Submission Number: PET11-11-00053

Public health expenditure, longevity, and fertility

Tatsuya Omori
Mie Chukyo University

Abstract

Introducing public health expenditure and longevity into the overlapping generations model with social security, we study how public health expenditure affects fertility in a small open economy. This paper shows that a higher wage income tax rate decreases fertility and that when a wage income tax rate is constant, allocating public funds from social security benefits to public health expenditure decreases fertility. In this model, both the wage income tax for public health expenditure and the wage tax for social security decrease fertility.

Submitted: February 21, 2011.

Public health expenditure, longevity, and fertility*

Tatsuya OMORI†
Mie Chukyo University

February 22, 2011

Abstract

Introducing public health expenditure and longevity into the overlapping generations model with social security, we study how public health expenditure affects fertility in a small open economy. This paper shows that a higher wage income tax rate decreases fertility and that when a wage income tax rate is constant, allocating public funds from social security benefits to public health expenditure decreases fertility. In this model, both the wage income tax for public health expenditure and the wage tax for social security decrease fertility.

Key Words: Public health expenditure; Longevity; Fertility

JEL Classification: E62, H51, H55

---

*This paper is a revised paper presented at Nagoya Macroeconomics Workshop in Mie Chukyo University, the 2010 Fall Meeting of Japan Association of Applied Economics in Takasaki City University of Economics and the 24th Annual Conference of ARSC (Applied Regional Scinece Conference) in Nagoya university. I would like to thank Alesandro Cigno, Gerhard Glomm, Makoto Hirazawa, Koji Kitaura, Kazutoshi Miyazawa, Tomoya Sakagami and Akira Yakita for their valuable comments and suggestions. My sincerest thanks as well also for the research grants from Mie Chukyo University. All errors are mine.

†Correspondence to: Tatsuya OMORI, Faculty of Law and Economics, Mie Chukyo University, 1846 Kubo-cho Matsusaka Mie 515-8511 Japan. E-mail: omori@mie-chukyo-u.ac.jp. Phone: +81-(598)-29-1122. Fax: +81-(598)-29-1014.

1 Introduction

As the economy grows, the pattern of demographic transition changes. Recently, in many countries, the pattern of demography has been characterised by low mortality and low fertility. In such countries, expanding longevity causes the aging of population, in which the ratio of the elderly to total population boosts up. For individuals, the longer life span affects not only the saving behaviour but also the behaviour to have children. As having children enhances parents' utility and generates the increase in cost for these children, longer longevity causes the agent to save more for their life after retirement and gives the disincentive to have children due to the rising cost.

One of the factors prolonging life, among others, is public health expenditure. As shown by Organization for Economic Co-operation and Development (OECD) (2010), the ratio of public health expenditure to total health expenditure of the US increased from 44.9 percent in 1995 to 46.5 percent in 2008 and that of Italy also increased from 70.8 percent in 1995 to 77.2 percent in 2008.[1] In most OECD countries, the ratio of public health expenditure will continue to increase and will have a critical role in national health.

Murphy and Topel (2003), who analyse the social returns to health-related research, show that in 1995, the US federal expenditure accounted for about 38 percent of the annual total investment in medical research and that a reduction in mortality due to heart disease alone amounted to about $1.5

[1] For such health data in other OECD countries, see OECD (2010).

trillion per year over the 1970−1990 period.[2] Public health expenditure contributes to expanding longevity and generating social returns.

In an aging society, the government should adopt a policy to enhance fertility and increase the total population. Such policy can lower the ratio of the elderly to total population and provide a solution to the issues caused by an aging population. Based on this point, Blackburn and Cipriani (2002) and Chen (2010) discuss the relations between longevity and fertility. However, they do not focus on the effects of government policy on fertility in a model with longevity.

Aging also affects the social security system. As expanding longevity increases the number of elderly, increasing public health expenditure requires the government to pay more social security benefits to the elderly. In an aging economy, social security recipients outnumber social security contributors. In an aging society characterised by low mortality and low fertility, public policies should consider both the incentive to have children and social security for the elderly.

According to the study by Becker and Barro (1988), social security may affect private saving and the demand for children.[3] Among others, introduc-

[2]Murphy and Topel (2006) develop a framework for valuing improvements in health based on willingness to pay and estimate the value of past and prospective health advances. Hall and Jones (2007) show that the optimal health share of spending is likely to exceed 30 percent by the middle of the 21st century.

[3]Empirical studies for the effects of social security on private saving and the fertility decision are presented in Cigno and Rosati (1992), Cigno and Rosati (1996), Cigno and Rosati (1997), Ehrlich and Zhong (1998), Cigno, Casolaro and Rosati (2003), Zhang and Zhang (2004) and others.

ing parents' child care time into the model, Zhang and Zhang (1998) show that a higher social security tax rate tends to be detrimental to economic growth and welfare. Incorporating an uncertain lifetime into Zhang and Zhang (1998), Yakita (2001) shows that an increasing life expectancy lowers fertility and that a pay-as-you-go social security does not reverse the fertility. Van Groezen, Leers, and Meidam (2003), Fenge and Meier (2005), Zhang and Zhang (2007), Hirazawa and Yakita (2009), Omori (2009), and others analyse social security and child support in a model with endogenous fertility. However, as public health expenditure is not included in these all models, there is room for us to examine the effects of public health expenditure on fertility.[4]

Without introducing social security into the model, Bhattacharya and Qiao (2007) and Leung and Wang (2010) discuss longevity and private health care. Cigno (1998) discusses the relation among fertility, infant mortality and private health care. On the other hand, on the discussions about public health care and social security, Chakraborty (2004) examines how expanding longevity by augmenting public health expenditure is conducive to growth and shows that high-mortality societies do not grow rapidly because a shorter

[4] Abel (1985), Hubbard and Judd (1987), and others discuss social security in the framework of uncertain lifetimes. Abel (1985) shows that, in the absence of a private annuity market, the introduction of actuarially fair social security crowds out private wealth and reduces national wealth. Hubbard and Judd (1987) also show that the introduction of social security increases lifetime welfare and reduces national savings when borrowing against future resources is limited. They also do not consider public health expenditure in the model. Thus, there is opportunity for us to examine the relation among public health expenditure, social security, and fertility.

lifespan discourages savings.[5] Zhang, Zhang, and Leung (2006) study the effects of social security and health subsidies on private savings, private health investment, and welfare in the overlapping generations model.[6] Pestieau, Ponthiere, and Sato (2008) show that the sign of optimal subsidy on health expenditures tends to be negative when the replacement ratio is sufficiently large. In these discussions, the effects of public health expenditure to expand longevity on fertility are not included. Thus, there is room for us to examine the connections between public health expenditure, social security and fertility in an overlapping generations model.

