise in the factor prices.

Overall, contrasting with the benchmark case, population aging enhances the demand-side effect of transfer payments, leading to a greater increase in the inflation rate.



[6] The dynamics of the labor and capital markets are analogous to the case of government consumption in Section 4.1, and therefore, will not be elaborated further.

Figure 4: Impulse responses to a 0.01% increase of GDP in one-time transfer.
(Basis point deviation from steady state values)

Note: Impulse responses reflect basis point deviations from steady-state values. Red lines labeled "ϕ=0.85" show responses from the model with higher labor participation, while blue lines labeled "ϕ=0.55" show responses from the model with lower labor participation.

4.3 Case 3: Effects of an increase in public investment

Figure 5 depicts the impulse responses to a 0.01% increase in GDP resulting from public investment. On the demand side, public investment works similarly to the benchmark ones. Therefore, the aggregate demand increases.

Meanwhile, this policy enhances the productivity of intermediate good firms, leading to higher future income rise for workers. Therefore, the increase in factor supply from workers is less than that in the benchmark case. Simultaneously, the increased productivity moderates the factor demand compared to the benchmark. As a result, in the initial period, real wages are almost invariant and real interest rates increase more in contrast to the benchmark case. The mixed effects of this invariant wage and the increased real interest rates initially drive up the marginal costs and inflation rates.

Following these initial shocks, public investment starts generating positive externalities in the productivity of intermediate goods, causing their marginal cost to decrease as public capital accumulates. This downward trend leads to a gradual decrease in inflation. The nominal inflation rate reflects these responses through the Taylor rule. In addition, the accumulation of public capital results in an increase in output, which subsequently causes both consumption and investment to respond positively in the medium term.

In an aging economy with ϕ=0.55, the increase in output after public investment becomes lower, but the impact is quantitatively insignificant, as shown on the vertical scale. Qualitatively, the influence of aging manifests as follows:

On the demand side, the additional income generated by public investment concentrates on a smaller proportion of workers, and this, in turn, increases consumption per worker. However, the demand-side aging effect works, so a comparatively lower aggregate consumption is observed in an aging economy.

Meanwhile, because of this increased income per worker, the supply-side aging effects is weakened in the aging economy. Consequently, real wage decreases in lesser extent and real interest rates increases slightly more. These make the marginal cost and inflation rate raised up in the same manner so far.

Overall, policy effects are weakened in an aging economy akin to the benchmark. However, effects of a lowered factor supply support factor prices, so inflation rates and nominal interest rates are higher under aging.

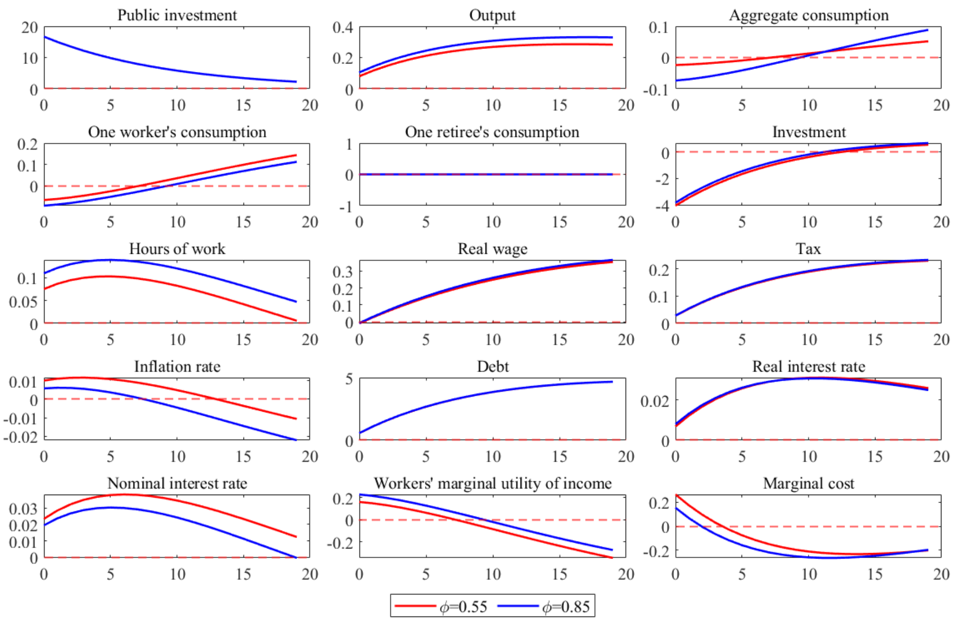


Figure 5: Impulse responses to a 0.01% increase of GDP in public investment.
(Basis point deviations from steady state values)

Note: Impulse responses reflect basis point deviations from steady-state values. Red lines labeled "ϕ=0.85" show responses from the model with higher labor participation, while blue lines labeled "ϕ=0.55" show responses from the model with lower labor participation.

