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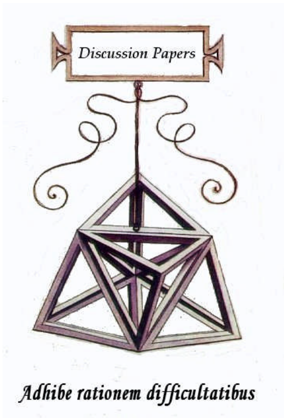

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Endogenous lifetime in an overlapping generations small open economy

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Abstract Using a simple overlapping generations small open economy, we show that endogenous longevity – through public health expenditure – may reduce both the saving rate and per capita domestic income, while increasing the per capita foreign debt in a country. Moreover, despite funding public health capital is always beneficial for life expectancy, it may or may not represent a Pareto improvement with respect to the *laissez-faire* solution depending on whether the world interest rate is high or low enough, respectively.

Keywords Health; Life expectancy; OLG model; Small open economy

JEL Classification I18; O41

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1. Introduction

The recent decades have seen dramatic increases in life expectancy in almost all countries in the world (e.g. Livi-Bacci, 1997), owing especially to the mortality decline in the later period of life that resulted, in the most part of developed nations during the past century, in a doubling of the ratio of life cycle years lived after 65 to years lived 20 to 64. Indeed, as well evidenced by demographers (Lee, 1994; Lee and Tuljapurkar, 1997), while early stages of the mortality decline brought upon an even more rapid population growth, because mainly children and young people in reproductive age were strongly affected by such a decline, in the recent stage most years of life are now gained at the older post-retirement ages causing (jointly with the very low fertility) population aging. Therefore, the economic consequences of a further mortality decline involve mainly the response of both individuals and governments, the latter facing with the need of funding consumption and health care for the additional life time of people as well as for the increasingly numerous elderly. In a dynamic life cycle context a rise in life expectancy produces its main effect on savings,[1] as well stressed by both Zhang et al. (2001, p. 486) "longer life may motivate increased life cycle saving and thereby stimulate growth", and Chakraborty (2004) "health plays a role quite unlike any other human capital: by increasing lifespans it makes individuals effectively more patient and willing to invest, and by reducing mortality risks, it raises the return on investment." (p. 120), that also states "in poorer societies, when life expectancy is low, individuals discount the future more heavily and are less inclined to save and invest." (p. 120).

Other papers have mainly focused on the role of the mortality decline also in the early stages of life: in their pioneering study about longevity in an endogenous growth context, Ehrlich and Lui

[1] Of course there may be other effects: for instance bequests are strongly affected, as Zhang et al. (2003, p. 84) maintain: "Lengthening life also means that bequests may be received later in life by the children of the elderly, and the amount of bequests may be diminished by longer consumption on the part of the elderly". Therefore, the effect on bequests further affects, in turn, savings.

(1991) showed that exogenous declines in mortality reduce fertility, raise human capital investment in children and stimulate growth with positive old-age material support from children to old parents. Likewise in a neoclassical growth setting, Mateos-Planas (2003) finds that declines in child mortality can explain the non-monotonic path of fertility observed in the demographic transition. However, all the above mentioned papers treat longevity as exogenous.

Recent papers by Lagerlof (2000), Blackburn and Cipriani (2002) and Chakraborty (2004) treat longevity as endogenous. Nevertheless, the former two papers do neither feature savings nor the public health spending.[2] Chakraborty, instead, introduced endogenous longevity through public health expenditure, but his focus is mainly on the possibility of multiple steady states in a closed economy. He found, in particular, that raising the public health tax may lead individuals to live longer and this, in turn, provides an incentive to greater savings, physical capital accumulation and, hence, higher life expectancy as well.

In this paper we investigate whether and how the belief concerning the positive effect of longevity on savings is warranted, using the usual (see, e.g., all the above mentioned papers) the overlapping generations (OLG) framework to investigate the relationship between public health spending, longevity and macroeconomic outcomes in a small open economy. As in Chakraborty (2004), the novelty in our paper is the endogenous treatment of longevity determined by public health spending funded by labour income taxation. However, different from Chakraborty (2004) we found that despite that raising the public health tax lengthens the individual life span and this, in turn, provides an incentive to save, the funding of public health may even always reduce both savings and domestic income, while increasing foreign indebtedness. Moreover, the welfare analysis shows that: (*i*) the public provision of health capital is Pareto improving (worsening) if the

[2] The first paper is concerned with explaining the transition from a Malthusian Regime to a Modern Growth Regime, while Blackburn and Cipriani (2002) focus on the effect of increasing longevity on the timing of childbearing and on educational investment.

world interest rate is sufficiently high (low) – and/or, the "natural" rate of longevity is relatively low (high) –, and (*ii*) in former case an optimal provision of health spending does exist.