In our model, the government is assumed to collect wage income tax to finance public health expenditure and social security benefits. We examine not only the effects of wage income tax on fertility but also the effects of reallocating public funds from social security benefits to public health expenditure on fertility. As public health expenditure and social security can be viewed as mechanisms of intergenerational transfer, we examine the effects on fertility of such reallocation and discuss how intergenerational transfers affects fertility. To clarify how income tax affect fertility decision, we also examine the effects of different types of income taxes on fertility. When government budget constraint is decoupled and there are dedicated taxes for both public health expenditure and social security benefits, we can consider the effect

[5] Davies and Kuhn (1992) show that social security never increases welfare in a pure moral hazard economy and that social security may either increase or reduce longevity depending on the characteristics of the health-related goods consumed.

[6] Through simulations, Zhang, Zhang, and Leung (2006) find that pension and health subsidies increase life expectancy at the cost of reducing savings and future output.

of health tax (tax for public health expenditure) on fertility while keeping the social security tax (tax for social security benefits) constant and that of social security tax with a constant health tax. These different financing mechanisms have potentially different implications for fertility. These discussions clarify how parents' decisions on children depends on public health expenditure and/or social security benefits.

To keep the analysis simple, we develop the overlapping generations model in a small open economy.[7] Kolmer (1997), Fenge and Meier (2005), Hirazawa and Yakita (2009), and others discuss social security and fertility in a small open economy. Hashimoto and Tabata (2010) discuss the effects of aging and private health care on growth in a small open economy without social security. However, we do not have enough information on public health expenditure and fertility in a small open economy.

In this paper, introducing public health expenditure and longevity into an overlapping generations model in a small open economy, we study how public health expenditure affects fertility. We do not discuss the spillover effects of public policy on private health care in this paper. Private health expenditure has also direct effect on longevity. Cigno and Pinal (2004) show the evidence that public health expenditure crowds in private health expenditure in Argentina. However, the purpose of this paper is to discuss the effects of public

[7]We can also develop the similar model in a closed economy. The path in a closed economy may not be essentially different from the one in a small open economy. However, to simplify the discussion, we examine the effects of public health expenditure on fertility in a small open economy.

health expenditure on fertility. As introducing the spillover effects of public health expenditure on private health expenditure makes difficult for us to discuss how public health expenditure affects longevity and fertility, we assume away private health expenditure in this paper. The questions addressed in this paper are as follows. First, what is the effect of wage income tax for financing public health expenditure and social security benefits on fertility? Second, how does a change in the allocation between public health expenditure and social security benefits influence fertility? Third, when government budget constraint is decoupled and there are dedicated taxes both for public health expenditure and for social security, how can such taxes affect fertility?

The rest of the paper is organised as follows. Section 2 presents the model. Section 3 shows the optimal plans for the consumer in an equilibrium. Based on section 3, sections 4 and 5 clarify the effects of wage income tax and allocation between public health expenditure and social security benefits on fertility, respectively. In section 6, the effects of health tax and social security tax on fertility are examined. The last section presents the concluding remarks.

2 Model

As developed in Diamond (1965), we consider an overlapping generations model of a small open economy. For simplicity, we assume that the level of the world interest rate remains constant over time. The capital labor ratio and wage rate are also constant. The economy is comprised of identical three-period-lived agents, perfectly competitive firms, and a government.The production technology is assumed to be governed by a standard neoclassical constant-returns-to-scale production function.

2.1 Consumers

Agents in the first period of their lives, the young generation, are raised by their parents. Agents in the second period of their lives, the working generation, supply their labor inelastically to firms. They divide their after-tax income among current consumption, savings for consumption when old, and child raising expenditures. With probability p_t, an agent who worked during period t will live throughout old age, and with probability $1 - p_t$, the agent will die before the onset of the third period, old age. In this model, similar to Chakraborty (2004) and Pestieau et al.(2008), when introducing longevity into the overlapping generations model, we assume that the probability of survival, p_t, is the same for all individuals.

Agents in the final period of their lives, the old generation, consume their social security benefits and accumulated savings. If an agent dies at the onset of old age, accidental bequests emerge. However, introducing an annuity market into the model, we do not suppose accidental bequests. The return in the annuity market at period t is the interest rate, $1 + r$, divided by $p_{t-1}\left(i.e., \frac{1+r}{p_{t-1}}\right)$.

As the working generation at period t is called generation t, the preference of a representative agent of generation t is

$$u\left(c_t^t,\ c_{t+1}^t,\ n_{t+1}\right) = \ln c_t^t + p_t \ln c_{t+1}^t + \epsilon \ln n_{t+1}. \tag{1}$$

where c_t^t and c_{t+1}^t are the consumption of generation t during the working generation period and the old period, respectively, and n_{t+1} is the number of children. Let N_t be the total working generation population at period t, and thus we have $N_{t+1} = (1 + n_{t+1})\, N_t$.[8]

The budget constraints of a representative agent of generation t in the working and old periods are given respectively by

$$c_t^t + s_t + \Lambda n_{t+1} = (1 - \tau)\, w, \tag{2}$$

and

$$c_{t+1}^t = \left(\frac{1+r}{p_t}\right) s_t + T_{t+1}, \tag{3}$$

where τ is the wage income tax rate, w is the wage rate, s_t is his/her savings, Λ is the parents' child cost per child, and T_{t+1} is the social security benefits at $t + 1$.

Given the wage rate, interest rate, wage income tax rate, probability to survive, and child care cost per child, a representative agent chooses c_t^t , c_{t+1}^t and n_{t+1} to maximise utility, (1), subject to the budget constraints, (2) and (3). The first−order conditions are as follows:

$$\frac{1}{c_t^t} = \lambda, \tag{4}$$

[8] Similar to Omori (2009), to show the population growth explicitly, we define that as $N_{t+1} = (1 + n_{t+1})\, N_t$. However, even when we define that as $N_{t+1} = n_{t+1} N_t$, we can derive the similar implications.

$$\frac{p_t}{c_{t+1}^t} = \frac{p_t \lambda}{1+r}, \tag{5}$$

$$\frac{\epsilon}{n_{t+1}} = \lambda \Lambda, \tag{6}$$

and

$$(1-\tau)\, w - c_t^t - \frac{p_t c_{t+1}^t}{(1+r)} + \frac{p_t T_{t+1}}{(1+r)} - \Lambda n_{t+1} = 0, \tag{7}$$

where λ is a Lagrangian multiplier.

