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 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 (1, 2):

$$c_t^t = w_t - s_t - m_t \tag{1}$$

$$c_{t+1}^t = R_t s_t, \quad \text{where} \tag{2}$$

$$R_t = \frac{1 + r_{t+1}}{p(m_t)}, \quad \text{and} \tag{3}$$

$$p(m_t) = p_0 + \bar{p}\sqrt{\frac{m_t}{1 + m_t}} \tag{4}$$

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 (3). R_t is the average return on investment (2). 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.

$$Y_t^H = A_t^H L_t^H \tag{5}$$

$$Y_t^N = F K_t, A_t^N L_t^N \tag{6}$$

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

$$q_t = \bar{w}\frac{A_t^N}{A_t^H} \tag{7}$$

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.

Similar studies, mostly two-period models, tell different stories. Fougère et al. (2007) also studies the effect of population ageing on the economy with a multi-industry setup in their OLG model. They found similar results as (Hashimoto and Tabata, 2010) in that a labor supply shock will lead more labor to health care industry and less labor in other industries. Cipriani (2014) added a pay-as-you-go pension system to OLG and showed that an ageing population resulted from increased longevity will decrease pension payout. Aísa et al. (2004) allows for not only endogenous quantity of health care, but also quality, to probe the dynamic bidirectional relationship between longevity and economics, mediated by human capital accumulation. Galama et al. (2013) relaxes the assumption that the agent makes optimal decision regarding her health, and make the decision to retire an endogenous one. They found that healthier workers do choose to retire later and their health deteriorates more slowly.

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.

2 Model

In this section I will introduce a OLG model where agents live S periods and labor supply is exogenous. The model will rely heavily on Professor Richard Evans' OLG model with demographic dynamics and exogenous labor (Evans and DeBacker, 2018). In compliance with Grossman Model, the agent will choose an optimized amount of health expenditure, in addition to consumption and savings as specified in Professor Evan's model, to maximize her utility. Improved health will also make her a more productive worker.

2.1 Demographics

Following Evans and DeBacker (2018), the demographic profile evolves according to the following rules

$$\omega_{1,t+1} = (1-\rho_o)\sum_{s=1}^{E+S} f_s\omega_{s,t} + i_1\omega_{1,t}, \quad \forall t \tag{8}$$

$$\begin{aligned} \omega_{s+1,t+1} &= (1-\rho_s)\omega_{s,t} + i_{s+1}\omega_{s+1,t}, \\ &\forall t \quad \text{and} \quad 1 \leq s \leq E+S-1 \end{aligned} \tag{9}$$

$$N_t = \sum_{s=1}^{E+S} \omega_{s,t} \qquad \tilde{N}_t = \sum_{s=E+1}^{E+S} \omega_{s,t} \tag{10}$$

$$g_{n,t+1} = \frac{N_{t+1}}{N_t} - 1 \qquad \tilde{g}_{n,t+1} = \frac{\tilde{N}_{t+1}}{\tilde{N}_t} - 1 \tag{11}$$

$$n_{s,t} = \begin{cases} 1, & E+1 \leq s \leq E + round(\frac{2S}{3}) \\ 0.2, & s \geq E + round(\frac{2S}{3}) \end{cases} \tag{12}$$

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. 8 writes the number of newborns at time $t+1$ as the sum of immigration and childbirth at time t. 9 writes the population, barring newborns, at time $t+1$, as the surviving agents and immigrants from time t. ρ_s stands for mortality rate at age s. 10 sums up the all households in the population to be the participating labor force, where N_t is the total population in the economy $\tilde{N}_t$ is the working age population. 11 calculates the total population growth rate g_t and working population growth rate $\tilde{g}_t$. 12 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.

2.2 Firm

Borrowing Hashimoto and Tabata (2010)'s idea, here I also make the distinction between a market for health care goods, and a market for non-health-care goods.