4.4 Case 4: Effects of an increase in R&D expenditure

Figure 6 illustrates the impulse responses to a 0.01% rise in R&D expenditure as a percentage of GDP. Its effects differ entirely from the public investment case. The large increase in TFP resulting from government R&D expenditure enhances the lifetime income of workers. Consequently, despite the increased tax burden, there is a *decrease* in labor supply in the initial period.

After this initial shock, output remains much higher than that of the benchmark case due to the elevated TFP. This output expansion triggers deflation. Specifically, the improved TFP enhances the marginal productivity of capital and labor for intermediate goods firms, leading to a decrease in demands for both factors. Therefore, despite the decreased labor supply, real wage gradually decreases in the medium term as R&D expenses accumulate. Meanwhile, the decrease in capital demand surpasses an increase in public debt, even considering a reduction in saving, resulting in an immediate decline in real interest rates. These two factors depress the marginal cost of intermediate firms, causing a decline in inflation rate. This deflationary impact results in a decline in nominal interest rates through the Taylor rule.

Although the demand effects continue, and the cumulative R&D expenditure enhances TFP, these effects will eventually dissipate. In particular, TFP depreciation is relatively rapid, so the peak of the TFP level is at the eighth period. After that, the TFP level declines, causing the marginal cost increase. This is the reason why responses of the output and the marginal costs exhibit a hump-shaped pattern.

Similar to public investment, the quantitative impact of aging on R&D expenditure is insignificant.[7]

Since the demand side aging effect is similar to the case of public investment, we observe the lower response of aggregate consumption in an aging economy. On the supply side, workers decrease their labor supply more in an aging economy because of a higher increase in their lifetime income per capita. This leads to an amplification in the rise of real wages. In the capital market, the amplified increase in income elevates worker savings, resulting in a slightly lower real interest rate compared to the case with $\phi = 0.85$. However, changes in factor prices are minimal, resulting in similarly minimal impacts on the marginal cost, inflation rate, and nominal interest rate.

Overall, the substantial impact of R&D expenditure on output

[7] We summarize a difference in aging affects among four types of fiscal spendings in the next section.

enhancement diminishes the relative significance of changes brought about by demographic shifts. The dominant role of R&D investment in driving economic growth effectively overshadows the effects of population aging.

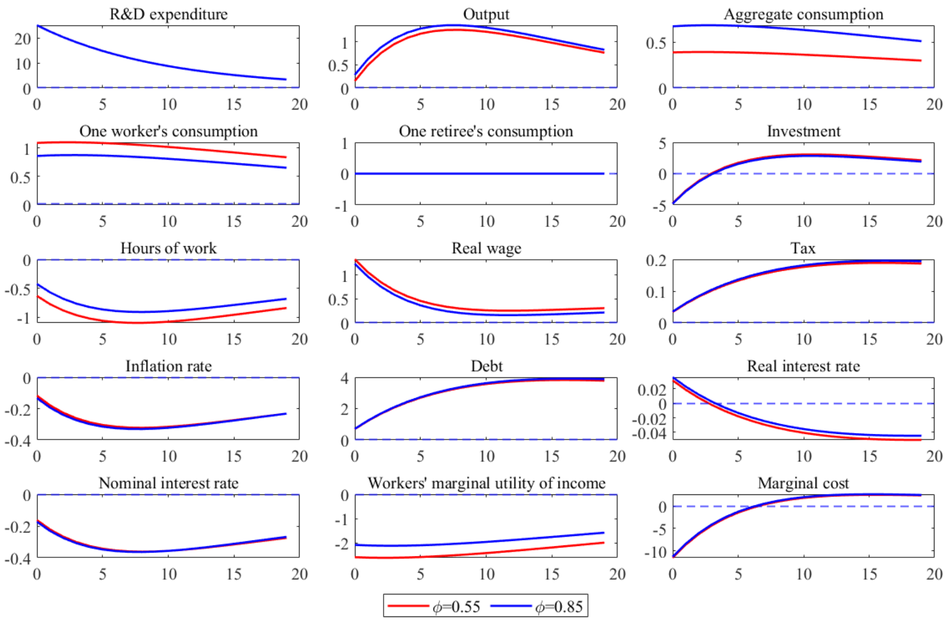


Figure 6: Impulse responses to a 0.01% increase of GDP in R&D expenditure. (Basis point deviations from steady state values)

Note: Impulse responses reflect basis point deviations from steady-state values. Red lines labeled "ϕ=0.85" show responses from the model with higher labor participation, while blue lines labeled "ϕ=0.55" show responses from the model with lower labor participation.