Based on the first−order conditions, the optimal plans for c_t^t, c_{t+1}^t, and n_{t+1} are

$$c_t^t = \frac{1}{(1+p_t+\epsilon)} \left[(1-\tau)\, w + \frac{p_t T_{t+1}}{1+r} \right], \tag{8}$$

$$c_{t+1}^t = \frac{(1+r)}{(1+p_t+\epsilon)} \left[(1-\tau)\, w + \frac{p_t T_{t+1}}{1+r} \right], \tag{9}$$

and

$$n_{t+1} = \frac{\epsilon}{(1+p_t+\epsilon)\, \Lambda} \left[(1-\tau)\, w + \frac{p_t T_{t+1}}{1+r} \right]. \tag{10}$$

Substituting (9) into (3), the saving function, s_t, is

$$s_t = \frac{p_t}{(1+p_t+\epsilon)} \left[(1-\tau)\, w - \frac{T_{t+1}\,(1+\epsilon)}{(1+r)} \right]. \tag{11}$$

2.2 Government

The government is assumed to behave under a balanced budget regime. Tax revenues are collected and finance public health expenditure and social security benefits in the current period.

We suppose the agents to enjoy the public health expenditure through expanded longevity. Due to public health expenditure, if new medications for diabetes and high blood-pressure are developed and the working generations take these medications, their longevity will be expanded. In this paper, we discuss the effects of public health expenditure on fertility. For simplicity, we assume away the private medical research sector and any spillover effect of health expenditure. Similar to Bhattacharya and Qiao (2007), Osang and Sarkar (2008) Pestieau et al. (2008), Leung and Wang (2010), and others, we assume that the probability to live into the old period is a function of public health expenditure, G_t^p. That is,

$$p_t \equiv p\left(G_t^p\right). \tag{12}$$

For analytical simplicity, following Osang and Sarkar (2008) and Leung and Wang (2010), we assume the following conditions: $0 < p < 1$, $p\prime > 0$, $p\prime\prime < 0$, $p\left(0\right) = \bar{p}$ ($\bar{p}$ is constant), $0 < \bar{p} < 1$, and $\lim_{G_t^p \to \infty} p\prime\left(G_t^p\right) = 0$.

The government budget constraint per the working generation at period t is

$$\tau w = G_t^p + \frac{p_{t-1} T_t}{1 + n_t}. \tag{13}$$

Let us further define the parameter Δ to denote the fraction of government revenue allocated to public health expenditure. Public health expenditure can be written as

$$G_t^p = \Delta \tau w, \tag{14}$$

and the social security benefits at t is

$$T_t = \frac{\left(1 + n_t\right)}{p_{t-1}} \left(1 - \Delta\right) \tau \ w. \tag{15}$$

Note that the fraction parameter, Δ, is between 0 and 1. In the following discussions, the government predetermines the sequences of τ and Δ for simplicity.

3 Optimal plans

In equilibrium, based on (14) and (15), the optimal plan for the number of children, (10), is rewritten as

$$n_{t+1} = \frac{\epsilon\,(1-\tau)\,w\,(1+r) + \epsilon\,(1-\Delta)\,\tau w}{(1+p\,(G_t^p)+\epsilon)\,\Lambda\,(1+r) - \epsilon\,(1-\Delta)\,\tau w}. \tag{16}$$

As this economy is supposed to be a small open economy, and the capital labor ratio, interest rate, and wage rate are constant, τ and Δ are assumed to be predetermined and fixed over time. Public health expenditure, G_t^p, is fixed over time because the government budget constraint of (14) shows $G_t^p = \Delta\tau w$. Therefore, n_{t+1} is the time-invariant variable in equilibrium. Moreover, as n_{t+1} is required to be positive, on the right hand side of (16), $(1+p\,(\Delta\tau w)+\epsilon)\,\Lambda\,(1+r) - \epsilon\,(1-\Delta)\,\tau w$ is assumed to be positive.

Similarly, for the optimal plans for c_t^t, c_{t+1}^t and s_t, (8), (9) and (11)are rewritten as

$$c_t^t = \frac{1}{(1+p\,(G_t^p)+\epsilon)}\left[(1-\tau)\,w + \frac{(1+n_{t+1})\,(1-\Delta)\,\tau w}{1+r}\right], \tag{17}$$

and

$$c_{t+1}^t = \frac{(1+r)}{(1+p\,(G_t^p)+\epsilon)}\left[(1-\tau)\,w + \frac{(1+n_{t+1})\,(1-\Delta)\,\tau w}{1+r}\right], \tag{18}$$

and

$$s_t = \frac{1}{(1+p_t+\epsilon)(1+r)} \left[p_t (1+r)(1-\tau) w - (1+n_{t+1})(1-\Delta)\tau w (1+\epsilon)\right]. \tag{19}$$

As n_{t+1} is the time-invariant variable in equilibrium from (16), c_t^t in (17), c_{t+1}^t in (18) and s_t in (19) are also the time-invariant variables in equilibrium.

4 Effects of wage income tax on fertility

In this section, we examine the effects of changes in wage income tax on fertility. We express the effect of wage income tax on fertility as follows,

Proposition 1

If

$$\frac{dp}{dG^p} > \frac{\epsilon(1-\Delta)}{\Lambda(1+r)\Delta}, \tag{20}$$

then, a higher wage income tax rate decreases fertility.

Proof: We derive the derivative of (16) with respect to τ as

$$\begin{aligned}\frac{dn_{t+1}}{d\tau} = {} & \frac{1}{\left[(1+p(G_t^p)+\epsilon)\Lambda(1+r) - \epsilon(1-\Delta)\tau w\right]^2} \\ & \times \Bigg[\left[(1+p(G_t^p)+\epsilon)\Lambda(1+r) - \epsilon(1-\Delta)\tau w\right] \\ & \times \left[-\epsilon w(1+r) + \epsilon(1-\Delta) w\right] \\ & - \left[\epsilon w (1-\tau)(1+r) + \epsilon(1-\Delta)\tau w\right] \\ & \times \left[\Lambda(1+r)\frac{dp}{dG^p}\frac{dG^p}{d\tau} - \epsilon(1-\Delta) w\right]\Bigg]\end{aligned} \tag{21}$$