Unlike in Hashimoto and Tabata (2010), we do not make the assumption that the health care market is only labor-intensive. We assume that due to hospitals invest heavily in medical equipments, the market is also capital–intensive. Suppose the price of non-health-care goods is numeraire, and the price of health care good is p_t^H at time t. The market then becomes:

$$Y_t^H = A_t^H (K_t^H)^{\alpha_H} (L_t^H)^{(1-\alpha_H)} \tag{13}$$

$$Y_t^N = A_t^N (K_t^N)^{\alpha_N} (L_t^N)^{(1-\alpha_N)} \tag{14}$$

Then, the companies in the two markets will optimize the profit according to

$$\max_{K_t^H, L_t^H} P_t^H A_t^H (K_t^H)^{\alpha_H} (L_t^H)^{(1-\alpha_H)} - (r_t^H + \delta) K_t^H - w_t^H L_t^H \tag{15}$$

$$\max_{K_t^N, L_t^N} A_t^N (K_t^N)^{\alpha_N} (L_t^N)^{(1-\alpha_N)} - (r_t^N + \delta) K_t^N - w_t^N L_t^N \tag{16}$$

Here we make the assumption that both the health care and non-health-care markets are perfectly competitive with no barriers to entry, and thus the wages and interest rates become the same.

$$r_t^H = r_t^N$$

$$w_t^H = w_t^N$$

Based on 15 and 16 we can get r_t, w_t and P_t^H.

$$r_t = \alpha_N (\frac{L_t^N}{K_t^N})^{(1-\alpha_N)} - \delta_N \tag{17}$$

$$w_t = (1-\alpha_N)(\frac{K_t^N}{L_t^N})^{\alpha_N} \tag{18}$$

$$P_t^H = \frac{(1-\alpha_N)(\frac{K_t^N}{L_t^N})^{\alpha_N}}{(1-\alpha_H)(\frac{K_t^H}{L_t^H})^{\alpha_H}} \tag{19}$$

There is an over-identification problem for P_t^H here that needs to be addressed.

2.3 Households

$$n_{s,t} = n_s \tag{20}$$

$$c_{s,t} + b_{s+1,t+1} + P_t^H h_{s,t} = (1 + r_t)b_{s,t} + w_t n_{s,t} f(h_{s-1,t-1}) \tag{21}$$

$$U = ln(c^{\gamma}_{s,t+s-E-1} h^{1-\gamma}_{t+1}) \tag{22}$$

Labor is exogenous in this model (20). 21 states the budget constraint, where $f(h_{s-1,t-1})$ is a boost to productivity, that augments $n_{s,t}$. The agents derive utilities from both consumption and health care, in accordance to 22. The households in the economy then optimize according to:

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

$$s.t. \quad 20 \quad \text{and} \quad 21, \quad \text{and} \quad b_{E+1,t}, b_{E+S+1,t} = 0 \quad \forall t \quad \text{and} \quad c_{s,t} \geq 0 \quad \forall s, t \tag{23}$$

This optimization will give a system of $S - 1$ Euler Equations:

$$U'(c_{s,t}, h_{s,t}) = \beta(1 + r_{t+1})(1 - \rho_s)U'((c_{s+1,t+1}, h_{s+1,t+1}) \tag{24}$$

$$\forall t, \text{and } E + 1 \leq s \leq S - 1$$

2.4 Market Clearing

Here, the labor market, capital market, and both the health care good and non-health-care good market have to clear.

$$K_t^N + K_t^H = \sum_{s=E+2}^{E+S} b_{s,t} \tag{25}$$

$$L_t^N + L_t^H = \sum_{s=E+1}^{E+S} \omega_{s,t} n_s f(h_{s-1,t-1}) \tag{26}$$

$$Y_t^N = C_t + I_t^H + I_t^N - \sum_{s=E+2}^{E+S} i_s \omega_{s,t} b_{s,t+1} \quad \text{where} \tag{27}$$