The remainder of the paper is organised as follows. Section 2 introduces the model. Section 3 analyses and discusses the steady state effects of longevity on savings, domestic income and foreign indebtedness. Section 4 extends the analysis to account for the welfare effect of funding health capital. Section 5 concludes.

2. The model

Consider an OLG small open economy with perfect capital mobility that faces an exogenously given constant interest rate, r. Production takes place according to a standard neoclassical constant-returns-to-scale technology $f(k)$, where k represents the per capita stock of capital installed in the whole economy. Since capital is perfectly mobile, both the capital-labour ratio and the wage rate w are fixed and constant.

The economy is populated by identical individuals, and agents of each generation live for two periods (Diamond, 1965): youth (working time) and old age (retirement time). Young agents of measure N_t[3] offer inelastically one unit of labour on the labour market and receive a unitary wage income at the rate w in each period. Moreover, the probability of surviving from youth to old age is endogenous and determined by the individual health level, which is, in turn, given by the public provision of a certain health measure such as, for instance, hospitals, vaccination programmes and so on (see Chakraborty, 2004). The survival probability of a young person born at t, π_t, depends upon her health capital, h_t, and is given by a non-decreasing concave function $\pi_t = \pi(h_t)$. We

[3] Without loss of generality, we assume that population does not grow over time.

specialise this relationship with the following function of health capital (see Blackburn and Cipriani, 2002):[4]

$$\pi_t = \pi(h_t) = \frac{\pi_0 + \pi_1 h_t}{1 + h_t}, \tag{1}$$

satisfying the following properties: $0 < \pi_1 \leq 1$, $0 \leq \pi_0 < \pi_1$, $\pi(0) = \pi_0 > 0$, $\pi'_h(h) = \frac{\pi_1 - \pi_0}{(1 + h_t)^2} > 0$, $\pi''_{hh}(h) = \frac{-2(\pi_1 - \pi_0)}{(1 + h_t)^3} < 0$,[5] $\lim_{h \to \infty} \pi(h) = \pi_1 \leq 1$ and $\lim_{h \to 0} \pi'_h(h) = \pi_1 - \pi_0 < \infty$. We define π_0 as being the "natural" rate of longevity in a country, that may be affected by both economic and non-economic conditions. For instance, π_0 may be thought to be higher: the better the lifestyle of people (e.g. a higher attention to a healthy life), the higher the importance to the protection of the workers' rights, the higher the investment in social infrastructures, education and so on. However, π_0 may be influenced even by climate conditions, ethnical and civil wars, endemic diseases and so on. Thus, we may expect π_0 to be higher in developed rather than developing or under-developed countries,[6]

[4] Although the independent variable in the analysis conducted by Blackburn and Cipriani (2002) is human capital instead of public health capital, the line of reasoning to justify this formulation may be the same.

[5] This function shows that realistically health capital is more effective when the longevity is relatively low, while becoming scarcely effective when longevity is close to its saturating value. Although it might be thought that health investment has a more intense effect in reducing adult mortality when a certain threshold level of public health expenditure has been reached and subsequently beyond another higher threshold rapidly becomes "saturating" (e.g., the functional relationship between health investment and longevity may be S-shaped), in this paper, for the sake of simplicity, we limit the analysis only to a concave saturating function. With a S-shaped function (which on the other hand is used by Blackburn and Cipriani, 2002), our results would be confirmed a fortiori.

[6] For instance Mirowsky and Ross (1998) suggest that both higher economic growth and standards of living encourage, especially through a better education, the adoption of more healthy lifestyles on the part of individuals for various socio-economic reasons. Indeed as argued by Blackburn and Cipriani (2002, p. 188) "personal education improves personal health primarily because it improves personal effective agency: that is, education allows people to develop

and the higher the natural rate of longevity, the smaller the reduction in adult mortality due to a rise in public health expenditure. This means that in economies where individuals naturally live longer (developed countries), the effectiveness of an additional increase in public health capital will be lower as that would be experienced in economies where individuals naturally live shorter (developing or under-developed countries).