On the right hand side of (21), $(1 + p(G_t^p) + \epsilon)\Lambda(1 + r) - \epsilon(1 - \Delta)\tau w$ is assumed to be positive. If

$$\Lambda(1+r)\frac{dp}{dG^p}\frac{dG^p}{d\tau} - \epsilon(1-\Delta)w > 0$$

are satisfied, then $\frac{dn_{t+1}}{d\tau} < 0$. That is, as $\frac{dG^p}{d\tau} = \Delta w$ from (14), if

$$\frac{dp}{dG^p} > \frac{\epsilon(1-\Delta)}{\Lambda(1+r)}, \tag{20}$$

then

$$\frac{dn_{t+1}}{d\tau} < 0.$$

Increasing income tax has four effects. First, increasing income tax rate decreases after-tax income and fertility because having children generates cost, and children are normal goods in this model. Second, a higher income tax rate increases public health expenditure and expands longevity. Expanding longevity urges consumers to need more savings for their old period consumption. Increasing savings by expanding longevity and children raising cost gives the working generations the disincentive to have more children. Third, by increasing income tax rate, public health expenditure and expansion of longevity lower the return in annuity market. These three effects of increasing income tax rate on fertility are negative. Fourth, increasing the income tax rate gives more social security benefits. Consumers have the incentive to have children because increasing social security benefits covers the cost to have children. This wealth effects is positive. When the first three effects dominate the last effect, that is, if $\frac{dp}{dG^p} > \frac{\epsilon(1-\Delta)}{\Lambda(1+r)\Delta}$, then a higher wage income tax rate decreases the fertility. If the former effects are greater than the latter effect, consumers need more savings to compensate for the decreasing income at the old period. Having children entails costs, and thus consumers have the negative incentive to have children. Increasing the wage income tax rate for both public health expenditure and social security benefits gives the agents the disincentive to have more children.

In *Proposition* 1, the condition (20) is only a sufficient condition but not a necessary condition. In (21), when

$$\Bigg[\left[\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\left(1-\Delta\right)\tau w\right] \\ \times\left[-\epsilon w\left(1+r\right)+\epsilon\left(1-\Delta\right)w\right] \\ -\left[\epsilon w\left(1-\tau\right)\left(1+r\right)+\epsilon\left(1-\Delta\right)\tau w\right] \\ \times\left[\Lambda\left(1+r\right)\frac{dp}{dG^p}\frac{dG^p}{d\tau}-\epsilon\left(1-\Delta\right)w\right]\Bigg]$$

is positive, that is, when $\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\left(1-\Delta\right)\tau w$ is small enough and $\epsilon w\left(1-\tau\right)\left(1+r\right)+\epsilon\left(1-\Delta\right)\tau w$ is large enough, $\frac{dn_{t+1}}{d\tau}$ is positive. If social security benefits can cover the cost of having children through changing the saving, then the working generations have the incentive to have more children.

Next, is the condition (20) more or less likely to occur in rich or poor countries? The probability to survive depends on the size of public health expenditure. As government revenue increases, public health expenditure increases. Based on the assumption of p, in a rich country that can afford to pay public health expenditure, $\frac{dp}{dG^p}$ is smaller than that in poor country.

When ϵ and τ are the same parameters in both countries, $\frac{dp}{dG^p}$ depends on the rising cost, Λ, and/or the allocation ratio, Δ. As consumers can also afford to pay the rising cost in rich countries, the rising cost and public health expenditure tend to be high in rich countries. This condition is more likely to occur in rich countries.

In Appendix A, we discuss the welfare effects of wage income tax in this model. A higher wage income tax rate expands longevity, and the agents enjoy the consumption in the old period. This effect is the positive welfare effect. However, such tax rate decreases the disposable income and fertility (*Proposition* 1). Lower fertility decreases social security benefits. Increasing the wage tax rate generates negative welfare effects, causing agents to not enjoy the consumption and having children. Therefore, when the former effect is less than the latter effect, a higher income tax rate decreases the welfare.

5 Effects of allocation from social security benefits to public health expenditure on fertility

Both public health expenditure and social security can be viewed as mechanisms of intergenerational transfer. In this section, to discuss the effects of intergenerational transfers on fertility, we examine the effect on fertility of reallocating public funds from social security benefits to public health expenditure. We show the following proposition,

Proposition 2 *When the wage income tax rate is constant, allocating from security benefits to public health expenditure decreases fertility.*

Proof: We derive the derivative of (16) with respect to Δ as follows;

$$\frac{dn_{t+1}}{d\Delta} = \frac{1}{\left[\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\left(1-\Delta\right)\tau w\right]^2} \times \Bigg[\left[\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\left(1-\Delta\right)\tau w\right]\times\left[-\epsilon\tau w\right]$$
$$-\left[\epsilon w\left(1-\tau\right)\left(1+r\right)+\epsilon\left(1-\Delta\right)\tau w\right]\times\left[\left(1+r\right)\tau w\frac{dp}{dG^p}+\epsilon\tau w\right]\Bigg] < 0. \quad (22)$$

Note that $\frac{dp}{d\Delta} = \tau w \frac{dp}{dG^p}$ based on (14). Then, as $\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\left(1-\Delta\right)\tau w > 0$,

$$\frac{dn_{t+1}}{d\Delta} < 0.$$

When income tax rate is constant, reallocation public funds from social security benefits to public health expenditure has two effects: the effects of expanded longevity through reallocation from social security benefits to public health expenditure on the return in annuity market and the effects of reallocation that decreases the income for the old generation through the social security benefits. By increasing public health expenditure, consumers need more savings for their old period. Through these effects, consumers need more savings to compensate for the decreasing lifetime income. As having children entails costs, consumers have the disincentive to have children. Decreasing the return in annuity market and social security benefits give consumers the incentive to save more for their old period consumption and to have fewer children.

Appendix B examines the welfare effects of allocating from security benefits to public health expenditure at a constant wage income tax rate. Such allocation change generates the positive welfare effect because it expands longevity, and the agents enjoy more consumption in the old period. However, such change decreases fertility (*Proposition* 2). Lower fertility decreases the social security benefits and income in the old period. This shows the negative welfare effect, as agents enjoy consumption and having children less. Therefore, if the former effect is less than the latter effect, allocating public funds from security benefits to public health expenditure decreases the welfare when the wage income tax rate is constant.

Propositions 1 and 2 show that, through the existence of both public health care and social security benefits, government promotes aging and fertility decline in an economy.

6 Health tax and social security tax

When the government budget constraint is decoupled and there are dedicated taxes both for public health expenditure and social security benefits, we can consider the effect of tax for public health expenditure (health tax) on fertility while maintaining a constant social security tax and that of social security tax with a constant health tax.[9] This discussion clarifies to show how parents ' decision to have children depends on public health expenditure and/or social security benefits.

