論　　文

Population Aging and the Impact on Industrial Structure in Japan from a Multi-Sector OLG-CGE Model Perspective＊

By Shin KIMURA＊＊

Abstract

One of the major impacts of population aging is the increasing demand for medical and long-term care services. With respect to the anticipated increased demand for healthcare, how social security benefits and burdens are harmonized has become an important issue. In terms of industrial activity, the healthcare industry is labor intensive, and there is the possibility of labor force shortages. Will an increase in demand for medical and long-term care services due to the aging of society increase the social burden and lead to a decrease in gross domestic product, or will the growth of healthcare industries positively affect other industries and lead to economic growth? How will labor demand in medical and long-term care industries affect other industries? To address these research questions, this study developed a multi-sector dynamic computable general equilibrium model with overlapping generations (multi-sector OLG-CGE model) to produce quantitative estimates by simulation. The simulation results showed that the increasing demand for healthcare due to population aging led to slightly lower economic growth by increasing the social burden and fiscal deficits in the long run. From the perspective of sectoral analysis, healthcare and B to C manufacturing industries grew in the short term, while other industries experienced a negative impact in the long run.

JEL Classification Codes: C67, C68, D58, E17, H51, H55, H68, I15, J11, J20, O41
Keywords: Population Aging, Healthcare demand, Industrial structure, Dynamic CGE model

＊ This research was conducted as a part of the Economic and Social Research Institute (ESRI) research project (International Collaborative Research 2019-2020: Working Group on People’s Security and Sustainability of Related Institutions for 2025 and beyond). I would like to thank all of the participants for valuable comments and suggestions. This research was also supported by JSPS KAKENHI Grant Number 16K03639.
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人口高齢化による医療介護需要の増加と産業構造への影響：多部門世代重複モデルによる動学的応用一般均衡分析

木村 真

＜要旨＞

人口高齢化がもたらす大きな影響の一つが医療・介護需要の増大である。予想される医療介護需要の増大に対し、社会保障の面からは給付と負担のバランスをいかにとるのかが課題となっている。また、医療や介護を一つの産業としてみた場合、医療介護産業は労働集約的な産業であり、需要の増大に応えられるだけの労働力を確保できるのかが課題となっている。医療・介護需要の増大による社会保障負担の増加で経済成長は落ちるのか。それとも、需要の増加が成長エンジンとなり、そのプラスの影響が他の産業に波及することで経済成長が促進されるのか。また、人口減少により希少な労働力が医療介護産業に集中すれば、他産業にどのような影響が及ぶのか。これらの疑問に答えるため、本稿では多部門世代重複モデル（Multi-sector OLG model）を構築し、これを用いて分析した。分析の結果、医療・介護需要の増大は成長を鈍化させることが示された。また、短期的には B to C 産業でプラスの効果が見られるが、長期的には高齢化に財政再建の効果が加わって、教育産業と不動産業、B to B 産業や建設業などが負の影響を受けることが示された。最後に、政府の機械的試算では人材確保に際して他産業との間で競争となる部分が加味されていないため、本研究に比べて就業者数の見込みが高めに出ることが示された。

JEL Classification Codes: C67, C68, D58, E17, H51, H55, H68, I15, J11, J20, O41

Keywords: 多部門世代重複モデル、医療・介護、産業構造、就業構造

1. Introduction

Japan has long been concerned about its aging population and the accompanying increase in social security costs. The proportion of people with illness increases with age, as does the demand for healthcare. The increase in the number of people in need of medical and long-term care has raised concerns among the working generation, who support the financial resources for social security. When elderly people receive benefits from social insurance, the purchasing power of younger people supporting the cost of the benefits is reduced. This structure is common to pensions, medical care, and long-term care.

However, there is a major difference between pensions and medical and long-term care services in that a public pension is a transfer of income, while medical and long-term care services are accompanied by actual demand for services and directly affect the industrial structure of the economy.

Simply providing pensions to the elderly and collecting financial resources from the young will not change the income of the entire economy. The impact of public pensions on the economy is mainly determined by the means of collecting premiums from young people and firms, the impact of pension benefits on elderly people's willingness to work, and the difference in propensity to consume between elderly and young people. Similar to distortionary taxes, social insurance premiums induce distortions and reduce economic efficiency. Moreover, if people can obtain adequate old-age pensions, their willingness to work during old age will decrease due to the income effect.

On the other hand, in the field of medical and long-term care, although a portion of the financial resources for the elderly's medical expenses are collected from young people, it is not a mere transfer of funds but involves actual demands such as the use of hospitals and long-term care facilities and the purchase of drugs. Increased use of hospitals, long-term care facilities, and pharmacies will increase demand for doctors, nurses, and pharmacists as well as for medical equipment and drugs. If production activities in the medical and long-term care service industries and medical equipment and pharmaceutical industries accelerate, the impact of the increased demand will spread to the resource industries, thereby increasing the number of jobs for young people. However, while the youth labor force is valued owing to the declining birthrate and population aging, an increase in labor demand in the medical and long-term care industries implies that the labor force competition among other industries will become fierce. Ultimately, there will be some industries in which the increase in demand for medical care services will have a positive effect through the introduction of intermediate equipment and others in which the negative effect will be greater due to the loss of labor. Will an increase in demand for medical and long-term care services due to the aging of society increase the social burden and lead to a decrease in gross domestic product, or will the growth of healthcare industries positively affect other industries and lead to economic growth? How will labor demand in the medical and long-term care industries affect other industries? The aim of this study was to develop a multi-sector dynamic computable general equilibrium model with overlapping generations (multi-sector OLG-CGE model) to address these research questions and to produce quantitative estimates by simulation.

Few studies have examined the impact of population aging on the industrial structure using the framework of the multi-sector OLG-CGE model used in this study. Fougère et al. (2007) constructed a 14-sector OLG model of a small open economy using an input–output table. They assumed that the labor market in each industry was divided by occupation and qualification level and conducted a quantitative analysis of the effect of population aging on the economy and labor market in Canada. Rausch (2009) constructed a 17-sector OLG model and carried out a comprehensive analysis of the effect of population aging in Germany on the macroeconomy, such as the change in industrial structure, using input–output table data.

In Japan, Kimura and Hashimoto (2010) developed a 12-sector model of a closed economy for the first time to meet the growing demand for medical care and long-term care. This model examined the differences in results from the conventional single-sector model and the impact of these differences in fiscal reconstruction measures. Ishikawa et al. (2012) constructed a 4-sector OLG model based on the Rausch (2009) model and quantitatively analyzed the impact on current account balance as well as changes in the industrial structure. However, they assumed a finite lifespan of the household. The former did not consider intermediate input, and the latter had only 4 sectors for analyzing the industrial structure. Moreover, the burden of out-of-pocket expenses was not explicitly addressed in either case, and the impact of increased medical and long-term care costs could not be directly assessed. With a single-sector OLG-CGE model, Ihori et al. (2011) directly assessed the impact of increased medical and long-term care costs and showed that increased health benefits increased savings and accelerated economic growth. However, the effect disappeared over the long term.

In this study, we used a recursive 14-sector CGE model with OLG in a closed economy to evaluate the impact of increased medical and long-term care costs. The model was based on Hashimoto and Kimura (2010). The model has been greatly expanded to include simplification of income tax and pension benefits, introduction of intermediate input, co-payment of medical and long-term care expenses, and multiple consumption tax rates. A recursive dynamic CGE model is a dynamic version of the static CGE model, in which the savings rate is exogenous and dynamic, as in the Solow model, and the equilibrium solution is solved sequentially (Diao and Thurlow; 2012).[1] However, unlike typical recursive models, the model of this paper incorporates OLG's framework to endogenous savings decisions by assuming myopic expectations of households for future prices.[2]

The remainder of this paper is organized as follows. Section 2 presents a detailed description

[1] Hosoe (2014) and Huang and Kim (2019) are the recent studies using recursive CGE model of Japan. They also assume a constant saving propensity.
[2] This type of recursive model was developed by Hashimoto (1998), who was the pioneer of the multi-sector OLG-CGE model in Japan, followed by Kimura and Hashimoto (2010) and Hashimoto and Kimura (2010).

of the model. Section 3 describes the data and calibration procedure. Section 4 reports the simulation results. Section 5 concludes the paper.