4.5 Summary of Policy Comparison

The results of our policy simulation are summarized as follows: Firstly, the the effectiveness of three policies (namely, government consumption, one-time government transfer and public investment) in enhancing GDP-- excluding one-time government transfer-- diminishes with the aging population. This decline is attributed to an increase in the share of policy-irrelevant, stable consumption among retirees in aggregate consumption, which, in turn, weakens demand expansion effect of these three policies. Meanwhile, the transfer exhibits a greater demand expansion effect with aging due to a larger increase in retirees' consumption. On the other hand, because aging concentrates the tax burden and income fluctuations on smaller workers, their savings and labor supply increase, thereby strengthening the policy effect on the supply side. In DSGE models, as policy-induced changes in GDP are generally determined by demand-side policies, they dictate policy effects. Therefore, aging fundamentally weakens the GDP-enhancing effects of policies other than one-time transfers and strengthens the GDP-enhancing effect of one-time transfers. Note that supply-side policy effects significantly influence factor prices and inflation rates. Secondly, regardless of the degree of aging, R&D expenditure consistently emerges as the most effective measure across all time spans. Public investment is identified as the second most effective in the long run, while government consumption takes this position in the short run. The one-time transfer is the least effective in boosting GDP in any time span except for the very short term. If R&D expenditure such as robots which will assist participation of elderly workers into labor force will have bigger impact on the economy since it will increase the value of Φ.

5. Impact of Aging Population on Fiscal Multipliers and Welfares

5-1. Comparison of Fiscal Multipliers by changes in demography

To compare the effects of four fiscal spending types and to analyze the impact of supply-side and demand-side aging effects on the multipliers further, we refer to Mountford and Uhlig (2009) to compute present value output multipliers under varying demographic structures. These output multipliers are calculated as follows:

$$PV(Y_k|_\phi) = \frac{E_0 \Sigma_{j=0}^{k} \beta^j \Delta Y_j|_\phi}{E_0 \Sigma_{j=0}^{k} \beta^j \Delta G_j|_\phi} \ , \ k \in \{5, 20\}$$

where $\Delta Y_j|_\phi$ and $\Delta G_j|_\phi$ represent the deviations of output and various fiscal expenditures from their steady states in period j after policy implementation, under the labor participation rate ϕ.

Figure 7 and Table 2 illustrates the short- and long-term fiscal multipliers under different labor participation rates.

A systematic comparison within the same panel reveals the relative effectiveness of various fiscal policies.Notably, the multiplier for R&D expenditure outperforms those of other fiscal measures across all demographic structures and throughout policy implementation timeline, establishing it as the most effective fiscal policy. Moreover, even in an economy with large amount of rule-of-thumb retirees, one-time transfer remains the least effective fiscal expenditure policy. Furthermore, although the short-term multiplier effect of public investment policies is lower than that of government consumption, its long-term impact is noteworthy.

Observing the shift of the same policy multipliers across different panels enables a comparison of policy effectiveness over time. Under any demographic structure, the multiplier for government consumption generally decreases with the periods after policy implementation k, suggesting a higher short-term economic stimulus but weaker long-term effects. The one-time transfer multiplier remains relatively stable over time. Lastly, the multipliers for public investment and R&D expenditure, dependent on the accumulation of public capital and TFP, increase with the duration of policy implementation k.

Finally, comparing fiscal multipliers within the same panel allows us to observe changes in policy effectiveness across different population structures. In the short term (k=5), the demand side aging effect predominates, reducing the multipliers for government consumption, public investment, and R&D expenditure with aging, while increasing the multiplier for one-time transfers. In the long term (k=20), the supply side aging effect becomes apparent, while the multiplier for government consumption is weakened.

In conclusion, facing population aging, governments should prioritize R&D expenditures to foster TFP accumulation, in line with the principle of wise spending. If there are significant barriers to this policy implementation, public investment emerges as a viable alternative. Lastly, even in the event of a substantial economic downturn, governments should not consider one-time transfers as a key component of their policy package.

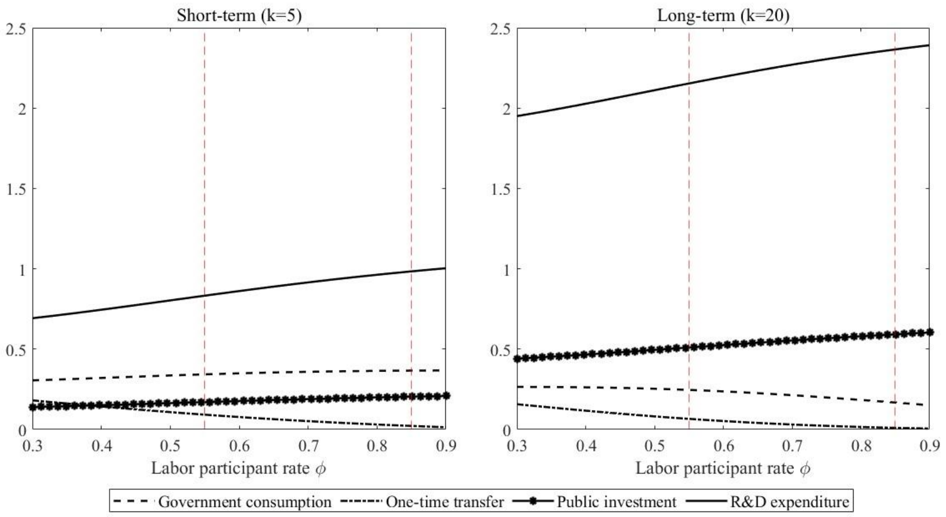


Figure 7: Present value fiscal multipliers of four fiscal expenditures under different demographic structures