The budget constraint of a representative agent of generation t in the working period, (2), should be changed to

$$c_t^t + s_t + \Lambda n_{t+1} = (1 - \tau_H - \tau_s)\, w, \tag{23}$$

where τ_H is the wage income tax rate for public health expenditure, and τ_s is the wage income tax rate for social security benefits. Given the wage rate, interest rate, wage income tax rates, probability to survive, and child care cost per child, a representative agent of generation t chooses c_t^t, c_{t+1}^t, and n_{t+1} to maximise utility, (1), subject to the budget constraints, (23) and (3). From the first-order conditions, we express the optimal plans for c_t^t, c_{t+1}^t, and n_{t+1} as

$$c_t^t = \frac{1}{(1 + p_t + \epsilon)} \left[(1 - \tau_s - \tau_H)\, w + \frac{p_t T_{t+1}}{1 + r} \right], \tag{24}$$

$$c_{t+1}^t = \frac{(1 + r)}{(1 + p_t + \epsilon)} \left[(1 - \tau_s - \tau_H)\, w + \frac{p_t T_{t+1}}{1 + r} \right], \tag{25}$$

and

$$n_{t+1} = \frac{\epsilon}{(1 + p_t + \epsilon)\, \Lambda} \left[(1 - \tau_s - \tau_H)\, w + \frac{p_t T_{t+1}}{1 + r} \right]. \tag{26}$$

The government budget constraint for public education per the working

[9]In developed countries such as Japan, governments adopt the earmarked tax policy to finance public health insurance (expenditure) and social security benefits. Omori (2009) examines the effects of earmarked tax for social security and public education on fertility, respectively.

generation at period t is given by

$$\tau_H w = G_t^p, \tag{27}$$

and

$$\frac{1+n_t}{p_{t-1}}\tau_s w = T_t. \tag{28}$$

In equilibrium, based on (27) and (28), the optimal plan for the number of children, (26), is expressed as

$$n_{t+1} = \frac{\epsilon\left(1-\tau_H-\tau_s\right)w\left(1+r\right)+\epsilon\tau_s w}{\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\tau_s w}. \tag{29}$$

As τ_H and τ_s are assumed to be predetermined and r and w are fixed over time in this model, the government constraint of (27) shows that G_t^p is constant over time. Therefore, n_{t+1} is the time-invariant variable in equilibrium. Moreover, because n_{t+1} is positive, $\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\tau_s w$ is assumed to be positive.

Based on (27) and (28), the optimal plans for c_t^t in (24) and c_{t+1}^t in (25) are rewritten respectively as follows;

$$c_t^t = \frac{1}{\left(1+p\left(G_t^p\right)+\epsilon\right)}\left[\left(1-\tau_H-\tau_s\right)w+\frac{\left(1+n_{t+1}\right)\tau_s w}{1+r}\right], \tag{30}$$

and

$$c_{t+1}^t = \frac{\left(1+r\right)}{\left(1+p\left(G_t^p\right)+\epsilon\right)}\left[\left(1-\tau_H-\tau_s\right)w+\frac{\left(1+n_{t+1}\right)\tau_s w}{1+r}\right]. \tag{31}$$

As n_{t+1} is the time-invariant variable in equilibrium from (29), c_t^t in (30) and c_{t+1}^t in (31) are also time-invariant variables in equilibrium.

6.1 Health tax

While holding the social security tax constant, the effects of health tax on fertility is shown in the following proposition,

Proposition 3 *When the wage income tax rate for social security is constant, increasing the health tax rate decreases fertility.*

Proof: The derivative of (29) with respect to τ_H is

$$\begin{aligned}\frac{dn_{t+1}}{d\tau_H} &= \frac{1}{\left[\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\tau_s w\right]^2} \\ &\quad\times\left[\left[\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\tau_s w\right]\times\left[-\epsilon w\left(1+r\right)\right]\right. \\ &\quad\left.-\left[\epsilon\left(1-\tau_H-\tau_s\right)w\left(1+r\right)+\epsilon\tau_s w\right]\times\left[w\frac{dp}{dG}\right]\right]<0. \quad (32)\end{aligned}$$

Note that $\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\tau_s w>0$ and $\frac{dp}{d\tau_H}=\frac{dp}{dG_t^p}\frac{dG_t^p}{d\tau_H}=w\frac{dp}{dG_t^p}$ from (27).

Increasing health tax rate expands longevity and lowers the return in annuity market. Consumers need more savings for consumption in the old period. Cutting the rising cost for children, they save more to compensate for their decreasing lifetime income. Consumers do have the incentive to have fewer children.

In Appendix C, we discuss the effects of health tax on welfare. A higher health tax rate expands longevity, and agents are able to enjoy consumption in the old period. This is the positive welfare effect. However, such tax rate decreases fertility (*Proposition* 3). Lower fertility decreases the social security benefits. Increasing the health tax rate generates the negative welfare effect because agents enjoy consumption and having children less. Therefore, when the former effect is less than the latter effect, a higher health tax rate decreases the welfare.

6.2 Social security tax

The effects of social security tax on fertility while holding the health tax constant is shown in the following proposition,

Proposition 4 *When the wage income tax rate for public health expenditure is constant, if $r > n_{t+1}$, increasing social security tax rate decreases fertility and vice versa.*

Proof: We derive the derivative of (29) with respect to τ_s as

$$\frac{dn_{t+1}}{d\tau_s} = \frac{1}{\left[(1 + p(\tau_H w) + \epsilon)\Lambda(1+r) - \epsilon\tau_s w\right]^2} \times \left[\left[(1 + p(G_t^p) + \epsilon)\Lambda(1+r) - \epsilon\tau_s w\right] \times [-\epsilon w r] - \left[\epsilon(1-\tau_H-\tau_s) w(1+r) + \epsilon\tau_s w\right] \times [-\epsilon w] \right]. \quad (33)$$

Focusing on the right hand side of (33), if

$$r > \frac{\epsilon(1-\tau_H-\tau_s) w(1+r) + \epsilon\tau_s w}{(1 + p(G_t^p) + \epsilon)\Lambda(1+r) - \epsilon\tau_s w}, \quad (34)$$

$\frac{dn_{t+1}}{d\tau_s} < 0$ and vice versa. However, based on (29), the right hand side of (34),

$$\frac{\epsilon\left(1-\tau_H-\tau_s\right)w\left(1+r\right)+\epsilon\tau_s w}{\left(1+p\left(G_t^p\right)+\epsilon\right)\Lambda\left(1+r\right)-\epsilon\tau_s w}=n_{t+1}.$$

That is, if $r > n_{t+1}$, then $\frac{dn_{t+1}}{d\tau_s} < 0$ and vice versa.

A higher social security tax rate increases the social security benefits. That effect on benefits are reflected on right hand side of (34) and are equal to n_{t+1}. However, as the private interest rate in the annuity market is greater than that in tax effects, when the government increases the social security tax rate, the disposable income for the working generation decreases, and the working generation pays less cost for having children. That is, they have the incentive to have fewer children. As the fertility declining makes the tax payer for social security decrease, social security benefits decrease.