2. The model

There is only one closed economy—Japan—with competitive markets. The mobility of labor and capital is not restricted. No private life insurance is assumed.

2.1. Households

The representative household consists of the head and their related members. The head is the decision maker of a household. The number of heads of generation *i* and age *j* (referred to as household of generation *i* and age *j*) N_j^i is defined as a fixed proportion of the population of generation *i* and age *j* $\widehat{N}_j^i$ as follows:

$$N_j^i = \zeta \widehat{N}_j^i, \tag{1}$$

where ζ is the ratio of the head to the population. Moreover, the family size of the household of generation *i* and age *j* is defined as:

$$men_j^i = \begin{cases} \widehat{N}_j^i / N_j^i & (j \geq 65) \\ \widehat{N}_j^i / N_j^i + \sum_0^{22} \widehat{N}_j^{t-j} \Big/ \sum_{23}^{64} N_j^{t-j} & (23 \leq j \leq 64) \end{cases}. \tag{2}$$

Some households have a spouse the same age as the head if the family size is over one.[3] The spouse is assumed to live in the same period as the head. In addition, the household has children if the age of the head is under 65, and the family size is over two. The number of children per household in a certain year is assumed to be equal to the number of children per household of working generations.

The household appears in the economy at age 23 and lives until age 105 at the most, with associated uncertainty concerning the time of death in each period. Thus, 83 generations of birth year *i* at age *j* coexist in each period *t* ($t = i + j$).

The household has no motives to leave any assets except for an accidental bequest due to death. Let ψ_j^i denote the survival rate of generation *i* from age *j* to *j*+1.

The household of generation *i* is assumed to maximize the following lifetime utility,

$$U(C_j^i) = \sum_{j=23}^{105} \psi_j^i \left(\frac{1}{1+\delta}\right)^{(j-23)} \frac{\left(C_j^i\right)^{1-\gamma^{-1}}}{1-\gamma^{-1}}, \tag{3}$$

[3] The family size is calculated in average. For example, if the family size is 1.2, there exists 0.2 spouse in the family on the calculation. It seems curious but it can be considered that there exist 10 households, consisting of 8 spouseless households and 2 households with a spouse.

where C_j^i is the composite consumption of generation *i*, γ the inter-temporal elasticity of substitution, and δ the pure rate of time preference. The composite consumption consisting of each consumption of good and service produced by the industrial sector *m* except for the healthcare sector (*m*=*hc*) is given by:

$$C_j^i = \prod_{m \neq hc} \left(c_{m,j}^i\right)^{\lambda_m}, \qquad \sum_{m \neq hc} \lambda_m = 1, \tag{4}$$

where λ_m represents expenditure shares for each good and service *m*.

The budget constraint of the household of generation *i* at age *j* is given by

$$S_{j+1}^i = (1+r_t)\left(S_j^i + BQ^i\right) + (1-\tau_t^w)\left(1-\tau_t^p-\tau_t^h\right)w_t LS_j^i + \left(1-\tau_t^{lc}\right)Z_j^i - \varphi H_j^i - q_t C_j^i, \tag{5}$$

where *r* denotes the interest rate, S_j^i is its savings, and BQ^i is the bequest received by generation *i* at the end of period *t*. Savings held by the household at the time of death are left as accidental bequests, and the household is assumed to receive them at age 33. The household supplies labor force LS_j^i inelastically until retirement at the end of age 64. w_t is the wage rate per efficiency unit of the labor force, and $w_t LS_j^i$ is the gross labor income. The contributions of public pension and public health insurance are imposed on gross labor income at rates of τ_t^p and, τ_t^h, respectively. These are deducted from the taxable income when the labor income tax is imposed at the rate of τ_t^w.

The pension benefit Z_j^i is two-tiered, consisting of a non-income-related basic pension Zb_j^i and an income-related pension Zw_j^i. The amount of the basic pension depends on the number of household members over the age of 65, since people over age 65 are eligible for the basic pension.[4] On the other hand, the only head of the household is assumed to be eligible for an income-related pension. In addition, the income-related pension age increases gradually from 62 in 2017 to 65 in 2025.[5] Therefore, some generations can receive an income-related pension while working. The calculation basis of the pension benefits is given by

$$Z_j^i = \begin{cases} Zb_j^i \cdot men_j^i + Zw_j^i & (j \geq 65) \\ Zw_j^i & (60 \leq j < 64 \;\&\; t \leq 2024) \\ 0 & (j \leq 59)\,. \end{cases} \tag{6}$$

This amount of pension benefit is adjusted through real wage indexation. Additionally, the modified indexation gradually suppresses the amount in each period until the replacement ratio reaches 50%. The adjustment period and the reduction rate are exogenously set according to the results of government projections. The pension benefit is assumed to be exempted from the income tax but taxable with respect to the contribution of long-term care insurance at the rate of. τ_t^{lc}.

Healthcare expenditure H_j^i includes both medical and long-term care expenditures. The house-

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4 The amount of the basic pension of each individual depends on total insured months during age 20-60. All of the people aged over 65 are assumed to have the same insured period here.

5 This assumption follows the case of the male in Japan.

hold needs it to be healthy in each period. To evaluate the effect of the change in healthcare expenditure, H_j^i is assumed to be exogenous. The age profile of healthcare expenditure does not change in the future, but the future increase in per capita expenditure due to technological progress will be set as in other scenarios. Denoting the age profile of medical and long-term care expenditures by $Med_{j,t}$ and $Lcare_{j,t}$, the healthcare expenditure is given by

$$H_j^i = \begin{cases} \left(Med_{j,t} + Lcare_{j,t}\right) \cdot men_j^i & (j \geq 65) \\ \left(Med_{j,t} + Lcare_{j,t}\right) \cdot \hat{N}_j^i / N_j^i + \bar{H}_{U23,t} \cdot \sum_0^{22} \hat{N}_j^{t-j} \Big/ \sum_{23}^{64} N_j^{t-j} & (23 \leq j \leq 64), \end{cases} \tag{7}$$

where $\bar{H}_{U23}$ is the per capita healthcare expenditure under the age of 23, that is, the healthcare expenditure for children.

The household is assumed to expect an exogenous future increase in healthcare expenditures due to aging. Therefore, the household will suppress consumption in the young period to prepare for an increase in healthcare expenditures in old age. Moreover, population aging results in an increase in aggregate healthcare expenditure because older people spend more on healthcare than younger people.

As social insurance for healthcare and long-term care reduces the burden, the household pays a part of the whole healthcare expenditure. φ denotes the rate of household out-of-pocket payments for healthcare expenditures. The out-of-pocket payments are assumed to be deducted from disposable income as compulsory consumption, like tax, before the final goods consumption.[6]

In the budget constraint, the value of the composite consumption must be equal to the aggregate consumption. It is assumed that the following relationship between the composite consumption, C_j^i, and consumption of final goods and services produced in sector m, $c_{m,j}^i$, holds,

$$q_t C_j^i = \sum_{m \neq hc} p_t^m (1 + \tau_t^m) c_{m,j}^i \ , \tag{8}$$

where p_t^m is the price of goods and services produced in sector m, and q_t denotes the composite price. τ_t^m is the consumption tax rate. The consumption tax rates differ depending on the sector because all of the indirect taxes in the input–output table are assumed to be treated as consumption tax. The households allocate their aggregate consumption expenditures across the final goods and services based on Eq. (4) and (8).

Assuming no borrowing constraints and perfect capital markets, the first-order condition of the household yields the following equations with respect to intertemporal and intratemporal allocation:

$$\frac{C_{j+1}^i}{C_j^i} = \left(\psi_j^i \frac{1 + r_{t+1}}{1 + \delta} \frac{q_t}{q_{t+1}}\right)^{\gamma} , \tag{9}$$

$$p_t^m (1 + \tau_t^m) c_{m,j}^i = \lambda_m q_t C_j^i \ . \tag{10}$$

[6] Ihori et al. (2011) treated medical expenditures covered by public health insurance as benefits or income.