$$I_t^H = K_{t+1}^H - (1-\delta)K_t^H \quad \text{and,}$$

$$I_t^N = K_{t+1}^N - (1-\delta)K_t^N \quad \text{and,}$$

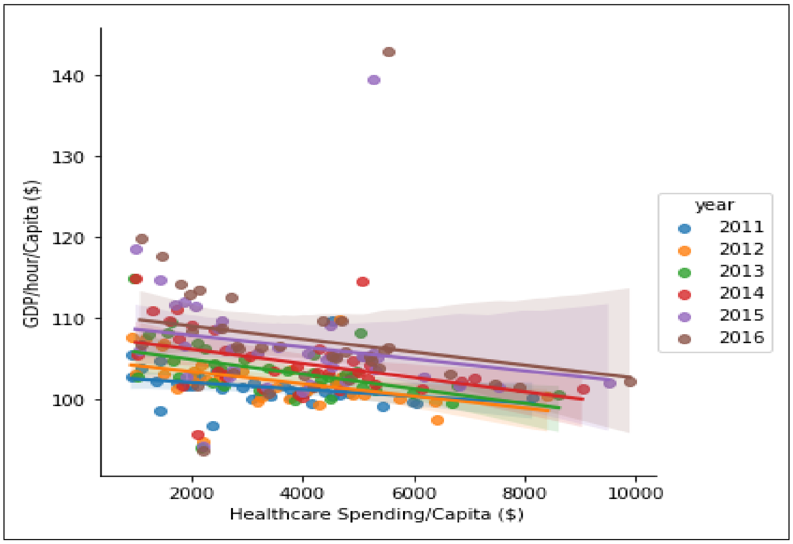
$$C_t = \sum_{s=E+1}^{E+S} \omega_{s,t} c_{s,t}$$

$$Y_t^H = \sum_{s=E+1}^{E+S} \omega_{s,t} h_{s,t} \tag{28}$$

3 Calibration

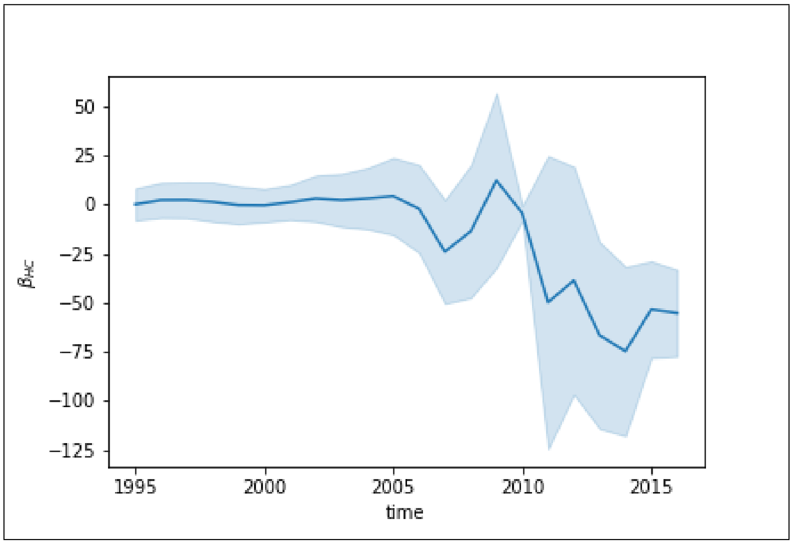
Here I use OECD countries' health care spending VS labor productivity data as a proxy for how much a marginal dollar on health care can boost labor productivity. As mentioned before, empirically, there are many confounding factors that decide how much a country spends on health care. This increase in productivity by no means exhibits a causal effect of great significance. However, here I am using it as a rudimentary calibration of $f(h_{s-1,t-1})$ that appeared in 26, namely how much the endogenous health care spending can boost labor productivity. The picture below shows the rudimentary relationship. It seems that the correlation between health care spending and labor productivity is negative (Figure 1). One fix of this empirical conundrum can be a regression. Here I included the most easily available covariate, the GDP of the country. As shown in Figure 2, after controlling for GDP, there are

Figure 1: Correlation between Health Care Spending and Productivity in OECD countries



a couple of years where $\beta_{HealthCare}$ is positive.

Figure 2: Boost of Productivity by Healthcare over Time in OECD countries



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