Child Health Investment and Human Capital Accumulation

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Abstract

This paper develops an overlapping-generations model to investigate how child health investment affects a family's decision in fertility and education of their children. By comparing the impacts under different healthcare systems and we find that under the hybrid healthcare system with public and private healthcare systems being imperfect substitutes, when income reaches above a certain level fertility decreases with health investment while education investment increases with health investment. Hence human capital is accumulated at an increasing rate. Furthermore, we conduct an econometric estimation to investigate the impact of child health investment on academic achievement which is a predictor of future income for two cohorts of Australian children. Regression results have shown that child health investment has significant impact on child's academic performance for 4-5 year old children.

Keywords: Health investment; human capital accumulation; mortality; education investment.

JEL Classification: I10, J24, C20

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1. Introduction

Children's access to education and to learning can be influenced by child characteristics such as aptitude, motivation and behaviour, which are associated with health status. Since education is a key element for human capital accumulation, ascertaining how child health contributes to human capital accumulation through a direct or indirect impact on academic performance, becomes an important question. In view of this, this paper aims at studying the impact of health spending on the effectiveness of education and as a result on human capital accumulation.

The importance of the nexus between health and education attainment has been highlighted in the literature.[3] This relationship has been extensively studied in the past especially in high-income countries. Unfortunately, there is no agreement in terms of the causality between health and education, according to reviews by Currie (2008) and Suhrcke and de Paz Nieves (2011). Gan and Gong (2007) strongly support the interdependence between health and education. Their estimations indicate that an individual's education, health expenditure, and previous health status all affect his or her health status. Moreover, the individual's health status affects his or her mortality rate, wage, home production, and academic success. Considering that education and health are interdependent, we will look at the mechanism that child health contributes to human capital accumulation through a direct or indirect impact on academic performance.

As 'health capital' is important for education and earnings (Grossman, 2000; Case, Fertig, and Paxson, 2005; Arrow et. al 2012), it is possible that health in childhood is an important mechanism for intergenerational transmission of education and economic status. Smith (2008) found that good health during childhood increased adult family income by 24% compared with poor health, using within-sibling models on panel data in the United States. Case, Fertig and Paxson (2005) also support that childhood health conditions have a lasting impact on health

[3] However, the implication of the health for education may not have received a due attention in practice. For example, Galal et al. (2005) raise a concern that a quarter of all children eligible to be in school are malnourished, and scarce attention is paid to the health and wellbeing of school children in education sector planning.

and socioeconomic status in middle adulthood. These adult outcomes in turn are likely to influence the health conditions and behaviours of the next generation, which would affect educational outcomes and overall future prospects in a self-reinforcing cycle (Suhrcke and de Paz Nieves 2011). Currie (2008) argues that health differences affecting the intergenerational transmission of poverty through educational outcomes may therefore explain a significant share of the existing socioeconomic inequalities in developing but also in industrial countries. On the other hand, education may drive the health status; however, this aspect lies beyond the focus of this paper.[4]

How does child health potentially affect human capital accumulation? A direct effect of health on learning is that malnourished and sick children are often absent from school and even less likely to be enrolled in school (Mayer-Foulkus 2005, Currie et al 2010). In addition, poor health can severely weaken the learning capacity of students as health may affect the physical energy level or mental status of a child that may have a direct impact on schooling performance (Mayer-Foulkus 2005, Bloom and Canning 2009). Empirical studies have shown strong evidence that health and nutrition influence children's performance in school (Behrman 1996, Glewwe and Jacoby 1995, Glewwe, et. 2001, Wisniewski 2010, Ding et. 2009 and Zhao 2012, etc.). Moreover, chronic poor health can adversely affect ideas production because it impairs creativity, entrepreneurship and lateral thinking (Howitt 2005).