Table 2: Output multiplier comparation

	Period after policy implication	**Government consumption**	**One-time transfer**	**Public Investment**	**R&D expenditure**
Young Population ($\boldsymbol{\phi = 0.85}$)	short-term ($k = 5$)	0.366	0.024	0.203	0.979
	long-term ($k = 20$)	0.171	0.011	0.589	2.359
Old Population ($\boldsymbol{\phi = 0.55}$)	short-term ($k = 5$)	0.342	0.094	0.170	0.830
	long-term ($k = 20$)	0.247	0.068	0.509	2.149

5-2. Welfare Comparison

Although the output multiplier is often regarded as an essential tool for assessing the effects of fiscal policies, it is also crucial to measure these policies' efficacy in enhancing social welfare. In the following, we construct a "welfare multiplier" for fiscal expenditures, comparing the impact of different policies on social welfare under various population structures. We construct a national welfare function utilizing the utility functions of workers and retirees as follows:

$$Welfare_t = \phi Welfare_{r,t} + (1-\phi) Welfare_{w,t},$$

where $Welfare_{w,t}$ and $Welfare_{r,t}$ represent the welfare of workers and retirees, as below.

$$Welfare_{w,t} = \frac{1}{1-\sigma}\left[\left\{\omega c_{w,t}^{\frac{\zeta-1}{\zeta}} + (1-\omega) g_t^{\frac{\zeta-1}{\zeta}}\right\}^{\frac{\zeta}{\zeta-1}}\right]^{1-\sigma} - \frac{h_{w,t}^{1+\mu}}{1+\mu} + \beta E_t Welfare_{w,t+1},$$

$$Welfare_{r,t} = \frac{1}{1-\sigma}\left[\left\{\omega c_{r,t}^{\frac{\zeta-1}{\zeta}} + (1-\omega) g_t^{\frac{\zeta-1}{\zeta}}\right\}^{\frac{\zeta}{\zeta-1}}\right]^{1-\sigma} + \beta E_t Welfare_{r,t+1}.$$

Similar to the output multiplier, we define the welfare multiplier as follows:

$$PV(Welfare_k|_\phi) = \frac{E_0 \Sigma_{j=0}^{k} \beta^j \Delta Welfare_j|_\phi}{E_0 \Sigma_{j=0}^{k} \beta^j \Delta G_j|_\phi} \ , \ k \in \{5, 20\}$$

Figure 8 and Table 3 show the short- and long-term welfare multipliers under different population structures. Overall, we find that:

Firstly, by comparing the welfare multipliers of different periods and population structures, we find that R&D expenditure has the highest welfare enhancement effect among all policies since R&D shows not only short-run but also long-run impacts on supply side.

Secondly, the lower the proportion of the elderly population in society, the higher the welfare multiplier of output-promoting policies (public investment, R&D spending). This is primarily because output-promoting policies increase the productivity of workers. As output per labor unit rises, a higher proportion of workers significantly increases the national welfare improvement.

Finally, similar to the output multiplier, the long-term welfare multiplier of output-promoting policies exceeds that of the short-term, whereas it is the opposite for demand-stimulating policies. This is mainly because the production-enhancing effect of output-promoting policies is more pronounced in the long term, fostering consumption. Moreover, in the long term, output-promoting policies reduce workers' labor hours through positive wealth effects. Both factors increase the long-term welfare enhancement effect of output-promoting policies.