The following condition between the composite price and each price for final goods is obtained from Eq. (4) and (10) as follows:

$$q_t = \prod_{m \neq hc} \left(\frac{p_t^m (1 + \tau_t^m)}{\lambda_m} \right)^{\lambda_m} . \tag{11}$$

2.2. Firms

Firms use primary factors, physical capital and labor force, and intermediate input goods to produce goods and services. The primary factors are mobile across sectors without friction. Firms face the following cost minimization problem in each sector:

$$\min \ \left(1 + \tau_t^{pf} + \tau_t^{hf}\right) w_t LD_t^m + \{(1 + \tau^k) r_t + \eta_m\} KD_t^m , \tag{12}$$

subject to the following set of firms' technologies,

$$V_t^m = \phi_t^m (KD_t^m)^{\beta_m} (LD_t^m)^{1-\beta_m} , \tag{13}$$

$$Y_t^m = \min \left(\frac{V_t^m}{a_{vm}}, \frac{X_t^{1m}}{a_{1m}}, \dots, \frac{X_t^{nm}}{a_{nm}} \right), \tag{14}$$

where η_m is depreciation rate, V_t^m value-added, ϕ_t^m total factor productivity (TFP), Y_t^m the amount of output, and X_t^{nm} intermediate inputs of industry *m* from industry *n*. a_{nm} is the input coefficient of sector *m* for intermediate input produced in sector *n*.

2.3. The government

The government consists of a general account, public pension accounts, public health insurance accounts, and public long-term care insurance accounts.

2.3.1. *The general account*

Expenditures include government consumption, public investment, interest payment, and transfers to social insurance accounts. The government levies labor income tax and consumption tax on the household and capital tax on firms and issues bonds in the capital market to finance expenditures. The government's budget constraint is as follows,

$$B_{t+1} - B_t = r_t B_t + \left(G_t^c + G_t^k\right) + \left(G_t^z + G_t^h + G_t^{lc}\right) - T_t, \tag{15}$$

$$T_t = \sum \tau_t^w \left(1 - \tau_t^p - \tau_t^h\right) w_t LS_t^m + \sum_m \tau_t^m p_t^m c_{m,j}^i + \sum_m \tau^k r_t KD_t^m , \tag{16}$$

where B_t and T_t denote the amount of outstanding government debt and total tax revenue, respectively. G_t^c and G_t^k are the sum of the government consumption and the sum of the public investment for each industrial good. They are assigned to each goods consumption and investment in a fixed proportion, respectively. $G_t^z, G_t^h,$ and G_t^{lc} are transfers to public pension, public health insurance, and public long-term care insurance, respectively.

2.3.2. Public pension

The revenue to finance pension benefits consists of contributions from households and firms, investment income, and transfers from the general account. The public pension holds reserve funds as a financial resource for future benefits. The budget constraint of the public pension account is

$$F_{t+1} - F_t = r_t F_t + w_t\left(\tau_t^{pf} LD_t + \tau_t^{p} LS_t\right) + G_t^z - \sum_j Z_{j,t}^{t-j} N_j^{t-j}, \quad (17)$$

$$G_t^z = \mu^z \sum_j Zb_j^{t-j} N_j^{t-j}, \qquad \tau_t^{pf} = \xi^p \tau_t^p, \quad (18)$$

where F_t denotes the amount of public pension fund. μ^z denotes the proportion of national subsidies for the basic pension set at one half. ξ^p denotes the match ratio of the employer to employee contribution with respect to the public pension. ξ^p and the contribution rates of public pensions τ_t^{pf}, τ_t^p are exogenously set.

2.3.3. Public health insurance

The public health insurance account pays a fixed portion $1-\varphi$ of households' medical expenditures to insurance medical institutions, such as hospitals, clinics, dispensing pharmacies, and not households. This payment is treated as consumption for the goods and services of the healthcare sector. The revenue to finance health insurance benefits consists of contributions from households and firms and transfers from the general account. The public health insurance account runs based on a balanced budget rule. The contribution rate is calculated to keep the budget balanced endogenously. The budget constraint of public health insurance is

$$(1-\varphi)\sum_j Med_{j,t} \widehat{N}_j^{t-j} = w_t\left(\tau_t^{hf} LD_t + \tau_t^{h} LS_t\right) + G_t^h, \quad (19)$$

$$G_t^h = \mu^h (1-\varphi)\sum_j Med_{j,t} \widehat{N}_j^{t-j}, \quad \tau_t^{hf} = \xi^h \tau_t^h, \quad (20)$$

where μ^h denotes the proportion of national subsidies to public health insurance accounts. ξ^h is the match ratio of the employer to employee contribution with respect to public health insurance.

2.3.4. Long-term care insurance

The public long-term care insurance account runs as well as the public health insurance account. The contribution rate is calculated endogenously based on the balanced budget rule. The long-term care benefits are treated as consumption for the goods and services of the healthcare sector. The budget constraint of public long-term care insurance is

$$(1-\varphi)\sum_j Lcare_{j,t} \widehat{N}_j^{t-j} = \tau_t^{lc} \sum_j Z_j^i N_j^{t-j} + G_t^{lc}, \quad (21)$$

$$G_t^{lc} = \mu^{lc}(1-\varphi)\sum_j Lcare_{j,t}\hat{N}_j^{t-j}\,, \tag{22}$$

where μ^{lc} denotes the proportion of national subsidies to public long-term care insurance accounts.

2.3.5. Investors

The transitions of aggregate physical capital stock are given by

$$\sum_m KD_{t+1}^m = I_t + \sum_m (1-\eta_m)\, KD_t^m\,, \tag{23}$$

where I_t denotes aggregate investment. Aggregate investment is financed by aggregate savings of households or public savings corresponding to government debt and public pension reserve. Investors allocate it into the investment final demand for sectoral goods in a fixed proportion θ_m.

2.3.6. Equilibrium condition

Market clearing conditions for goods and services are:

$$p_t^m Y_t^m = \begin{cases} \sum_n a_{mn} p_t^n Y_t^n + \sum_j H_j N_j^{t-j} + \hat{G}_m^c + \hat{G}_m^k + \theta_m I_t & (if\ \ m = hc), \\ \sum_n a_{mn} p_t^n Y_t^n + \sum_j p_t^m c_{m,j}^{t-j} + \hat{G}_m^c + \hat{G}_m^k + \theta_m I_t & (if\ \ m \neq hc), \end{cases} \tag{24}$$

where hat operator of $\hat{G}_m^c$ and $\hat{G}_m^k$ means excluding consumption tax.

Labor market:

$$\sum_j LS_j^{t-j} N_j^{t-j} = \sum_m LD_t^m\,. \tag{25}$$

Capital market:

$$\sum_j S_j^{t-j} N_j^{t-j} + F_t = \sum_m KD_t^m + B_t\,. \tag{26}$$

3. Data, assumptions and calibration

The data sources and calibration procedure to obtain the model parameters are described below.

3.1. Industrial activities

A social accounting matrix (SAM) was constructed to compute the parameters for industrial activity by sector using the National Accounts Statistics of Japan, at base year 2017. The number of industrial sectors was aggregated to 14 sectors from 29 of the SNA input–output table (SNA-IO table).[7] Exports

[7] The government of Japan reports two types of nationwide IO tables: the "input–output table" jointly provided by

and imports were incorporated into the final consumption of households by assuming a closed economy. Table 1 reports the sectoral aggregation that was adopted.