We assume that public health expenditure at time t is financed through a (constant) proportional tax $0 < \tau < 1$ according to the following technology (in accord with Chakraborty, 2004):

$$h_t = \tau w . \tag{2}$$

Therefore, in period t the budget constraint faced by an individual of the younger (working-age) generation reads as:

$$c_{1,t} + s_t = w(1-\tau), \tag{3.1}$$

i.e. wage income – net of contributions paid to finance health investments – is divided into material consumption when young, $c_{1,t}$, and savings, s_t.

When old, individuals are retired and live uniquely with the amount of resources saved when young plus the interest accrued at the constant rate prevailing in the world capital market, r. The existence of a perfect annuity market implies old survivors will benefit not only from their own past saving plus interest, but also from the saving plus interest of those who have deceased, and savings are intermediated through mutual funds. Hence, the budget constraint of an old retired individual started working at t can be expressed as

$$c_{2,t+1} = \frac{1+r}{\pi_t} s_t , \tag{3.2}$$

where $c_{2,t+1}$ is old-aged consumption.

knowledge, skills and abilities that make them better equipped to create a way of living that is conducive to their welfare and that is not mediated by economic status.”

The representative individual entering the working period at t must choose how much to save out of her disposable income to maximise the lifetime utility

$$U_t = \ln(c_{1,t}) + \pi_t \ln(c_{2,t+1}), \tag{4}$$

subject to Eqs. (3). The constrained maximisation of Eq. (4) gives the following – constant – saving rate:

$$s(\tau) = \frac{\pi(\tau)w(1-\tau)}{1+\pi(\tau)}. \tag{5}$$

with $\pi(\tau)$ being determined by Eq. (1).[7]

At time t the aggregate domestic income in this economy is given by $Y_t = wN_t + rs_tN_t$, that can be rewritten in per capita terms as

$$y(\tau) = w + rs(\tau), \tag{6}$$

since the saving rate is constant and $y := Y/N$.

The aggregate foreign debt in the country is determined as $D_{t+1} = K_{t+1} - S_t$, that can also be written in per capita terms as a function of the health tax rate, i.e.

$$d(\tau) = k - s(\tau). \tag{7}$$

As can be seen, public health affects both the per capita domestic income and per capita foreign debt uniquely through savings. Thus, it is sufficient to analyse how public health affects the saving rate to capture the transmission channels on the other macroeconomic variables, as described in the next section.

3. Health policy

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[7] Therefore, both young-aged and old-aged consumptions are constant and given by $c_1(\tau) = \frac{w(1-\tau)}{1+\pi(\tau)}$ and $c_2(\tau) = (1+r)c_1(\tau)$, respectively.

As regards the effect the health tax rate on savings, we find that:

$$\frac{ds}{d\tau} = \overbrace{\frac{\partial s}{\partial \tau}}^{-} + \underbrace{\overbrace{\frac{\partial s}{\partial \pi}}^{+} \cdot \overbrace{\frac{\partial \pi}{\partial \tau}}^{+}}_{+} \gtrless 0 . \tag{8}$$

Eq. (8) reveals that a rise in the health tax affects ambiguously the saving rate since there exist two counterbalancing forces at work: a negative direct effect on the disposable income of the young and a positive indirect effect that raises longevity due to higher public health capital, i.e. individuals live longer and discount the future at a lower rate to smooth consumption over the retirement period.

