

# Effect of Improved Survival and Population Ageing in an Overlapping Generation Model with Endogenous Health Care \*

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## **Abstract**

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# 1 Introduction

The Center for Medicare and Medicaid Services predicted that the healthcare spending in US is to grow 5.5% annually on average in 2017-2026, and will occupy 19.7% of the economy. These increases will be fundamentally driven by income growth, demographic changes and ageing population (Cuckler et al., 2018). Population ageing has long been identified as a major contributing factor to the increase in healthcare spending. As Mendelson and Schwartz (1993) pointed out, the costs of treating patients over age 65 and over grew more rapidly than their younger counterparts. With the baby boomers fast approaching their retiring age, the window of time to come up with the right policy that can digest the inescapable expansion of Medicare and extra burden of senior care is rapidly closing. In addition, recent technology advancement will increase life expectancy and postpone mortality, which will also add to the burden of health care spending. Barendregt et al. (1997) showed that a cessation of smoking behaviors in fact increases health care spending in that non-smokers tend to live longer as opposed to smokers, which can serve as evidence that prolonged life expectancy will increase health care spending in the long run. Thus, it is in a policy maker's favor to have a model that can simulate the effect of population ageing on the health care industry and the economy, reflected by indicators like health care good output, interest rate, savings rate, and etc.

## 1.1 Grossman Model

Grossman (1972) proposed a framework where health care is modeled as depreciative and durable capital good, with an initial endowment. The model reads:

$$H_{t+1} = (1 - \delta)(H_t + I_t)$$

where  $H$  is the health as capital good, and  $I$  stands for investments in health. The outcome of health comes twofolds, one enters the utility function as humans enjoy good health, while the other one is reduced amount of sick time, which makes room

for more work and leisure time. Due to its uniqueness at the time of its proposal, the **Grossman** model soon established itself to be the premiere model for demand for health, and found some level of empirical evidence and a range of applications (Cropper, 1981; Corman and Grossman, 1985; Leu et al., 1991; Grossman et al., 1972). However, the **Grossman** model does not meet critics' expectations of empirical validity. The idea behind its failure to map onto the real world lies in the fact that healthy people with a higher endowment of health capital good, tend to invest less in health but still inherit better health outcome from the last period, than those in poor health. Also, traditionally healthy people are usually more efficient producers of health care, and thus face a lower shadow price of health capital good (Wagstaff, 1986; Zweifel, 2012; Wagstaff, 1993). Despite these shortcomings, the dynamic nature of **Grossman** model makes it an ideal candidate to incorporate into an overlapping generations model, where decision from the last period affect the agent's optimized decision this period. In this case, the agent can not only choose consumption and savings, but also the amount of investment in health care, which will not only make her a happier person, but also a more productive worker.

## 1.2 Overlapping Generations Model

The model in this project will rely heavily on Professor Richard Evans' OLG model with demographic dynamics, like immigration rate, fertility rate, and mortality rate (Evans and DeBacker, 2018). The demographic profile evolves according to the fol-

lowing rule

$$\omega_{1,t+1} = (1 - \rho_o) \sum_{s=1}^{E+S} f_s \omega_{s,t} + i_1 \omega_{1,t}, \quad \forall t \quad (1)$$

$$\omega_{s+1,t+1} = (1 - \rho_s) \omega_{s,t} + i_{s+1} \omega_{s+1,t}, \quad \forall t \quad \text{and} \quad 1 \leq s \leq E + S - 1 \quad (2)$$

$$N_t = \sum_{s=1}^{E+S} \omega_{s,t} \quad \tilde{N}_t = \sum_{s=E+1}^{E+S} \omega_{s,t} \quad (3)$$

$$n_{s,t} = \begin{cases} 1, & E + 1 \leq s \leq E + \text{round}(\frac{2S}{3}) \\ 0.2, & s \geq E + \text{round}(\frac{2S}{3}) \end{cases} \quad (4)$$