Table 1 Industrial sector aggregates[8]

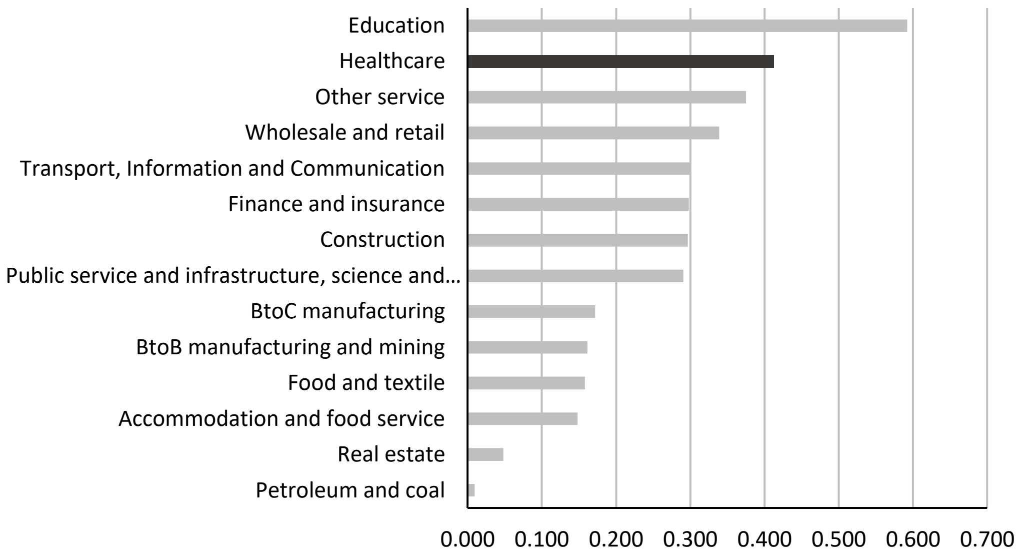
Sectors	Related sectors in the SNA-IO table
1. Food and textile	1, 3, and 4: agriculture, forestry and fishery; foods; textile products.
2. Petroleum and coal	7: petroleum and coal products.
3. BtoC manufacturing	6, 13, 14, and 16: chemical products; electrical machinery; information and communication electronics equipment; miscellaneous manufacturing products.
4. BtoB manufacturing and mining	2, 5, 8 to 12, and 15: mining; pulp, paper and wooden products; ceramic, stone and clay products; primary metal; metal products; general-purpose, production and business oriented machinery; electronic components and devices; transportation equipment.
5. Construction	18: construction.
6. Wholesale and retail	19: wholesale and retail trade.
7. Accommodation and food service	21: hotels, eating and drinking services.
8. Transport, Information and Communication	20 and 22: transport and postal services; information and communications.
9. Finance and insurance	23: finance and insurance.
10. Real estate	24: real estate.
11. Public service and infrastructure, science and technology	25 and 26: specialty, science and technology and buiness support services; public administration.
12. Education	27: education services.
13. Healthcare	28: health and social services.
14. Other service	29: other services.

Figure 1 shows the compensation of employees per unit of output by sector. The education and healthcare sectors are labor-intensive industries, while real estate, petroleum and coal are capital-intensive. Therefore, an increased demand for healthcare requires more labor force than other industries.

10 ministries and agencies every five years and the "SNA input–output table (SNA-IO table)" provided by the Cabinet Office annually. This study used the SNA-IO table, consistent with the National Accounts of Japan.

8 "B to C" and "B to B" in Table 1 mean "Business to Consumer" and "Business to Buisiness", respectively.

Figure 1 Compensation of employees per unit of output by sector



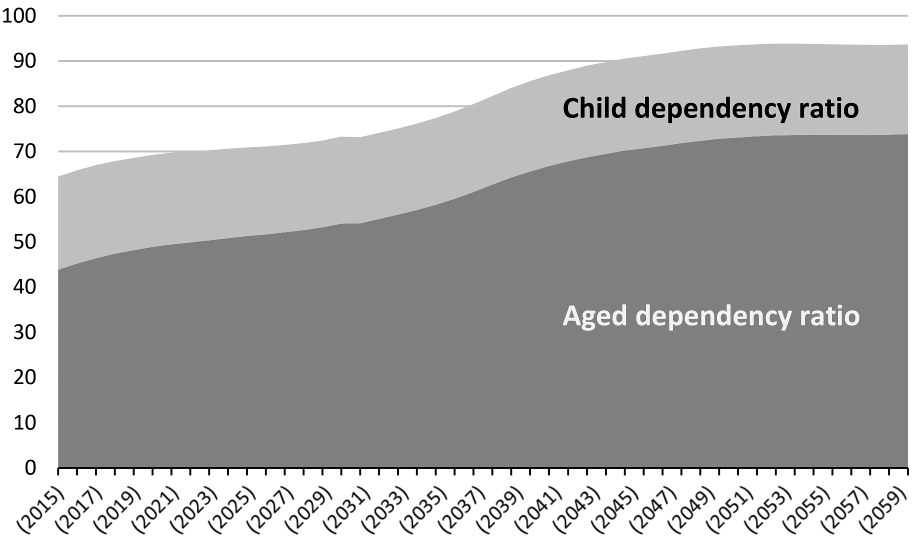
Source: SNA Input-Output table, 2017

Technical progress was assumed to be the common growth rates with respect to the total factor productivity (TFP) among sectors. In the short term, the TFP was set based on the Cabinet Office of Japan (2020) to reflect the recent situation considering the impact of the COVID-19 pandemic. In particular, the TFP decreased by 0.8% in 2018, 1.9% in 2019, 7.9% in 2020, and 3.5% in 2021 from the level of 2017. Assuming the level of 2017 is recovered in 2023, the TFP of 2022 was set to 0.9% lower than 2017. Thereafter, the TFP growth rate in the long run was set to 0.7%, which is the same assumption as the base line case of the Cabinet Office of Japan (2020).

3.2. Households

Regarding population and survival rates by age 0-105 from 2017 to 2115, the medium-fertility and medium-mortality projection of the National Institute of Population and Social Security Research (IPSS), *Population Projections for Japan: 2019*, were used. Every generation living in 2115 is assumed to die at the mortality rate by age of 2115 thereafter to solve their lifetime utility maximization problems. Figure 2 shows the medium variant projection of the dependency ratios. The rise in the dependency ratio is expected to be rapid during the 2030s due to the retirement of the second baby boomer generation in Japan.

Figure 2 Projection of dependency ratio



Source: Population projections for Japan: 2019*,* medium-fertility and medium-mortality

The decision maker of a household is the head. Their number was assumed to be the fixed proportion of insured and pensioners in the population set according to the ratio of 2017. Regarding the number of insured and pensioners in 2017, the results of *the 2019 Actuarial Valuation* of public pension were used.

The effective labor force of households was measured in wage units. The age profile of the effective labor force was set using the *Annual Report on Family Income and Expenditure Survey 2017* and adjusted to be equal to the aggregate compensation of employees in the SAM. The effective labor force was assumed to increase exogenously every year based on the future increase in labor force participation rate assumed in the *2019 Actuarial Valuation* (case 3). The age profile of savings was set using *the National Survey of Family Income and Expenditure 2014* and adjusted to be equal to the aggregate net assets calibrated.[9]

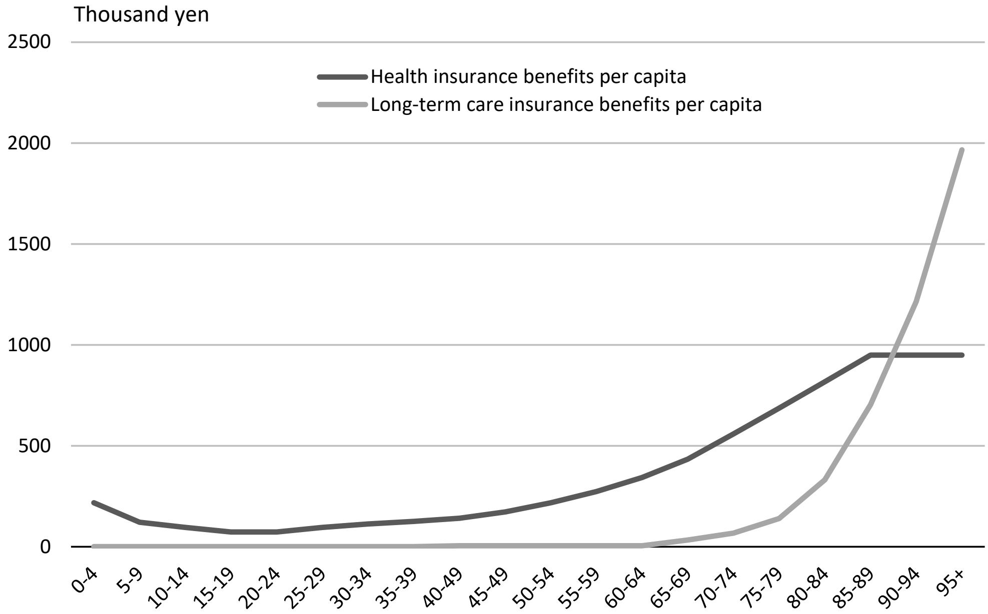
Regarding the amount of annual pension benefits, the basic pension per population aged 65 and over was calculated based on the *Annual Actuarial Report on the Public Pension System in Japan, fiscal year 2017*. The amount of the income-related pension was derived from the amount of basic pension benefits and public pension benefits of aged households in the *Annual Report on Family Income and Expenditures Survey 2017*. Some generations can receive the income-related part of their pension benefits from age 62–64 until 2024, as mentioned above. This amount is lower than the income-related pension benefits of households aged 65 because the benefits of working pensioners are reduced in the Japanese pension system. Furthermore, pension benefits basically increase at real wage growth rates every year. However, the benefits are adjusted annually through modified indexation to