Expanded longevity causes the working generation to need more savings for their consumption in the old period. However, as having children entails cost, consumers have the incentive to decrease the number of their children they want to have. The number of children depends on the savings for the consumption in old period. *Proposition* 4 shows that, even when longevity expands through public health expenditure and social security can compensate for the rising cost for children, possibilities in decreasing fertility exist.

When the private interest rate in annuity market, r, is greater than n_{t+1}, a higher social security tax rate increases the social security benefits and decreases the fertility because the consumers can consume and pay the cost of having children less. Therefore, as shown in Appendix D, a higher social security tax rate decreases welfare.

7 Concluding remarks

Public health expenditure contributes to expanding longevity and promoting an aging and fertility declining society characterised by low mortality and low fertility. For an aging society, one desirable government policy is to promote fertility. Government policies in an aging and fertility declining society should consider public health expenditure and social security for the elderly. In this paper, introducing public health expenditure and longevity into an overlapping generations model in a small open economy, we studied how public health expenditure affects fertility.

Increasing wage income tax to finance public health expenditure and social security has four effects. First, increasing wage income tax rate decreases the after-tax income and fertility because having children entails cost and children are normal goods in this model. Second, a higher wage income tax rate increases public health expenditure and expands longevity. Expanding longevity causes consumers to need more savings for their old period consumption. Increasing savings by expanding longevity and children raising cost gives the working generations the disincentive to have more children. Third, by increasing the income tax rate, public health expenditure and expansion of longevity lower the return in annuity market. Fourth, increasing the income tax rate provides more social security benefits. When the first three effects dominate the last effect, a higher income tax rate decreases fertility.

When an wage income tax rate is constant, the effects of reallocation from social security benefits to public health expenditure on the return in annuity market and social security benefits lower fertility. When the wage income tax rate for social security is constant, increasing the tax rate for public health expenditure decreases fertility. At a constant wage income tax rate for public health expenditure, increasing the tax rate for social security can decreases fertility. Even when longevity expands through public health expenditure, if social security can compensate for the rising cost for children, the government has the option to decrease fertility.

Public health expenditure contributes to expanding longevity. An additional child causes parents to cut down their savings to cover the cost of children. Although social security benefits partly compensate for the savings cut and give parents the incentive to have more children, expanding longevity through public health expenditure decreases fertility. In an aging society, when the government creates a policy to enhance fertility and to lower the ratio of the elderly on total population, the government should consider public health expenditure to expand longevity, the parental incentive to have children, and the social security benefits for parents.

Finally, we did not conduct a numerical analysis for the welfare effects of government policies in this paper. In this model, specialising function for probability to survive is difficult. Thus, doing so in this paper would be difficult. This issue is better left for future research.

Appendix A: The Welfare effect of wage income tax

In this model, the function for probability to survive is difficult to specialise. In the following Appendixes, we examine the welfare effects of government policies as discussed in this paper.

To discuss the welfare effects, we define the indirect utility function of generation t as

$$V^t = \ln c_t^t + p\left(G_t^p\right) \ln c_{t+1}^t + \epsilon \ln n_{t+1}. \tag{A1}$$

We derive the derivative of (A1) with respect to τ as

$$\frac{dV^t}{d\tau} = \frac{1}{c_t^t}\frac{dc_t^t}{d\tau} + \Delta w \ln c_t^t \frac{dp}{dG^p} + p\left(G_t^p\right)\frac{1}{c_{t+1}^t}\frac{dc_{t+1}^t}{d\tau} + \epsilon\frac{1}{n_{t+1}}\frac{dn_{t+1}}{d\tau}, \tag{A2}$$

where

$$\begin{aligned}\frac{dc_t^t}{d\tau} &= \frac{-\Delta w \frac{dp}{dG^p}}{\left[\left(1 + p\left(G_t^p\right) + \epsilon\right)\right]^2}\left[\left(1-\tau\right)w + \frac{\left(1+n_{t+1}\right)\left(1-\Delta\right)\tau w}{1+r}\right] \\ &+ \frac{1}{\left(1 + p\left(G_t^p\right) + \epsilon\right)}\left[-w + \frac{\left(1-\Delta\right)\tau w \frac{dn_{t+1}}{d\tau} + \left(1+n_{t+1}\right)\left(1-\Delta\right)w}{1+r}\right],\end{aligned} \tag{A3}$$

and

$$\begin{aligned}\frac{dc_{t+1}^t}{d\tau} &= \frac{-\left(1+r\right)\Delta w \frac{dp}{dG^p}}{\left[\left(1 + p\left(G_t^p\right) + \epsilon\right)\right]^2}\left[\left(1-\tau\right)w + \frac{\left(1+n_{t+1}\right)\left(1-\Delta\right)\tau w}{1+r}\right] \\ &+ \frac{1}{\left(1 + p\left(G_t^p\right) + \epsilon\right)}\left[-w + \frac{\left(1-\Delta\right)\tau w \frac{dn_{t+1}}{d\tau} + \left(1+n_{t+1}\right)\left(1-\Delta\right)w}{1+r}\right].\end{aligned} \tag{A4}$$

When (20) is satisfied, *Proposition* 1 shows that $\frac{dn_{t+1}}{d\tau}$ is negative in this model. Focusing on the second term on right−hand side of (A3) and (A4), if

$$\frac{dn_{t+1}}{d\tau}\frac{\tau}{(1+n_{t+1})} < -1, \tag{A5}$$

$\frac{dc_t^t}{d\tau}$ and $\frac{dc_{t+1}^t}{d\tau}$ are negative. When (20) and (A5) hold and, based on (A2), if

$$\Delta w \ln c_t^t \frac{dp}{dG^p} < -\left[\frac{1}{c_t^t}\frac{dc_t^t}{d\tau} + p\left(G_t^p\right)\frac{1}{c_{t+1}^t}\frac{dc_{t+1}^t}{d\tau} + \epsilon\frac{1}{n_{t+1}}\frac{dn_{t+1}}{d\tau}\right], \tag{A6}$$

then a higher wage income tax rate decreases the welfare.

A higher wage income tax rate expands longevity, and agents enjoy consumption in the old period, as shown on the left-hand side of (A6). This effect is called the positive welfare effects. However, such tax rate decreases the disposable income and fertility (*Proposition* 1). A lower fertility decreases the social security benefits. Increasing the wage tax rate generates the negative welfare effects, that is, the agents can not enjoy consumption and having children, as shown on the right-hand side of (A6). Therefore, when the former effect is less than the latter effect, a higher income tax rate decreases welfare.