The following proposition describes how public health affects the saving rate, the per capita domestic income and the per capita foreign debt in a country:

Proposition 1. *(Effects of public health on savings, domestic income and foreign indebtedness).*

(1) The introduction of a proportional tax to finance public health capital – evaluated at $\tau = 0$ *– increases (reduces)* $s(\tau)$ *and* $y(\tau)$ *(*$d(\tau)$*) if and only if* $0 < \pi_0 < \bar{\pi}_0$*, where*

$$\bar{\pi}_0 := \frac{1}{2}\left[-(1+w) + \sqrt{(1+w)^2 + 4\pi_1 w}\right], \quad 0 < \pi_0 < 1. \tag{9}$$

(2.1) Let $0 < \pi_0 < \bar{\pi}_0$ *hold. Then* $s(\tau)$ *and* $y(\tau)$ *are inverted U-shaped (*$d(\tau)$ *is U-shaped) with* $\tau = \bar{\tau}$ *being the saving-maximising and income-maximising (debt-minimising) health tax rate, where*

$$\bar{\tau}(\pi_0) := \frac{-(1+\pi_0)\pi_1 + \sqrt{(1+\pi_0)^2 \pi_1^{\,2} + \pi_1(1+\pi_1)\Pi_0}}{\pi_1(1+\pi_1)w}, \quad 0 < \bar{\tau}(\pi_0) < 1, \tag{10}$$

and $\Pi_0 := -\pi_0^{\,2} - (1+w)\pi_0 + \pi_1 w$.

(2.2) Let $\bar{\pi}_0 < \pi_0 < \pi_1$ *hold. Then* $s(\tau)$ *and* $y(\tau)$ *(*$d(\tau)$*) decrease (increases) monotonically with* τ *for any* $0 < \tau < 1$.

Proof. Differentiating Eq. (5) with respect to τ and evaluating it at $\tau = 0$ gives:

$$\frac{\partial s(\tau)}{\partial \tau}\Big|_{\tau=0} = \frac{w\Pi_0}{(1+\pi_0)^2}. \tag{11.1}$$

Applying the Descartes' rule of sign we find that there exist two real roots $\underline{\pi}_0 < 0$ and $\bar{\pi}_0 > 0$ (see Eq. 9) such that $\Pi_0 = 0$. Since $\underline{\pi}_0 < 0$, it can be ruled out, while $0 < \bar{\pi}_0 < \pi_1$ is the unique economically relevant solution. Therefore, $\Pi_0 > 0$ (< 0) and from (11.1) $\frac{\partial s(\tau)}{\partial \tau}\Big|_{\tau=0} > 0$ (< 0) for any $0 < \pi_0 < \bar{\pi}_0$ ($\bar{\pi}_0 < \pi_0 < \pi_1$).

Now, differentiating Eq. (5) with respect to τ yields

$$\frac{\partial s(\tau)}{\partial \tau} = \frac{w_t\left\{-\pi_1(1+\pi_1)w^2\tau^2 - 2(1+\pi_0)\pi_1 w\tau + \Pi_0\right\}}{\left[1+\pi_0+(1+\pi_1)\tau w\right]^2}. \tag{11.2}$$

Applying the Descartes' rule of signs we find that there exist two real roots of (11.2) for τ, namely $\underline{\tau}(\pi_0) < 0$ and $\bar{\tau}(\pi_0) > 0$ (see Eq. 9), the latter being the sole economically relevant solution. Therefore, if $0 < \pi_0 < \bar{\pi}_0$ then analysis of (11.2) implies $\frac{\partial s(\tau)}{\partial \tau} \gtrless 0$ for any $\tau \lessgtr \bar{\tau}(\pi_0)$, where $0 < \bar{\tau}(\pi_0) < \bar{\tau}(0)$ for any $0 < \pi_0 < \bar{\pi}_0$, is an interior global maximum ($\frac{\partial \bar{\tau}(\pi_0)}{\partial \pi_0} < 0$ for any $0 < \pi_0 < \bar{\pi}_0$ and $0 < \bar{\tau}(0) < 1$). In contrast, when $\bar{\pi}_0 < \pi_0 < \pi_1$, then there exist two negative real roots of Eq. (11.2) and $\frac{\partial s(\tau)}{\partial \tau} < 0$ for any $0 < \tau < 1$, i.e. a rise in the health tax rate always reduces the saving rate.