[9] Both were linearly interpolated with five-year age-grouped data to obtain the data by age.

balance pension finances over a 100-year period and retain the minimum benefit level (50% replacement ratio). In terms of the annual adjustment rate deducted from the real wage growth rate, the results of the *2019 Actuarial Valuation* (case 3) were used. The end of the adjustment period was set to 2038, when the replacement ratio had reached almost 50%. The adjustment period was shorter than the results of the *2019 Actuarial Valuation* (case 3) because the adjustments of the income-related pension and basic pension were assumed to terminate at the same time.[10]

The age profile of health insurance and long-term care insurance benefits were set using the *Estimates of National Medical Care Expenditure 2019* and *Survey of Long-term Care Benefit Expenditures 2019*, respectively. Health insurance benefits of age 85+ were fixed owing to data limitations, as shown in Figure 3.

Figure 3 Age profile of health insurance and long-term care insurance benefits



The intertemporal elasticity of substitution γ was set to 0.8, as reported by Rausch (2009) and Ishikawa et al. (2012). The subjective discount factor γ was calibrated to be consistent with the aggregate consumption and savings at the base year.

3.3. The government

The consumption tax rate was increased by 1% for food and 2% for other goods every five years after

10 The *2019 Actuarial Valuation* estimates that the end of adjustment of the income-related pension is earlier than the basic pension. Especially, no more adjustment of the income-related pension is estimated in the best scenario. However, it seems to be quite difficult to reduce only the basic pension benefits that the low income elderly people more relies on it as the basic income (Kimura: 2020).

2030 and up to 15% for food and 24% for other goods in 2060 and thereafter, as unanticipated tax increases for the household. The government expenditure rapidly increased due to the COVID-19 pandemic. The increase in government consumption and public investment, except for healthcare from the base year 2017, was set to 0% in 2018, 4.8% in 2019, 67.8% in 2020, and 0% in 2021, referring to the Cabinet Office of Japan (2020). Thereafter, government expenditures, except for healthcare, were assumed to change at the real wage growth rate minus 2% every year to prevent the debt-to-GDP ratio from increasing exponentially until 2100. Government consumption and public investment, except for healthcare, were allocated to each sector in the same proportions as in the base year 2017.

Table 2 Model parameters and initial values

Parameter	Description	Value
r_{2017}	Interest rate	1.066%
ζ	Ratio of the head of household to population	0.650
γ	Intertemporal elasticity of substitution	0.8
δ	Subjective discount factor	-0.056
Zb	Basic pension benefits (per population age 65+ ,2017, yen)	712,902
Zw	Income-related pension benefits (per household, 2017, yen)	
	• age 60-64 (reduced pension for active employee)	632,575
	• age 65+	1,059,014
μ^z	Proportion of national subsidies: The Basic Pension	0.5
μ^h	Proportion of national subsidies: Health insurance	0.318
μ^{lc}	Proportion of national subsidies: Long-term care insurance	0.551
ξ^p	Match ratio of pension contribution	0.933
ξ^h	Match ratio of health insurance contribution	0.739
φ	Out-of-pocket rate for healthcare expenditure	0.257
τ^w	Labor income tax rate	0.141
τ^k	Capital income tax rate	0.299
τ^p	Pension contribution rate	0.183
F_{2017}	Pension reserve fund (Trillion yen)	271.242
B_{2017}	Government bond (Trillion yen)	882.030
G^c_{2017}	Government consumption (Trillion yen)	59.783
G^I_{2017}	Public investment (Trillion yen)	19.172

3.4. Calibration

Many parameters were calculated to reproduce the SAM based on the Japanese input–output table and the national accounts for the reference year 2017. The benchmark risk-free interest rate on the government bond of the base year 2017 was set to 1.066%. Government deficits and public pension reserve fund at the end of the reference year 2017 were based on the national accounts of Japan. The other data, including aggregate private capital stock and net assets of the households, were calculated based on the benchmark interest rate and the model. Table 2 summarizes the model parameters and initial values. Table 3 reports the expenditure share parameters of households and the consumption tax rates in the reference year 2017 for sectoral goods.

Table 3 Expenditure share parameters of households and consumption tax rates

Sectors	λ_m	τ_{2017}^m
1. Food and textile	0.078	0.166
2. Petroleum and coal	0.013	1.950
3. BtoC manufacturing	0.021	0.387
4. BtoB manufacturing and mining	0.045	0.369
5. Construction	0.000	0.009
6. Wholesale and retail	0.191	0.131
7. Accommodation and food service	0.082	0.058
8. Transport, Information and Communication	0.107	0.145
9. Finance and insurance	0.061	0.023
10. Real estate	0.225	0.058
11. Public service and infrastructure, science and technology	0.046	0.079
12. Education	0.032	0.006
13. Healthcare	—	—
14. Other service	0.099	0.112

4. Simulation results

To examine how healthcare expenditure increases affect the economy through the industrial structure, the following two cases on healthcare expenditure are explored.

In CASE1, medical expenses per capita increase at the real wage growth rate plus 0.2%, and long-term care expenses per capita increase at the real wage growth rate minus 0.5%, according to the assumption of the projection with respect to social security cost by the National Council on Social Security in 2008.[11]

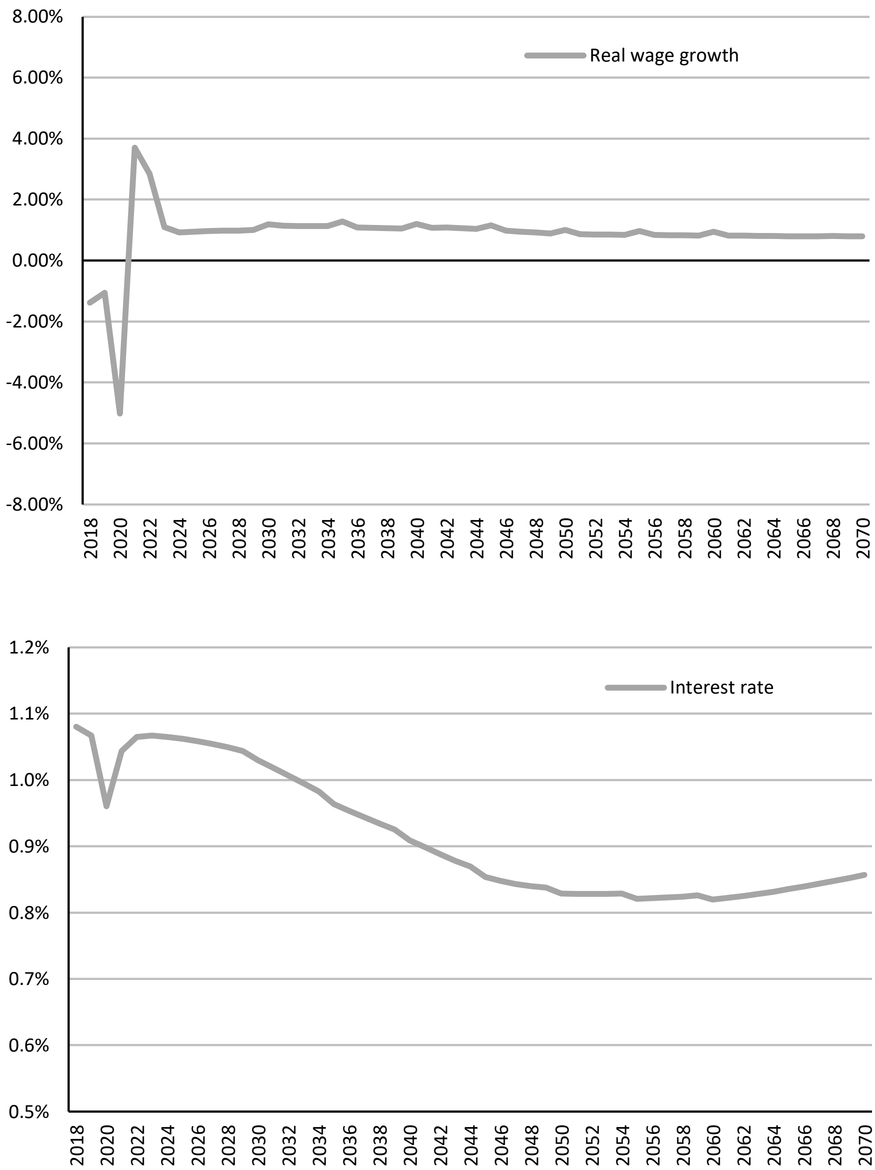
In CASE2, healthcare costs increase at a lower rate than CASE1. Medical expenses per capita increase at the real wage growth rate, and long-term care expenses per capita increase at the real wage growth rate minus 0.7%.