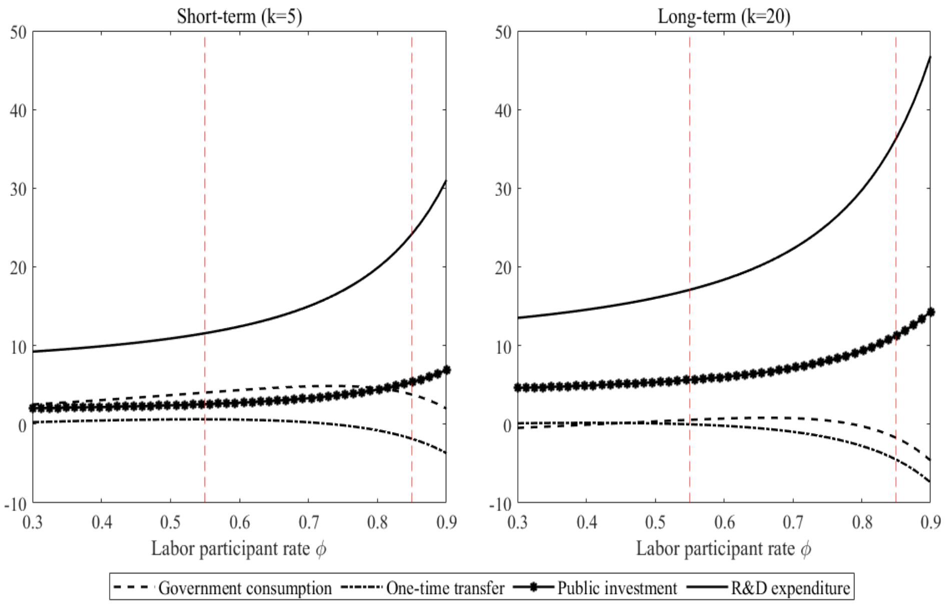


Figure 8: Present value welfare multipliers of four fiscal expenditures under different demographic structures

Table 3: Welfare multiplier comparation

	Period after policy implication	**Government consumption**	**One-time transfer**	**Public Investment**	**R&D expenditure**
Young Population ($\phi = 0.85$)	short-term ($k = 5$)	3.754	-1.548	5.102	24.281
	long-term ($k = 20$)	-1.300	-4.020	10.751	36.478
Old Population ($\phi = 0.55$)	short-term ($k = 5$)	3.990	0.627	2.501	11.490
	long-term ($k = 20$)	0.541	0.008	5.530	16.964

6. Conclusion

This study examined the channels through which demographic changes influence the effectiveness of fiscal policies, utilizing four policy tools: (i) government consumption, (ii) one-time government transfers, (iii) public investment, and (iv) R&D expenditures.

The findings of our policy simulation are summarized as follows: Firstly, the impact of government consumption, public investment, and R&D expenditure on augmenting GDP diminishes with an aging population. An increase in the share of stable retirees' consumption weakens the macroeconomic response derived from these fiscal expansions. Meanwhile, the effectiveness of the universal one-time government transfer to all generations intensifies with aging. Although aging contributes to increasing savings and labor supply among workers, the demand-side effects overwhelm these effects.

Secondly, regardless of the aging level, R&D expenditure consistently emerges as the preeminent measure across all time spans. Public investment takes a secondary position in the long run, while government consumption assumes this role in the short term. The transfer is the least effective in expanding GDP across any temporal scope without a relatively short-term perspective.

Thirdly, government consumption multipliers tend to diminish after policy implementation, indicating heightened short-term efficacy but attenuated long-term effects. Multipliers for the transfers persist at a low magnitude, whereas those associated with public investment and R&D expenditure exhibit an upward trajectory contingent upon the accumulation of public capital and TFP. These tendencies become noticeably pronounced with the progression of aging.

Much remains for further research. To delve deeper into the channels through which aging impacts the effectiveness of fiscal policy, this study employed a relatively simplified market structure model akin to Yoshino and Miyamoto (2017). However, given the substantial social security pressures induced by aging and their profound implications for public finances, incorporating the financial risks of public debt becomes crucial in future research. Kameda (2014) highlighted that persistent increases in national debt could lead to a rise in long-term interest rates, weakening its effectiveness through the crowding-out effect.

For a more comprehensive understanding of this process, future models should incorporate financial frictions like Fernández-Villaverde (2010) and Ashihara and Kameda (2018). These models would specifically analyze how expectations of rising national debt due to aging affect the lending behaviors of the financial sector and how these changes further influence the effectiveness of fiscal policy. This allows for a more detailed analysis of the overarching impacts of aging on the efficacy of fiscal policy.