Moreover, from Eqs. (6) and (7) we find that $\frac{\partial y(\tau)}{\partial \tau} = r \cdot \frac{\partial s(\tau)}{\partial \tau}$ and $\frac{\partial d(\tau)}{\partial \tau} = -\frac{\partial s(\tau)}{\partial \tau}$, respectively. Hence, the public health tax affects in the same (opposite) way the per capita domestic income (foreign debt). Therefore, Proposition 1 follows. **Q.E.D.**

Proposition 1 shows that a higher lifespan, through higher taxes to finance public health expenditure, may discourage savings and per capita domestic income, while augmenting the per capita foreign indebtedness. The analysis of how a change in health taxes affects savings has already shown the existence of two counterbalancing forces at work: a negative direct effect through a reduced disposable income of individuals and a positive indirect effect through owing to an increased survival probability at the end of youth. In particular, the higher π_0 the lower the intensity of health investment in reducing adult mortality, and this effect is stronger the more π_0 is close its saturating value, π_1. If the natural length of life is low enough ($0 < \pi_0 < \bar{\pi}_0$), a rise in π_0 due to some exogenous reasons softens the gain in longevity due to an additional increase in public health capital, and thus the increase in savings caused by a higher health tax is worsened. The more an economy develops the more π_0 may be thought to be higher due to some exogenous reasons. So, if the natural length of life if high enough ($\bar{\pi}_0 < \pi_0 < \pi_1$), the positive effect of τ on savings due to the gain in life expectancy becomes negligible and, hence, rising health taxes always reduces savings due to the reduced disposable income of the young.

As a consequence, a reduced saving rate due to higher health taxes shrinks domestic income and augments foreign indebtedness.

4. Welfare

Another important effect of public health investment is represented by its impact on the individual well-being. The public health spending is financed exclusively by a proportional wage tax levied on the income of current workers. Thus, only the young benefit from the advantages of the public health expenditure, while also bearing the cost of funding it. The health tax, therefore, does not hurt the old people living at the moment of the introduction of the health reform, since the interest rate is kept constant at the level prevailing in the world capital market. This means that the current old people are welfare neutral with respect to benefits and costs of the public health policy. Moreover, the welfare of young generation living at the time of the introduction of the health policy is the same as that will be obtained by all the future generations.

Assume that the health policy is introduced at time t. Then, the indirect lifetime utility index of the currently living people, $V_t(\tau)$, and the welfare of the generations born in all future periods, $V(\tau)$, are uniquely described by the following utility function:

$$V(\tau) = \ln\left(\left[\frac{w(1-\tau)}{1+\pi(\tau)}\right]^{1+\pi(\tau)} \cdot (1+r)^{\pi(\tau)}\right). \tag{12}$$

From Eq. (12) the following propositions holds:

Proposition 2. *Let $r > \bar{r}$ $(r < \bar{r})$ hold. The introduction of a proportional tax to finance public health capital – evaluated at $\tau = 0$ – is Pareto improving (worsening), where*

$$\bar{r} := \frac{1+\pi_0}{w} \cdot e^{1+\frac{1+\pi_0}{w(\pi_1-\pi_0)}} - 1. \tag{13}$$

Proof. The proof can easily be derived by differentiating Eq. (12) and evaluating it at $\tau = 0$, that is:

$$\frac{\partial V(\tau)}{\partial \tau}\Big|_{\tau=0} = -(1+\pi_0) - w(\pi_1 - \pi_0)\left[1 - \ln\left(\frac{w(1+r)}{1+\pi_0}\right)\right]. \tag{14}$$

Therefore, $\frac{\partial V(\tau)}{\partial \tau}\Big|_{\tau=0} > 0$ (< 0) if and only if $r > \bar{r}$ $(r < \bar{r})$, see Eq. (13). **Q.E.D.**

A rise in the health tax rate causes, (*i*) a negative welfare-effect because both young-aged and old-aged consumptions are reduced through two channels: (*i*.1) a lower disposable income when young and (*i*.2) a higher longevity, and (*ii*) a positive welfare-effect because individuals now live longer and then wish to discount the future at a lower rate, i.e. $\pi(\tau)$ increases. Hence, the final effect depends on which of the two forces dominates and this, in turn, depends on the mutual relationship between the key parameters of the problem. Proposition 2 disentangles these effects, showing that when the market interest rate is high enough the positive effect of longevity on welfare dominates and, hence, a public health policy represents a Pareto improvement, because it makes the current and all future generations better off without hurting the current old (that are policy neutral). This result occurs more likely the higher the wage received by the young workers, w, the higher the rate of longevity linked directly to public health capital, π_1, and the lower the natural rate of longevity, π_0, since it reduces the effectiveness of an additional increase in public health capital.