[11] National Council on Social Security, (2008), *Iryō, Kaigo Hiyō no Simulation Kekka ni tsuite (On the simulation results of medical and long-term care costs)*, Retrieved June 11, 2012 from https://www.kantei.go.jp/jp/singi/syakai-hosyoukokuminkaigi/iryou.html

4.1. Macroeconomic effects

Figure 4 shows the results of wage growth and interest rate in CASE1. The real wage growth is approximately 0.8%–1.0% after 2023, and the geometric mean during 2023–2070 is 0.96%. The interest rate shows trends at a lower level. However, the assumed fiscal consolidation, that is, the consumption tax increase and the government expenditure cut, reduce the government deficit and thus affect the lower interest after 2030.

Figure 4 Interest rate and real wage growth

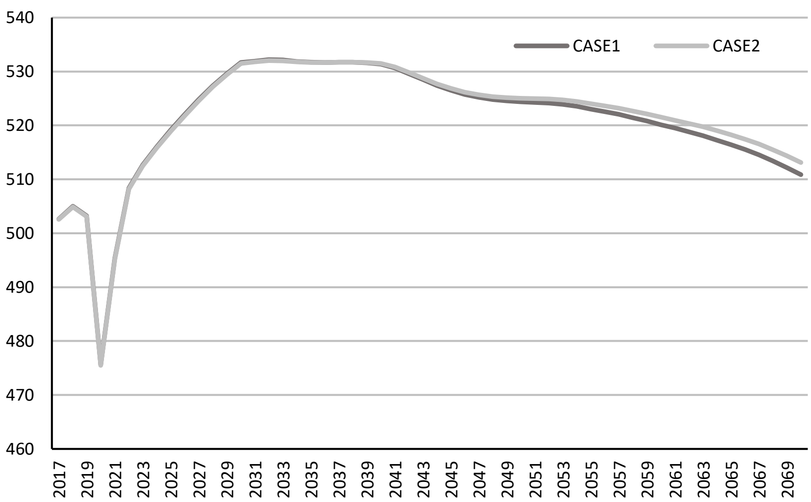


Note: Transitions in CASE1.

Figure 5 shows the effect of healthcare demand increase on real GDP in the high-increase CASE1 and lower-increase CASE2. The rising per capita healthcare expenditures result in lower real GDP in the long run. The contribution rates and national subsidies need to be increased to finance the increasing health insurance and long-term care insurance benefits. Thus, the burden of households rises, and government debt increases. In addition, increasing the social insurance contributions reduce the income tax revenue through the social insurance deduction. This also become another factor of government debt increase and the crowding-out effect. Conversely, in the short term, the real GDP growth rate in CASE1 is only slightly higher than CASE2 until 2026. This is due to the households' precautionary savings for a future increase in healthcare costs.

Using a single-sector model, Ihori et al. (2011) showed that the real growth rate rose in the short term, but the positive effect disappeared in the long run. This difference seems to result from the different assumptions with respect to healthcare insurance benefits: they treat the benefits as income in the households' budget constraint, like cash benefits, and rising healthcare costs, therefore, lead to asset accumulation in the household. By contrast, this study treated the benefits of government consumption to maintain the health of households; therefore, rising healthcare costs meant an increase in compulsory out-of-pocket expenses. Besides, not considering the decrease in tax revenue caused by increasing the social insurance deduction affects their result of positive economic growth.

Figure 5 The real GDP

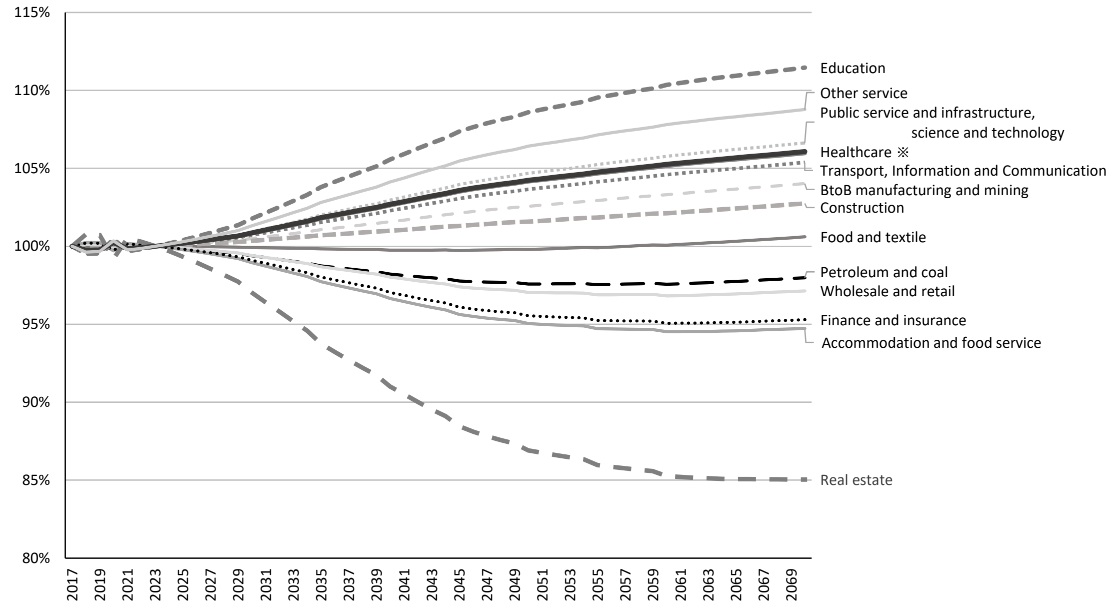


Note: GDP at factor price (i.e., consumption tax is excluded)

4.2. Sectoral impact

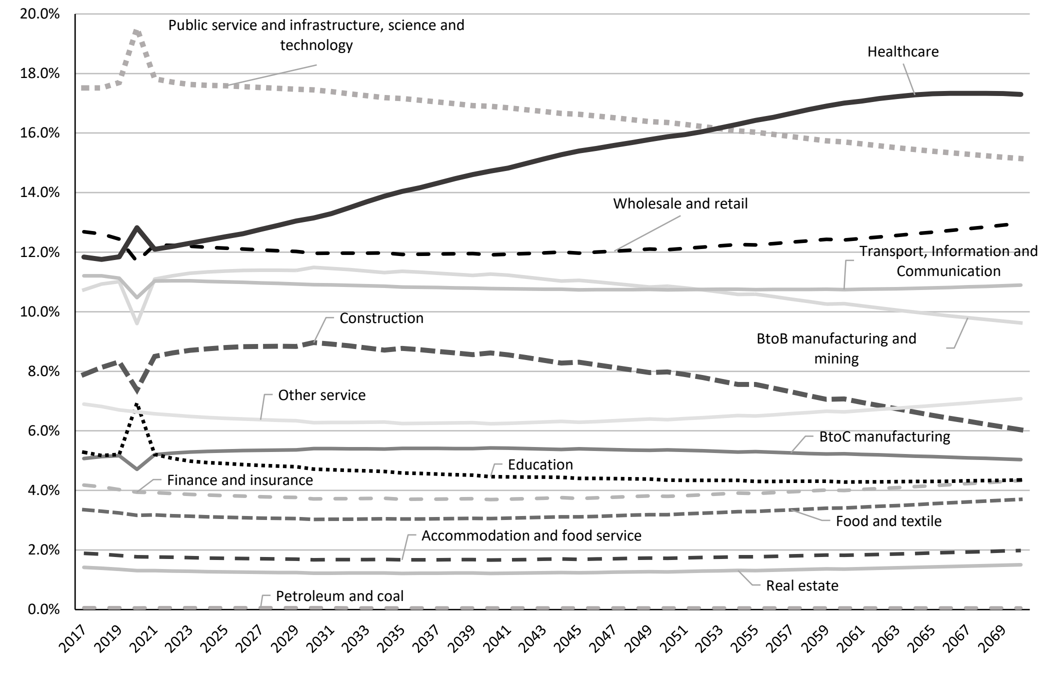
Figure 6 shows the price changes in goods and services by sector in CASE1. In the healthcare sector, the increasing demand due to population aging induced a price hike. Similarly, the price rose in some sectors: education, public services, transport, information and communication, BtoB manufacturing and mining, and construction. On the other hand, the price fell in other sectors: petroleum and coal, wholesale and retail, finance, accommodation and food service, and real estate.