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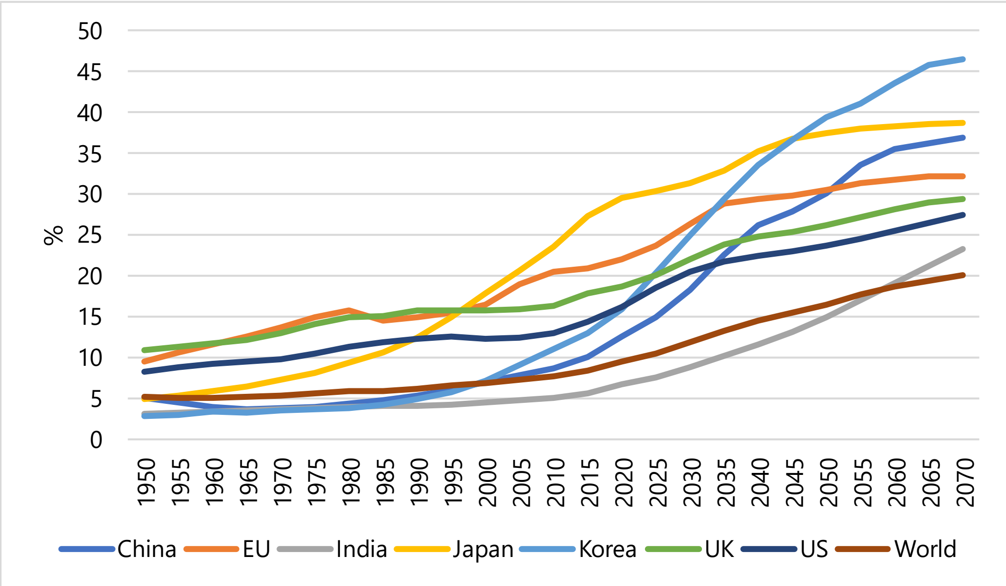
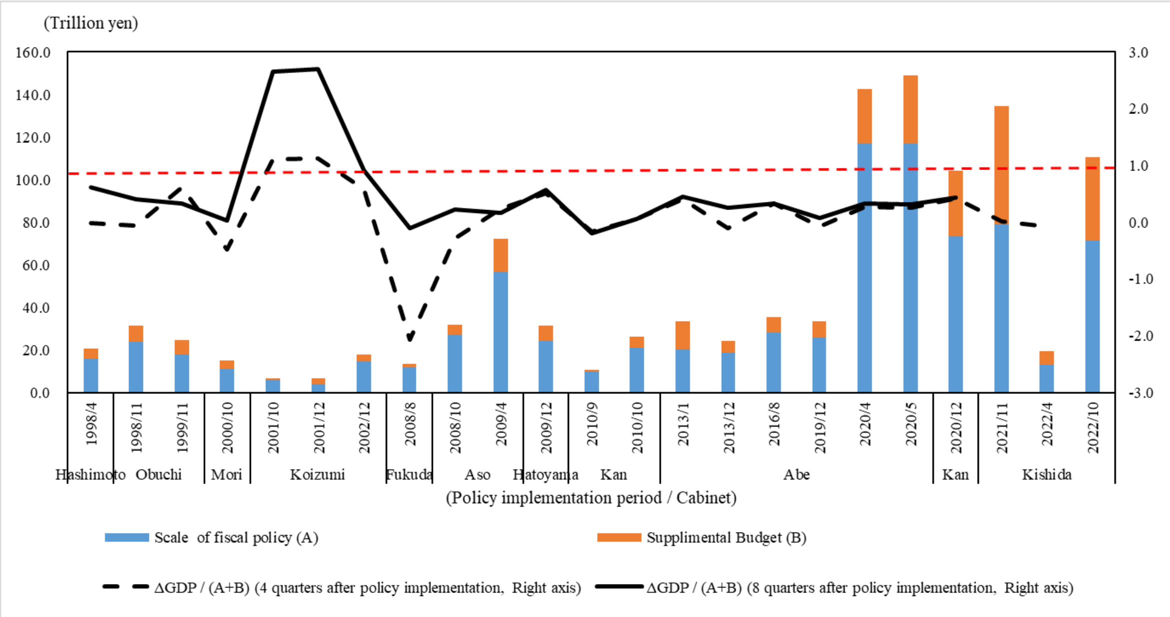
Figure 1: Share of population aged 65 and older.



Source: United Nations



Source: https://honkawa2.sakura.ne.jp/5090.html and Cabinet Office, National Accounts of Japan (SNA)