There are some studies looking at the role of health in human capital accumulation. For example, Strauss and Thomas (1998) have proved a positive relationship between health and earnings holds across education levels, suggesting a health human capital is complementary to the

[4] The empirical review undertaken by Grossman (2005) has provided a good deal of evidence for the proposition that the education effects on health are causal although specific mechanisms are not identified. Cutler and Lleras-Muney (2006) has paid attention to health gradients by education. Silles (2009) has shown a causal effect of education on health by using multiple measure of overall health. Some other studies have examined the impact of education for a wide variety of health indicators. Deaton and Paxson (2001), Lleras-Muney, A. (2005), Albouy and Lequien (2009) and Clark and Royer (2010) etc. have analysed the variability in educational differences in adult mortality. Nayga, R.M. (2000), Ahrendt, J. (2005), Kenkel et al (2006), Grimard and Parent (2007), Cutler and Lleras-Muney (2010) and Jürges et al (2011) have addressed the causal effect of education for health risk factors; For disease morbidity, Pincus, Callahan and Burkhauser (1987) have found that most chronic diseases in the age 18-64 population are reported significantly more frequently by individuals with fewer than 12 years of formal education; Lundborg (2008) has used experimental data on identical twins to conclude that higher educational levels positively reduce the number of chronic conditions.

importance of education. Galor and Mayer-Foulkes (2002) illustrate that health as a form of human capital can be instrumental in generating persistent inequality. In this paper, health is not taken as a type of human capital, however, it affects human capital through a direct impact on education investment. We do not compare the difference in impacts between public and private education system here. When education is publicly provided its effect will be homogeneous on human capital formation. Since we are more interested on the interaction of both health and education spending at the individual level and how these together with other factors can explain the variation of education attainment outcomes, this aspect of education system may not be that important here.

At the micro level, some papers have examined the impact of child health on fertility and education using different methodologies (Kalemli-Ozcan, 2003; Ehrlich and Kim, 2005; and Fioroni, 2010). A common feature in these papers is that health status is taken as exogenous or dependent on other variables characterizing the stage of economic development. Thus, health level is external to the individual's optimization problem and has no feedback effect on the individual's choice of human capital investment. At the macro level, Knowles and Owen (1997) employ an effective-labour growth model incorporating education and health as labour-augmenting factor to find a strong positive relationship between growth and health. On the contrary, van Zon and Muysken (2001) show that a preference for health in an economy may discourage growth with decreasing returns in the health sector. Based on the Schumpeterian growth model, Howitt (2005) and Madsen (2012) empirically find out a high influence of health on schooling, innovations and growth for 21 OECD countries over the past two centuries. In addition, Zhang and Zhang (2005) conduct cross-section analyses using data from 76 countries to find that health has a significant positive effect on schooling and growth.

Although, the previous studies obtained some useful intuitions into the relationship between health and education, they do not identify the channels through which child health influence human capital. In light of this, we aim at obtaining new meaningful insights into how health status of a child affects educational outcomes. We address this question through developing an overlapping-generations (OLG) model to investigate how child health investment affects human capital accumulation through the behaviour and choice of households.

In our model, child health investment is internalized in an agent's optimization problem with the initial hypothesis that the level of child's health is assumed to be an increasing function of parents' health investment which is related to their income and preference, and other variables. Due to the endogeneity of the health variable, most studies had difficulties in assessing the impact of health investment on educational outcomes. To address this issue, we will adopt an endogenous framework and look at how health spending affects a family's decision in fertility and education investment, and hence human capital stock for the economy. Incorporating health spending in family's decision-making process could provide some insight to policy makers regarding the importance of health in wellbeing of individuals and development of the whole economy.

Since, healthcare systems can be both privately and publicly provided, we also compare the impact of child health investment under specific healthcare systems and a hybrid system. The main rationale for the ways how these systems differ between each other stems from the following. In a private healthcare system, individuals have to measure the benefit of more children and benefit of human capital investment to maximise their utility subject to budget constraint. When income cannot sustain subsistence consumption, individuals choose to have no children and hence there is no human capital accumulation. When income reaches above a certain level, with a larger opportunity costs of child bearing parents are more willing to exchange quantity for quality of children. Hence child's health investment reduces the fertility rate but encourages the education investment on children and human capital is accumulated at an increasing rate. In a public healthcare system, with certainty of survival probability, child education investment rises with parents' income, which leads to human capital growth at an increasing rate. The positive effect on human capital accumulation makes the introduction of public health investment especially important for developing countries where high opportunity cost of childcare, low income, poor health services and inadequate schools often discourage education investment. However, one needs to be cautioned that mere public healthcare system may contribute to the wealth inequality problem. Under a hybrid healthcare system, a better public health system enhances the positive impact of private child health investment on human capital accumulation. The hybrid system overcomes the shortages of public and private healthcare systems. Individuals with low income may rely on public health services to reduce mortality rate of children and they can still spend limited resources to improve the quality of children. Taking advantage of public health service the rich can invest extra on child's health for more human capital accumulation.