Figure 6 Price changes in goods and services by sector



Note: Transitions in CASE1. BtoC manufacturing almost overlaps with healthcare.

Figure 7 Industrial distribution of employment by sector

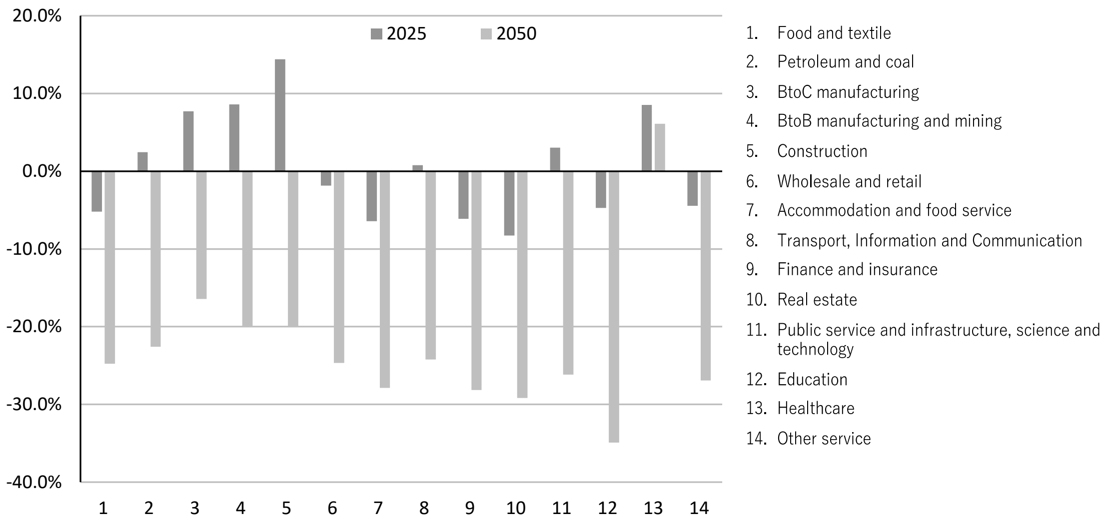


Note: Transitions in CASE1.

In the background, the change in demand for labor affects such price changes. Figure 7 shows the transitions of the industrial distribution of employment by sector in CASE1. Population aging and the increased demand for healthcare increase the labor demand of healthcare industries, and the share of the healthcare sector in total employment increases from about 12% to 17%. As a result, labor shortages occur in other sectors. In particular, labor-intensive industries such as education, shown in Figure 1 are greatly influenced. The share of employment decreases, and the output price increases in those industries.

Next, to explore the impact, Figure 8 shows the growth rates of employment by sector from 2017. Most sectors reduced employment owing to population decline in the long run. The share of employment in education and real estate became smaller, but the impacts were large. On the other hand, employment increased in some sectors in the earlier period. Employment in the construction sector and BtoB manufacturing and mining sectors rose with an increase in private capital stock but decreased based on a reduction in public investment due to fiscal reconstruction. On the other hand, an increase in employment in the BtoC manufacturing sector seems to have been induced mainly by the increased demand for healthcare. Because the input coefficient in the BtoC manufacturing sector is much larger than the others in the healthcare sector, only the coefficient on the BtoC manufacturing sector is above 0.1.

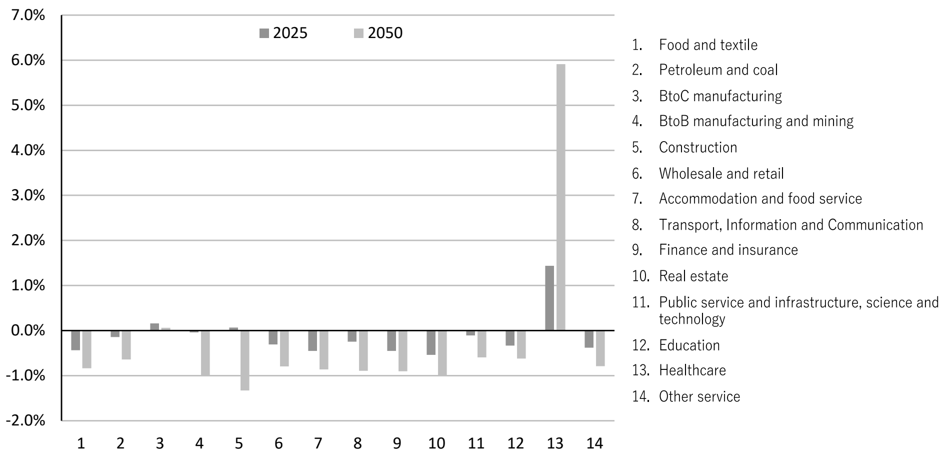
Figure 8 Change in employment by sector



Note: Changes from 2017 in CASE1.

Figure 7 and Figure 8 include the effect of assuming fiscal reconstruction. To clarify the impact of rising healthcare costs, Figure 9 shows the difference in the change in employment by sector between CASE1 and CASE2. Rising healthcare expenditures (CASE1) induce increasing employment in the B to C manufacturing sector and construction sector in the short term. At the same time, they increase the healthcare burden of households and reduce households' disposable income, thereby decreasing the demand with respect to the other sectors. Moreover, rising healthcare costs increase the fiscal deficit through national subsidies and thus decrease private investment. Therefore, employment in the B to B and construction sectors declines in the long run.

Figure 9 Difference of change in employment by sector



Note: Changes in CASE1 minus those in CASE2.

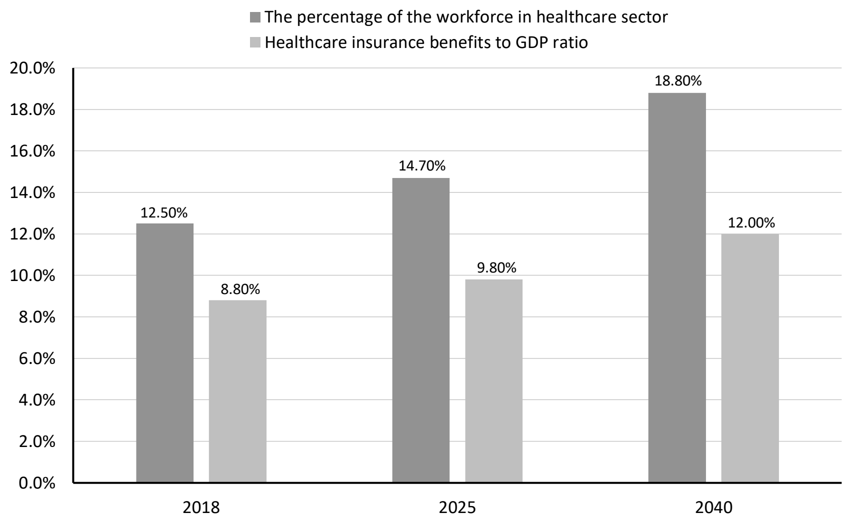
4.3. Comparison with a fixed proportion projection

The Japanese government is also interested in perspectives on social security and employment structure (Figure 10). The benefits of healthcare insurance (health insurance and long-term care insurance) are estimated to increase from 8.8% to 12.0%, and the workforce in the healthcare sector increases from 12.5% to 18.8% in the baseline case. These figures are similar to the simulation results of this study; nevertheless, the definitions are not exactly the same.