Here,  $\omega_{s,t}$  stands for the number of households of age  $s$  alive at time  $t$ .  $E$  stands for the amount of time the agent spends in preparation for labor, and  $S$  stands for the time post-education and before death. [1](#) writes the number of newborns at time  $t + 1$  as the sum of immigration and childbirth at time  $t$ . [2](#) writes the population, barring newborns, at time  $t + 1$ , as the surviving agents and immigrants from time  $t$ .  $\rho_s$  stands for mortality rate at age  $s$ . [3](#) sums up the all households in the population to be the participating labor force, and [4](#) specifies two-thirds of a person's lifetime  $\frac{2S}{3}$  to be the retiring age, before which the agent can contribute 1 unit of labor and after which she can only contribute 0.2 unit of labor. Just like any other overlapping generations model, the agents then optimizes her option by selecting the consumption and savings subject to a budget constraint, in accordance to [5](#).

$$\max_{\substack{\{c_{s,t+s-1}\}_{s=E+1}^{E+S}, \\ \{b_{s+1,t+s}\}_{s=E+1}^{E+S-1}}} \sum_{s=E+1}^{E+S} \beta^{s-E-1} [\Pi_{n=E}^{s-1} (1 - \rho_n)] U(c_{s,t+s-E-1}) \quad \forall s, t \quad (5)$$

$$s.t. \quad c_{s,t} + b_{s+1,t+1} = (1 + r_t) b_{s,t} + w_t n_s, \quad \text{and}$$

$$b_{E+1,t}, b_{E+S+1,t} = 0 \quad \forall t \quad \text{and} \quad c_{s,t} \geq 0 \quad \forall s, t$$

On the basis of [Evans and DeBacker](#)'s model, this project aims to add in the element of endogenous health. In compliance with Grossman Model, the agent will choose an

optimized amount of health expenditure to maximize her utility (inclusive of health). Improved health will also make her a more productive worker.

### 1.3 Endogenous Health

The idea of endogenous health care is by no means a strange one. This project will draw inspirations from a couple of recent ones.

[Leung and Wang \(2010\)](#) introduces a two-period model where agents optimize based on the following constraints (6, 7):

$$c_t^t = w_t - s_t - m_t \quad (6)$$

$$c_{t+1}^t = R_t s_t, \quad \text{where} \quad (7)$$

$$R_t = \frac{1 + r_{t+1}}{p(m_t)}, \quad \text{and} \quad (8)$$

$$p(m_t) = p_0 + \bar{p} \sqrt{\frac{m_t}{1 + m_t}} \quad (9)$$

Here, expenditure on health care  $m_t$  will increase the agent's chance of surviving to the next period  $p(m_t)$ .  $\bar{p}$  is the maximal chance of survival, which can be increased by technological advancement (9).  $R_t$  is the average return on investment (8). Their simulation shows health care to be growth promoting and welfare improving, especially in countries with advanced biomedical technologies.

[Hashimoto and Tabata \(2010\)](#) took one step further, and separated health care industry from non-health care industry. The model makes the assumption that the health care industry is a labor-intensive one, and thus needs no capital input.  $A_t$  here stands for labor augmenting factors.

$$Y_t^H = A_t^H L_t^H \quad (10)$$

$$Y_t^N = F K_t, A_t^N L_t^N \quad (11)$$

It also makes the assumption that the labor market is competitive, and thus eventually the wage in non-health care industry equals the wage in health care industry.

Eventually, the relative price of health care good satisfies

$$q_t = \bar{w} \frac{A_t^N}{A_t^H} \quad (12)$$

They find that population ageing induces a shift in labor supply from non-health care industry to health care industry, and lowers per capita income growth rate.

The model presented in this project will learn from the two-period models in previous literature, and allow the agents in the model to live for  $S$  number of years. Adding this layer of granularity will allow us to see how the income and health level change within the agent's lifetime.

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