By extending the existing fertility choice model developed in the literature and testing the hypotheses stemming from it, this paper makes three contributions to the literature. First, it incorporates health spending in family's decision-making process regarding to fertility and education investment in a micro economic environment. By using child mortality as an indicator for health status, we show that when human capital is the engine of growth, child health investment magnify income differences across countries. Second, by comparing the impact of child health investment on human capital accumulation under private and public and a hybrid healthcare system, we show the differences in their impact on human capital accumulation. These findings can have important policy implications. Third, an econometric estimation based on theoretical model has demonstrated that child health investment exerts a significant impact on children's academic performance.

The paper is organized as follows. Section 2 develops a two-period overlapping generations model showing how child health investment aiming to reduce mortality rate affect households' choices of fertility and education investment and hence children's human capital accumulation under different healthcare systems separately. Section 3 conducts an empirical investigation of the impact of child health investment on next generation's human capital accumulation using Australian data. Conclusion and policy implications are carried out in Section 4.

2. The model

2.1 Setup

Consider an OLG model, where individuals live for two periods: childhood and adulthood. A representative individual make decisions in the adult period of life, with an endowment level of human capital h_t determined by their parents. Assume that the labour market is perfectly competitive, so the wage of per unit of human capital is constant. For simplicity assume that wage rate is equal to one, then h_t is equal to income. Each individual, in the first period of life, consume a fraction of their parents' income; hence, their consumption is determined by their parents. In the second period of life, each agent makes a decision on fertility or the number of children, n_t, and consumption decision, c_t. With given income, agents ensure their consumption is no less than a subsistence level $\bar{c}$.

We follow de la Croix and Doepke (2003), Doepke (2004), Fioroni (2010) and assume that the agent's preferences are defined over current consumption, c_t , and future income of survived children $\pi(g_t)n_t h_{t+1}$. The number of surviving children is defined as $\pi(g_t)n_t$, where $\pi(g_t)$ is the survival rate during childhood period which is a function of the share of income spent on health investment, g_t. That is, health investment (private or public) is required to prevent child mortality.[5] Following the empirical investigation (Shultz,1993) and specification in Fioroni (2010), we specify the survival rate of children as $\pi(g_t)$ =$\pi_0(1 + a g_t)$, where $a \in (0,\frac{1}{2})$ is the efficiency parameter of private health investment and $\pi_0 \in (0,\frac{1}{2})$ is the initial probability of

[5] World Health Organization (WHO) has estimated that 17% of deaths in children younger than 5 years are due to the diseases that can be prevented by routine vaccination. WHO report (2009) has shown that by 2015 global childhood morbidity and mortality due to vaccine-preventable diseases will have been reduced by at least two thirds compared to 2000 levels by investing in immunization. In addition, Stenberg et al. (2013) have estimated additional health investment especially scaling up health services can prevent 47% of child death for 74 Countdown countries in 2013-35.

surviving to adult. Trivially, the survival probability π is assumed to be between 0 and 1. It is assumed that the survival rate of children satisfies following properties:

$$\pi(0) = \pi_0 \geq 0\,, \qquad (1)$$

$$\pi'(g_t) > 0, \qquad (2)$$

$$\pi''(g_t) < 0. \qquad (3)$$

The above properties imply that the survival rate rises with health investment but at a decreasing rate. Thus, using Stone-Geary preferences, the utility function of the representative agent of generation t is given as

$$U_t = \gamma \ln(c_t - \bar{c}) + (1-\gamma) ln\pi(g_t) n_t h_{t+1}, \qquad (4)$$

where $\gamma > 0$ is the preference parameter of an altruistic parent.

In what follows we will consider three different healthcare systems and their effect on the survival of children and ultimately on their human capital accumulation.