Appendix B: The welfare effect of allocation from social security benefits to public health expenditure

We derive the derivative of (A1) with respect to Δ as

$$\frac{dV^t}{d\Delta} = \frac{1}{c_t^t}\frac{dc_t^t}{d\Delta} + \tau w \ln c_t^t \frac{dp}{dG^p} + p\left(G_t^p\right)\frac{1}{c_{t+1}^t}\frac{dc_{t+1}^t}{d\Delta} + \epsilon\frac{1}{n_{t+1}}\frac{dn_{t+1}}{d\Delta}, \tag{A7}$$

where

$$\frac{dc_t^t}{d\Delta} = \frac{-\tau w \frac{dp}{dG^p}}{\left[(1+p(G_t^p)+\epsilon)\right]^2}\left[(1-\tau)w + \frac{(1+n_{t+1})(1-\Delta)\tau w}{1+r}\right]$$
$$+\frac{1}{(1+p(G_t^p)+\epsilon)(1+r)}\left[(1-\Delta)\tau w\frac{dn_{t+1}}{d\Delta} - (1+n_{t+1})\tau w\right], \quad \text{(A8)}$$

and

$$\frac{dc_{t+1}^t}{d\Delta} = \frac{-\tau w(1+r)\frac{dp}{dG^p}}{\left[(1+p(G_t^p)+\epsilon)\right]^2}\left[(1-\tau)w + \frac{(1+n_{t+1})(1-\Delta)\tau w}{1+r}\right]$$
$$+\frac{1}{(1+p(G_t^p)+\epsilon)(1+r)}\left[(1-\Delta)\tau w\frac{dn_{t+1}}{d\Delta} - (1+n_{t+1})\tau w\right]. \quad \text{(A8)}$$

As *Proposition* 2 shows that $\frac{dn_{t+1}}{d\Delta}$ is negative, $\frac{dc_t^t}{d\Delta}$ in (A8) and $\frac{dc_{t+1}^t}{d\Delta}$ in (A8) are negative. Based on (A7), if

$$\tau w \ln c_t^t \frac{dp}{dG^p} < -\left[\frac{1}{c_t^t}\frac{dc_t^t}{d\Delta} + p(G_t^p)\frac{1}{c_{t+1}^t}\frac{dc_{t+1}^t}{d\Delta} + \epsilon\frac{1}{n_{t+1}}\frac{dn_{t+1}}{d\Delta}\right], \quad \text{(A9)}$$

when the wage income tax rate is constant, allocating from security benefits to public health expenditure decreases welfare and vice versa.

When the wage income tax rate is constant, allocating from security benefits to public health expenditure generates the positive welfare effect because such allocation expands longevity and agents enjoy more consumption in the old period, as shown on the left-hand side of (A9). However, such change in allocation decreases fertility (*Proposition* 2). A lower fertility decreases the social security benefits and income in the old period. This is called the negative welfare effect, where agents enjoy consumption and having children less, as shown on the right-hand side of (A9). Therefore, if the former effect is less than the latter effect, when the wage income tax rate is constant, allocating public funds from security benefits to public health expenditure decreases welfare and vice versa.

Appendix C: The welfare effect of health tax

In the following Appendixes, we examine the effects of health tax and social security tax on welfare. When there are dedicated taxes both for public health expenditure and social security benefits, we note that G_t^p is equal to $\tau_H w$, as shown by (27), and n_{t+1}, as shown by (29). We redefine the indirect utility function of generation t as

$$V^t = \ln c_t^t + p\left(G_t^p\right) \ln c_{t+1}^t + \epsilon \ln n_{t+1}. \tag{A10}$$

We derive the derivative of (A10) with respect to τ_H as

$$\frac{dV^t}{d\tau_H} = \frac{1}{c_t^t}\frac{dc_t^t}{d\tau_H} + w \ln c_t^t \frac{dp}{dG^p} + p\left(G_t^p\right)\frac{1}{c_{t+1}^t}\frac{dc_{t+1}^t}{d\tau_H} + \epsilon \frac{1}{n_{t+1}}\frac{dn_{t+1}}{d\tau_H}, \tag{A11}$$

where

$$\frac{dc_t^t}{d\tau_H} = \frac{-w\frac{dp}{dG^p}}{\left[\left(1+p\left(G_t^p\right)+\epsilon\right)\right]^2}\left[\left(1-\tau_s-\tau_H\right)w + \frac{\left(1+n_{t+1}\right)\tau_s w}{1+r}\right] + \frac{1}{\left(1+p\left(G_t^p\right)+\epsilon\right)}\left[-w + \frac{\tau_s w \frac{dn_{t+1}}{d\tau_H}}{1+r}\right], \tag{A12}$$

and

$$\frac{dc_{t+1}^t}{d\tau_H} = \frac{-w\frac{dp}{dG^p}}{\left[\left(1+p\left(G_t^p\right)+\epsilon\right)\right]^2}\left[\left(1-\tau_s-\tau_H\right)w + \frac{\left(1+n_{t+1}\right)\tau_s w}{1+r}\right] + \frac{(1+r)}{\left(1+p\left(G_t^p\right)+\epsilon\right)}\left[-w + \frac{\tau_s w \frac{dn_{t+1}}{d\tau_H}}{1+r}\right]. \tag{A13}$$

Proposition 3 shows that $\frac{dn_{t+1}}{d\tau_H}$ is negative. Based on (A11), if

$$w \ln c_t^t \frac{dp}{dG^p} < -\left[\frac{1}{c_t^t}\frac{dc_t^t}{d\tau_H} + p\left(G_t^p\right)\frac{1}{c_{t+1}^t}\frac{dc_{t+1}^t}{d\tau_H} + \epsilon\frac{1}{n_{t+1}}\frac{dn_{t+1}}{d\tau_H}\right], \tag{A14}$$

then, a higher health tax rate decreases welfare and vice versa.

A higher health tax rate expands longevity, and agents enjoy consumption in the old period, as shown on the left-hand side of (A14). This is called the positive welfare effects. However, such tax rate decreases fertility (*Proposition* 3). Lower fertility decreases the social security benefits. Increasing the health tax rate generates the negative welfare effects, where agents enjoy consumption and having children less, as shown on the right−hand side of (A14). Therefore, when the former effect is less than the latter effect, a higher health tax rate decreases welfare and vice versa.