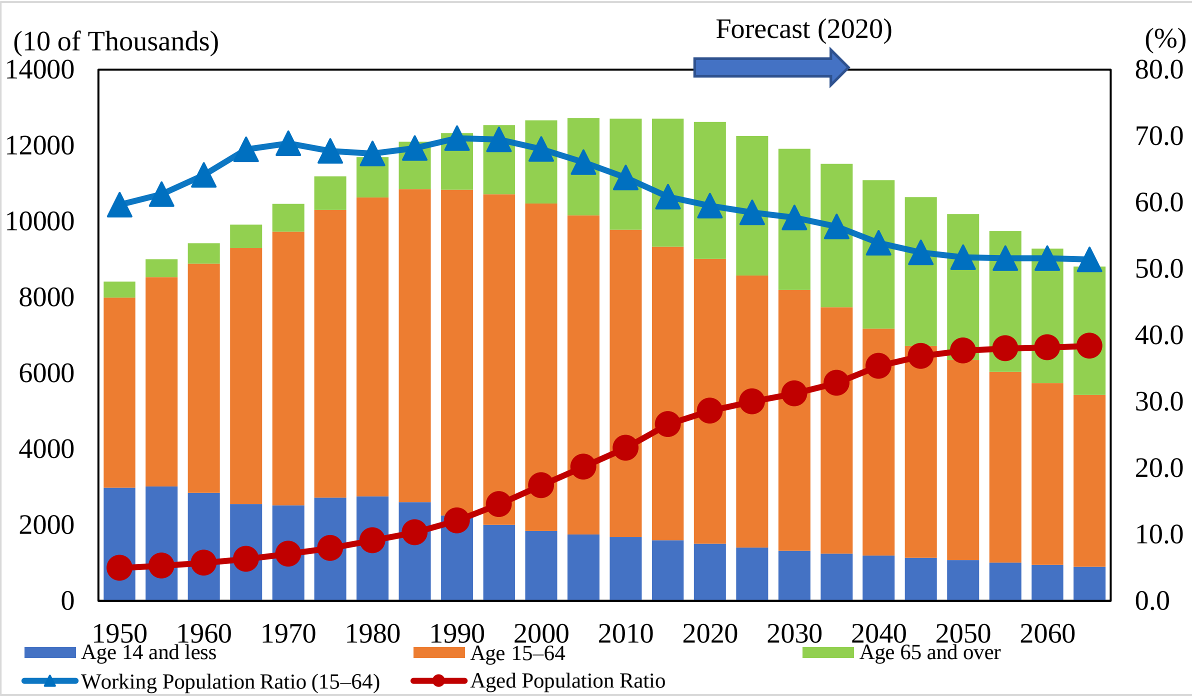
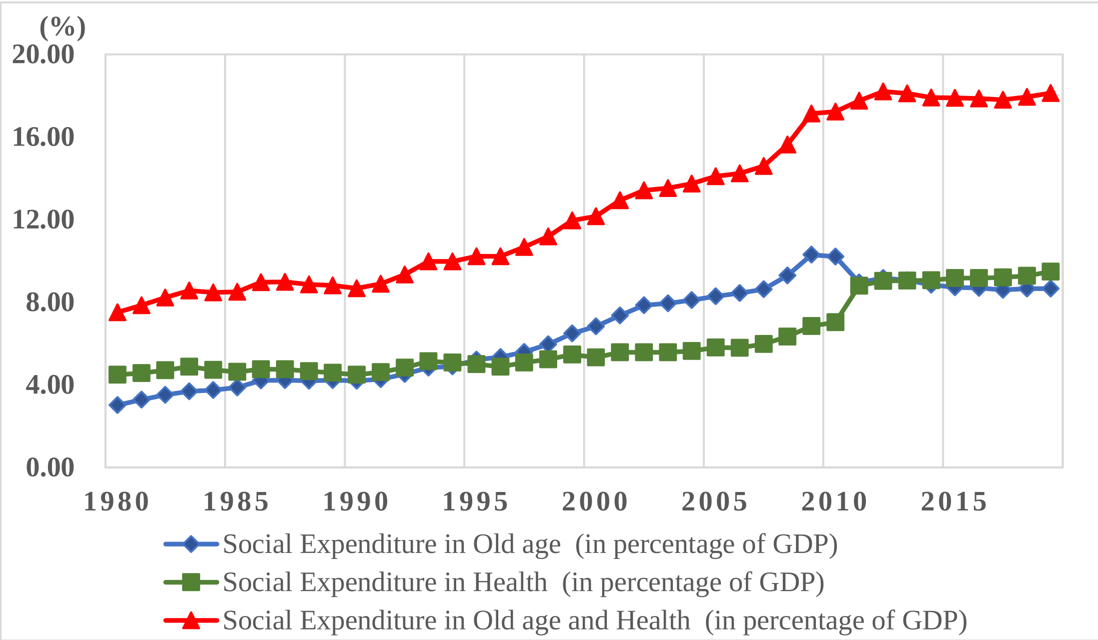