However, the government's outlook assumes a fixed proportion or linear relationship among the variables under exogenous economic scenarios. For example, the workforce in healthcare sector is estimated as a fixed proportion of the number of patients receiving medical treatment and long-term care under the assumption of the constant ratio of the patients to population. Therefore, it is important to examine how the outlook based on a fixed proportion projection is modified considering the impact on the macroeconomy and other industries using the multi-sector OLG-CGE model.

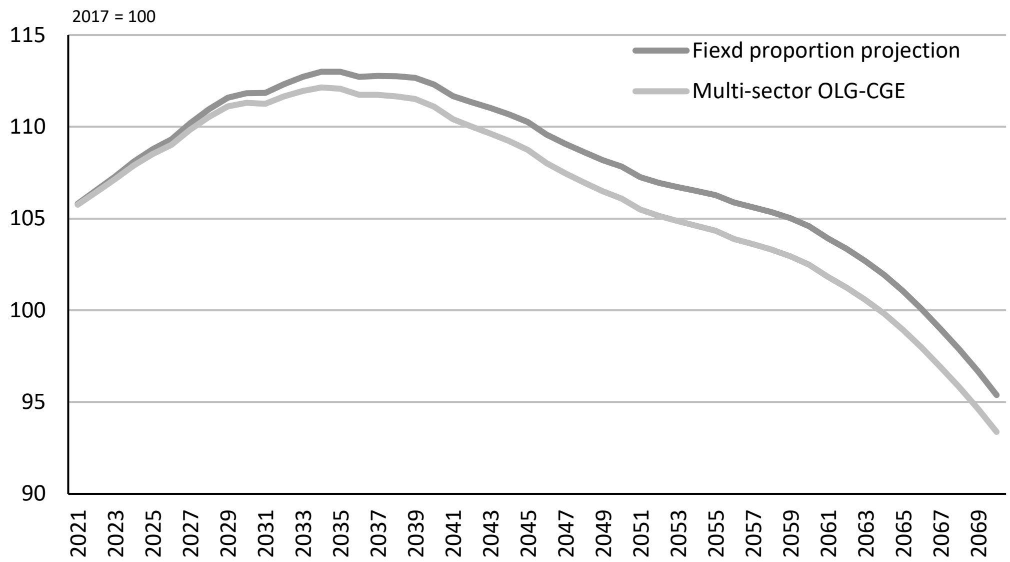
To explore this difference, Figure 11 shows a comparison between the results of CASE1 and an estimation obtained by multiplying the ratio of compensation of employees to the output in the healthcare sector by healthcare demand. The simulation results of employment in the healthcare sector are estimated at a lower level than the results based on the fixed proportion projection. This difference is caused by whether the supply side in the healthcare market is considered or not. The fixed proportion projection is calculated based on the estimated number of patients, that is healthcare demand, and hence the supply side is not considered. On the other hand, the simulation result of the multi-sector OLG-CGE model shows the equilibrium labor force allocation in each period, and hence both the demand side and the supply side are considered. The lower labor force in the equilibrium represents the difficulty of recruitment and retention of the labor force due to competition with the other sectors.

Figure 10 Social security outlook by the government (baseline)



Source: Social Security Outlook towards 2040 (May/2018), Cabinet Secretariat, Cabinet Office, Ministry of Finance, Ministry of Health, Labor and Welfare.

Figure 11 Comparison with a fixed proportion projection



Note: Transitions of employment in the healthcare sector.

5. Conclusion

This study explored how population aging affects the industrial structure and economic growth in Japan using a multi-sector OLG-CGE model. Population aging increases healthcare demand and social security benefits. Working generations suffer under this burden, which may decelerate economic growth. On the other hand, increased healthcare demand is growing the healthcare industry and changing the industrial structure.

The main findings of this study were that rising healthcare expenditures due to population aging are (1) decelerating economic growth, (2) increasing the share of the labor force in the healthcare sector from about 12% to 17%, (3) increasing the output and labor force in BtoC manufacturing and construction, while decreasing it in the real estate sector the most in the short term, and (4) decreasing employment in the BtoB manufacturing and mining, and construction sectors in the long run. Rising healthcare expenditures reduce disposable income while promoting households' precautionary savings. In addition, increasing health insurance and long-term care insurance benefits increase the fiscal deficit and thereby decrease private investment. The simulation results of this study showed that the effects of suppressing growth were larger.

In addition, this study showed that the government's outlook for employment in the healthcare sector is possible to be higher than the results regarding the impact on other sectors using a multi-sector OLG model. The government tends to estimate by assuming simple fixed linear relationships among the variables in the model. However, the results of this study showed how the government's outlook can be modified.

In this study, the impact of the COVID-19 pandemic was assumed as a common TFP shock among sectors reproducing the latest outlook by the Cabinet Office in July 2020. However, various restrictions and self-restraint requests from the government have changed the behavior of households and damage transport, accommodation, and the food service industry etc. If the pandemic were to last for a long time, people's preferences would change. In order to estimate the impact of the COVID-19 pandemic, different TFP shocks among sectors and perpetual change of households' deep parameters with respect to the allocation of consumption among different goods should be considered.

The model also could be extended in some ways for future research. Individual's consumption shares of sectoral goods are assumed to be independent of age in this study. However, incorporating an age-dependent sectoral demand could qualify the sectoral shift of output and labor share in response to demographic transitions. Moreover, it would be important to introduce heterogeneity in the labor force and labor market with frictions in order to estimate the mismatch across occupations and sectors. Finally, the price of healthcare services covered by social insurance is regulated by the government and the copayment ratio is different depending on age, income, and kind of social insurance in Japan. Future research should consider these to capture the characteristics of Japanese health and long-term care insurance systems.

References

Cabinet Office of Japan (2020), *Chū-Chōki no Keizai Zaisei ni kansuru Shisan (Economic and Fiscal Projections for Medium to Long Term Analysis*) (July 31, 2020). Retrieved December 31, 2020, from https://www5.cao.go.jp/keizai3/econome/r2chuuchouki7.pdf

Diao, X., and J. Thurlow (2012), "A recursive dynamic computable general equilibrium model", in Diao, X., Thurlow, J., Benin, S., and S. Fan (ed.), *Strategies and priorities for African agriculture: Economywide perspectives from country studies*, Ch. 2., pp.17-50, International Food Policy Research Institute (IFPRI).

Fougere, M., Mercenier, J. and M. Merette (2007), "A sectoral and occupational analysis of population aging in Canada using a dynamic CGE overlapping generations model", *Economic Modelling*, 24, pp.690-711.

Hashimoto, K. (1998), *Zeiseikaikaku no Ōyo Ippan Kinko Bunseki (Applied general equilibrium analysis of tax reform)*, Kansai University Press. (in Japanese)

Hashimoto, K. and S. Kimura (2010), "Economic effects of financing public pension plans from tax revenue", *RIETI Discussion Paper Series*, 10-J-038. (in Japanese)

Hosoe, N. (2014) , "Japanese manufacturing facing post-Fukushima power crisis: A dynamic computable general equilibrium analysis with foreign direct investment, *Applied Economics,* 46, 17, 2010-2020.

Huang, M. and C. J. Kim (2019), "Investigating cost-effective policy incentives for renewable energy in Japan: A recursive CGE approach for an optimal energy mix", *ADBI Working Paper Series*, No.1033.

Ihori, T., Kato, R. R., Kawade, M. and S. Bessho (2011), "Health insurance reform and economic growth: Simulation analysis in Japan", *Japan and the World Economy*, 23, pp.77-239.

Ishikawa, D., Ueda, J. and R. Arai (2012), "Future changes of the industrial structure due to aging and soaring demands for healthcare service in Japan – an analysis using a multi-sector OLG model in an open economy", *PRI Discussion Paper Series*, No.12 A-14.

Kimura, S. (2020), "Issues on application and termination of "Modified Indexation"", *Journal of Social Security Research (Shakai Hosho Kenkyu)*, 4 (4), 470-486. (in Japanese)

Kimura, S. and K. Hashimoto (2010), "Dynamic applied general equilibrium analysis for fiscal reconstruction based on a multi-sector overlapping generations model", *The Keizai Bunseki (The economic analysis)*, No.183, pp.1-24. (in Japanese)

Rausch, S. (2009), *Macroeconomic Consequences of Demographic Change*, Springer.