Appendix D: The welfare effect of social security tax

We derive the derivative of (A10) with respect to τ_s as

$$\frac{dV^t}{d\tau_s} = \frac{1}{c_t^t}\frac{dc_t^t}{d\tau_s} + p\left(G_t^p\right)\frac{1}{c_{t+1}^t}\frac{dc_{t+1}^t}{d\tau_s} + \epsilon\frac{1}{n_{t+1}}\frac{dn_{t+1}}{d\tau_s}, \tag{A15}$$

where

$$\frac{dc_t^t}{d\tau_s} = \frac{w}{\left(1 + p\left(G_t^p\right) + \epsilon\right)}\left[\frac{\tau_s\frac{dn_{t+1}}{d\tau_s} + \left(n_{t+1} - r\right)}{1+r}\right], \tag{A16}$$

and

$$\frac{dc_{t+1}^t}{d\tau_s} = \frac{\left(1+r\right)w}{\left(1 + p\left(G_t^p\right) + \epsilon\right)}\left[\frac{\tau_s\frac{dn_{t+1}}{d\tau_s} + \left(n_{t+1} - r\right)}{1+r}\right]. \tag{A17}$$

Proposition 4 shows that $\frac{dn_{t+1}}{d\tau_s}$ is negative when r is greater than n_{t+1}. Focusing on the right-hand side of (A16) and (A17), if r is greater than n_{t+1},

$\frac{dc_t^t}{d\tau_s}$ and $\frac{dc_{t+1}^t}{d\tau_s}$ are negative. If r is more than n_{t+1}, a higher social security tax rate decreases welfare.

As explained in *Proposition* 4, when r is greater than n_{t+1}, a higher social security tax rate increases the social security benefits but decreases fertility. That effects are summarised as n_{t+1}. Based on (A15), when the private interest rate in the annuity market is greater than n_{t+1}, consumers consume and pay the cost of having children less. Therefore, a higher social security tax rate decreases welfare.

References

Abel, A. B, 1985, Precautionary saving and accidental bequests. American Economic Review 75, 777-791.

Becker, G. S., Barro, R. J., 1988, A reformulation of the economic theory of fertility. Quarterly Journal of Economics 103, 1-26.

Bhattacharya, J., Qiao, X., 2007, Public and private expenditures on health in a growth model. Journal of Economic Dynamics and Control 31, 2519-2535.

Blackburn, K., Cipriani, G. P., 2002, A Model of longevity, fertility and growth. Journal of Economic Dynamics and Control 26, 187-204.

Chakraborty, S., 2004, Endogenous lifetime and economic growth. Journal of Economic Theory 116, 119-137.

Chen, H.-J., 2010, Life expectancy, fertility, and educational investment. Journal of Population Economics 23, 37-56.

Cigno, A., 1998, Fertility decisions when infant survival is endogenous. Journal of Population Economics 11, 21-28.

Cigno, A., Casolaro, L., Rosati, F., C., 2003, The impact of social security on saving and fertility in Germany. FinanzArchiv 59, 189-211.

Cigno, A., Pinal, G., 2004, Endogenous child mortality, price of child-specific goods and fertility decisions: evidence from Argentina, In: Heymann, D., Navajas, N., Bour, E. (Eds), Latin American Economic Crises, Palgrave Macmillan, London, U.K., 247-257.

Cigno, A.., Rosati, F., C., 1992, The effects of financial markets and social security on saving and fertility behaviour in Italy. Journal of Population Economics 5, 319-341.

Cigno, A., Rosati, F., C., 1996, Jointly determined saving and fertility behaviour: theory, and estimates from Germany, Italy, UK, and USA. European Economic Review 40, 1561-1589.

Cigno, A., Rosati, F., C., 1997, Rise and fall of the Japanese saving rate: the role of social security and intra-family transfers. Japan and the World Economy 9, 81-92.

Davies, J. B., Kuhn, P., 1992, Social security, longevity, and moral hazard. Journal of Public Economics 49, 91-106.

Diamond, P., 1965, National debt in a neoclassical growth model. American Economic Review 55, 1126-1150.

Ehrlich, I., Zhong, J., G., 1998, Social security and the real economy: An inquiry into some neglected issues. American Economic Review 88, 151-157.

Fenge, R., Meier, V., 2005, Pensions and fertility incentive. Canadian Journal of Economics 38, 28-48.

Van Groezen, B., Leers, B., Meijdam, L., 2003, Social security and endogenous fertility: pensions and child allowances as siamese twins. Journal of Public Economics 87,233-251.

Hall, R., E., Jones, C., I., 2007, The value of life and the rise in health spending. Quarterly Journal of Economics 122, 39-72.

Hashimoto, K., Tabata, K., 2010, Population aging, health care, and growth. Journal of Population Economics 23, 571-593.

Hirazawa, M., Yakita, A., 2009, Fertility, child care outside the home, and pay-as-you-go social security. Journal of Population Economics 22, 565-583.

Hubbard, R. G., Judd, K. L., 1987, Social security and individual welfare: precautionary saving, borrowing constraints, and the payroll tax. American Economic Review 77, 630-646.

Kolmar, M,. 1997, Intergenerational redistribution in a small open economy with endogenous fertility. Journal of Population Economics 10, 335-356.

Leung, M. C. M., Wang, Y. 2010, Endogenous health care, life expectancy and economic growth. Pacific Economic Review 15, 11-31.

Murphy, K. M., Topel, R. H., 2003, The economic value of medical research, In: Murphy, K. M., Topel, R. H. (Eds), Measuring the Gains from Medical Research, The University of Chicago Press, Chicago, U.S.A., 41-73.

Murphy, K. M., Topel, R. H., 2006, The value of health and longevity. Journal of Political Economy 114, 871-904.

Organization for Economic Co-operation and Development (OECD) 2010, OECD Health Data 2010, Paris, France.

Omori, T., 2009, Effects of public education and social security on fertility. Journal of Population Economics 22, 585-601.

Osang, T., Sarkar, J., 2008, Endogenous mortality, human capital and economic growth. Journal of Macroeconomics 30, 1423-1445.

Pestieau, P., Ponthiere, G.,Sato, M., 2008, Longevity, health spending, and pay-as-you-go pensions. FinanzArchiv 64, 1-18.

Yakita, A., 2001, Uncertain lifetime, fertility and social security. Journal of Population Economics 14, 635-640.

Zhang, J., Zhang, J., 1998, Social security, intergenerational transfers, and endogenous growth. Canadian Journal of Economics 31, 1225-1241.

Zhang, J., Zhang, J., 2004, How does social security affect economic growth? Evidence from cross-country data. Journal of Population Economics 17, 473-500.

Zhang, J., Zhang, J., 2007, Optimal social security in a dynastic model with investment externalities and endogenous fertility. Journal of Economic Dynamics and Control 31, 3545-3567.

Zhang, J., Zhang, J., Leung, M. C. M., 2006, Health investment, saving, and public policy. Canadian Journal of Economics 39, 68-93.