Figure 2: Population Aging of Japan

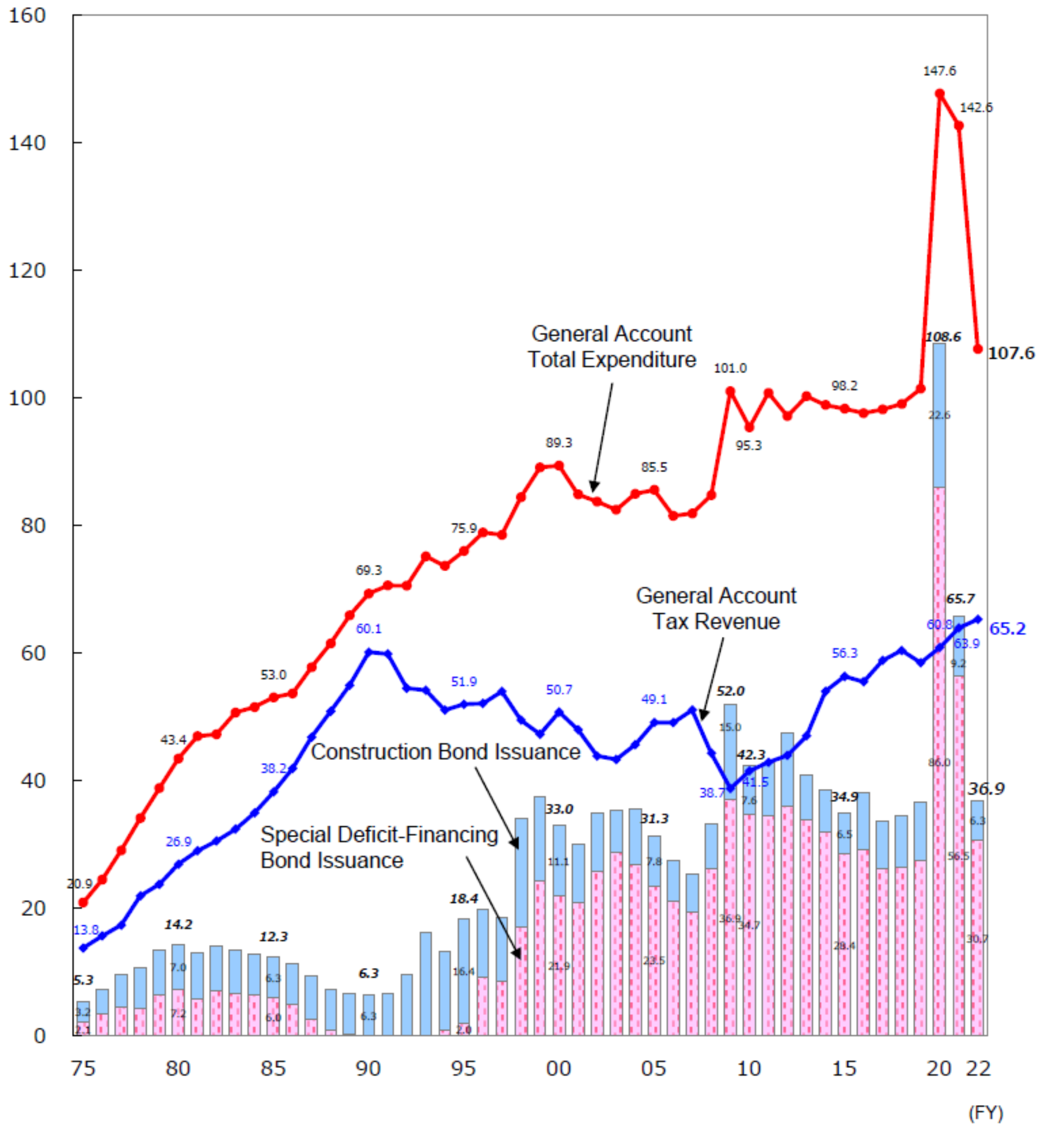
Source: Ministry of Internal Affairs and Communication

Figure 3: Social expenditure in health and elderly care (1980－2019)



Source: National Institute of Population and Social Security Research

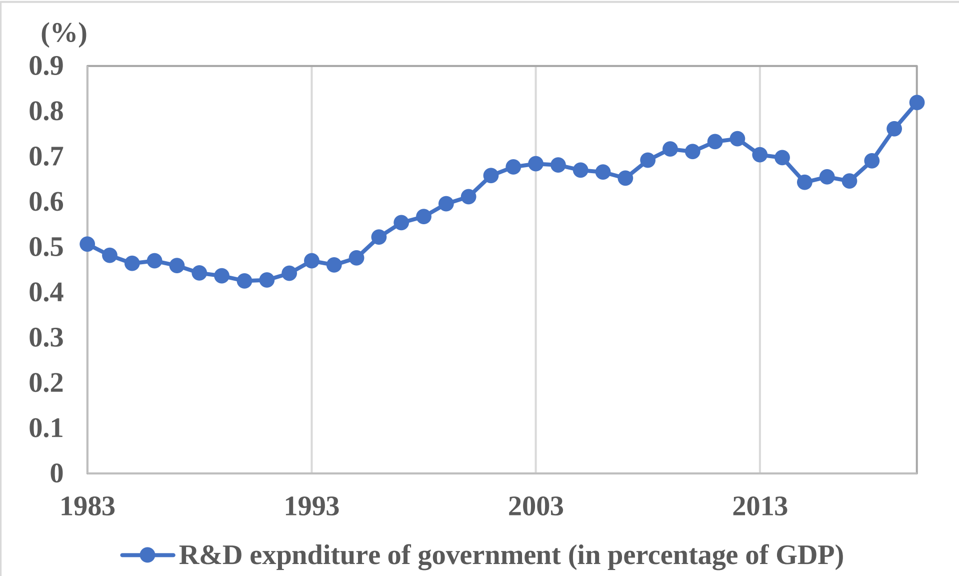
Figure 4: Japan's Government Expenditures and Tax Revenues (Unit: Trillion Yen)



Source: Ministry of Finance

Figure 5: R&D expenditure of Japanese government (1980－2019)

Source:



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