Moreover, the following proposition shows that an optimal provision of health capital exists when $r > \bar{r}$.

Proposition 3. *Let* $r > \bar{r}$ *hold. Then there exists a tax rate* $\tau = \tau^*$ *such that Pareto efficiency is achieved.*

Proof. From Proposition 2 we know that $\frac{\partial V(\tau)}{\partial \tau}\Big|_{\tau=0} > 0$ if and only if $r > \bar{r}$, i.e. the introduction of a public health programme is welfare-enhancing, and thus represents a Pareto improvement with respect the *laissez-faire*, only when the interest rate if high enough. Moreover, from (12) $\lim_{\tau \to 1} V(\tau) = -\infty$ for any r. Therefore, for any $r > \bar{r}$, at least a welfare-maximising value of the health tax rate $\tau = \tau^*$ ($0 < \tau^* < 1$) that marks the start of the welfare-declining region must necessarily exist. **Q.E.D.**

Proposition 3 shows that in the case $r > \bar{r}$ there exists an optimal provision of public health when $\tau = \tau^*$. Moreover, there exists a whole range of health taxes that allows for a Pareto improvement with respect to *laissez-faire* economy as well. This result is exemplified by the following numerical simulation. We take the parameter values (chosen only for illustrative purposes): $\pi_0 = 0.30$, $\pi_1 = 0.95$ and $w = 3$. This parameter set generates $\bar{r} \cong 1.30$. Then we assume a world interest rate r larger than the "threshold" one ($\bar{r}$), to allow for a Pareto improvement of the health policy (i.e. $r = 5$).

Table 1. Health tax and welfare.

τ	0	0.05	$\tau^* = 0.101553$	0.15	0.20	0.227	0.25
$V(\tau)$	1.624	1.688	1.707	1.694	1.655	1.625	1.596

Table 1 shows that when the interest rate is relatively high ($r = 5 > \bar{r}$), introducing health taxes (τ) up to almost 0.227 represents a Pareto improvement with respect to the *laissez-faire* ($\tau = 0$). Moreover, $\tau = \tau^* = 0.101553$ is the welfare-maximising tax rate allowing the achievement of the Pareto efficient allocation, since when $\tau = \tau^*$ it is impossible to make all generations better off by either increasing or decreasing the health tax rate. Furthermore, when the tax if fixed at too high a rate (higher than 0.227 in the table), the health policy becomes Pareto worsening. In that case, the reduction in both young-aged and old-aged consumptions due to the higher tax τ implies that the negative welfare-effects dominates the positive due to the increased longevity and, hence, welfare shrinks.

In conclusion, Table 1 above, therefore, serves as an example to illustrate that when $r > \bar{r}$, $\frac{\partial V(\tau)}{\partial \tau} \gtrless 0$ for any $\tau \lessgtr \tau^*$, i.e. the welfare of all generations increases (decreases) monotonically before (beyond) τ^*.

5. Conclusions

Using a simple overlapping generations small open economy, we show that longevity determined endogenously through public health expenditure may reduce both the saving rate and per capita domestic income, while increasing the per capita foreign debt in a country. This because, first a rise in health taxes affects negatively (positively) the saving rate through a reduced disposable income of individuals (an increased survival probability at the end of youth). Second, if the natural length of life is high, then the gain in longevity due to an additional increase in public health capital is weakened and thus the positive effect of the health tax on savings due to the gain in life expectancy tends to become negligible. Therefore, as a final consequence, when the natural length of life is high rising health taxes always reduces savings, shrinks domestic income and augments foreign indebtedness, because the negative effect of the reduced disposable income of the young always dominates. The policy suggestion is that, to the extent that the more an economy develops the more the natural length of life may be conjectured to be higher due to some exogenous reasons such as, for instance, higher education and peace, a high public health spending may be harmful for (exogenous) economic growth especially in developed countries.

Funding public health capital, however, is always beneficial for life expectancy and the welfare analysis has shown that may even represent a Pareto improvement with respect to the *laissez-faire* solution, under the circumstances that the world interest rate is high enough and the health tax is not fixed at too high a rate. Our findings suggest that the belief concerning the positive effect of a higher life span on both savings and income is not warranted in a small open economy with public health provision.

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