2.2 Private healthcare system

In a private healthcare system, agents allocate their income among consumption, child bearing, education and health services spending. Assuming that child raising cost for each born child is a fraction $\theta \in (0,1)$ of an agent's time, an agent's decision is subject to the following budget constraint:

$$c_t = h_t(1-\theta n_t) - e_t \pi_t n_t - g_t h_t n_t. \qquad (5)$$

We assume that $\pi_t = \pi_0(1 + a g_t)$, where the second term stands for the effect of private health spending on education investment and the last term stands for the resources spend on health care. Since $g_t \in (0,1)$ by definition, and assuming that $\pi_0 \in (0, \frac{1}{2})$ and $a \in (0, \frac{1}{2})$, with the assurance that $\pi_t \in (0,1)$, we can write the budget constraint as:

$$c_t = h_t(1-(g_t+\theta)n_t) - e_t n_t \pi_0(1+ag_t) \qquad (6)$$

That is having n_t children reduces time to work and effective income is given as $h_t(1-(g_t+\theta)n_t)$.

Similar to specifications in Azarnert (2006) and Fioroni (2010), from this effective income a parent spends on education of the surviving children, $e_t n_t \pi_0(1+ag_t)$.

The human capital of children h_{t+1} depends on child's ability parameter A, parent's human capital h_t and education investment e_t, which is

$$h_{t+1} = Ae_t{}^{\beta} h_t \qquad \text{for } 0<\beta<1. \qquad (7)$$

Health investment is spent on all children being born, which not only reduces the mortality rate, but also enhances the ability of the surviving children. For example, Meltzer (1992) demonstrates that declines in mortality can have quantitatively large effects on school enrolment. In this sense, health investment may contribute to human capital accumulation through a direct impact on educational attainment. To incorporate the latter idea we assume that child's ability is a function of health spending, $A = bg_t{}^{\alpha}$, where b represents a catch-all parameter that captures the effects of all other exogenous variables such as parents' education level and lifestyle on child's ability and α implies the efficiency of impact of health expenditure on child's ability. This approach allows us to have heterogeneity in terms of ability of individuals, and makes it possible that while spending the same amount on education one still may obtain different achievements.

Substituting Eqs. (6) and (7) into the utility function, the maximization problem of an agent of generation t is given by

$$U_t = \gamma ln[h_t(1-(g_t+\theta)n_t) - e_t n_t \pi_0(1+ag_t) - \bar{c}] + (1-\gamma)ln\left[\pi_0(1+ag_t)n_t b g_t{}^{\alpha} e_t{}^{\beta} h_t\right],$$

$$(n_t, e_t, g_t) \geq 0. \qquad (8)$$

For agents that have enough income to ensure a subsistence level of consumption $\bar{c}$, the optimal number of children n_t and the optimal level of education investment e_t can be expressed as a function of g_t:

$$n_t = \frac{(1-\gamma)(h_t-\bar{c})(1-\beta)}{h_t(g_t+\theta)} \quad (9)$$

$$e_t = \frac{h_t(g_t+\theta)\beta}{\pi_0(1+ag_t)(1-\beta)} \quad (10)$$

Equation (9) requires that $h_t \geq \bar{c}$, otherwise when income is very low so that it cannot sustain an agent's lowest consumption, the agent chooses not to have any children and hence no human capital accumulated.

The comparative statics of the above decision variables with respect to g_t and h_t are given by:

$$\frac{\partial n_t}{\partial h_t} = \frac{(1-\gamma)(1-\beta)\bar{c}}{(g_t+\theta){h_t}^2} > 0 \quad (11)$$

$$\frac{\partial n_t}{\partial g_t} = -\frac{(1-\gamma)(1-\beta)(h_t-\bar{c})}{h_t(g_t+\theta)^2} < 0 \quad (12)$$

$$\frac{\partial e_t}{\partial h_t} = \frac{(g_t+\theta)\beta}{\pi_0(1+ag_t)(1-\beta)} > 0 \quad (13)$$

$$\frac{\partial e_t}{\partial g_t} = \frac{\beta h_t(1-a\theta)}{(1-\beta)\pi_0(1+ag_t)^2} > 0 \quad (14)$$

We formulate the following lemma from the comparative statics of decision variables:

Lemma 1. *Under a private health system, both the number of children and education investment increase with income. When income is above the subsistence consumption, the optimal number of children decreases with child's health investment while the optimal level of education investment increases with child's health investment.*

From the above inequalities, we can see that an increase in income results in an increase in the number of children and educational spending. However, with higher income the opportunity cost of child bearing becomes larger, parents may prefer to have fewer children. It can be seen from the change rate of n_t with respect to h_t, $\frac{\partial^2 n_t}{\partial h_t^{\,2}} = -\frac{2(1-\gamma)(1-\beta)\bar{c}}{(g_t+\theta){h_t}^3} < 0$. Therefore, parents are more willing to exchange quality for quantity by reducing fertility and investing more in child.

On the other hand, higher child health spending discourages the fertility. An increase of private health spending raises survival probability, hence parents have less incentive to give birth to more children. The impact of private health spending on education investment depends on the efficiency of health spending a and the child bearing cost θ. It is clear that the allocation in education investment will be crowded out by healthcare spending and child bearing cost; however, higher probability of survival of children brought by more healthcare spending requires higher educational expenditure as education investment is made on survived children. In this case, the first effect is overcome by the latter part, as a result child health spending encourages higher educational investment.

By substituting (10) into (7), the dynamic of human capital accumulation can be characterised as follow:

$$h_{t+1} = b{g_t}^{\alpha}\left[\frac{\beta(g_t+\theta)}{(1-\beta)\pi_0(1+ag_t)}\right]^{\beta} {h_t}^{1+\beta} \qquad (15)$$

Linearizing the above equation, the effect of child's human capital with respect to health investment can be obtained as

$$\frac{\partial lnh_{t+1}}{\partial g_t} = \frac{\alpha}{g_t} + \frac{\beta(1-a\theta)}{(g_t+\theta)(1+ag_t)} > 0 \qquad \text{for } a \in (0,\tfrac{1}{2}), \theta \in (0,1) \quad (16)$$

From the above derivative, we have the following lemma:

Lemma 2. *In a private health system, human capital accumulation rises with private health investment in children.*

Now we look at the dynamic of human capital growth in private healthcare system. From (15), the growth rate of human capital is

$$\dot{h_t} = \frac{h_{t+1}-h_t}{h_t} = b{g_t}^{\alpha}\left[\frac{\beta(g_t+\theta)}{(1-\beta)\pi_0(1+ag_t)}\right]^{\beta} {h_t}^{\beta} - 1 \quad (16)$$

When $\dot{h_t} = 0$, there exists a steady state $\underline{h}_1 = b^{-\frac{1}{\beta}} g_t^{-\frac{\alpha}{\beta}} \frac{(1-\beta)\pi_0(1+ag_t)}{\beta(g_t+\theta)}$.

Based on the analysis of (15) and (16), the following proposition is stated.

Proposition 1. *In a private health system, an economy that starts with a human capital level below a certain threshold* $\underline{h}_1$ *has no growth in human capital. When the initial human capital in an economy starts with a level above* $\underline{h}_1$*, human capital is accumulated at an increasing rate.*

Under a private healthcare system, parents face a trade–off between the quantity and quality of children. The choices of consumption, health and education investment and the number of children are determined by parents' human capital stock. It is seen in Figure 2-1 that human capital accumulated by next generation depends on the human capital level at generation t. An agent in generation t endowed with a very low level of human capital $h_t < \underline{h}_1$ prefers not to have any children, and hence, there is no need to allocate income in investing in children's future. This will lead to a stagnating economy. When families cannot invest in basic needs and healthcare, and the mechanisms ensuring alternative financing are not available, there exists possibility of a poverty trap with low health, education and income outcomes (Galor and Mayer-Foulkes, 2002). The reason is that poor people discount the future more heavily; they prefer a current consumption and are less likely to invest part of their earnings for descendants. Therefore, the children from poorer households have less possibility to stay healthy and receive good education to acquire income earning skills.

When agent's human capital stock is above $\underline{h}_1$, the quality of child is valued by parents, the agent will choose to invest in children's health and education. The human capital is accumulated at an increasing rate in the long run. Intuitively, human capital is so useful in the accumulation of human capital that each marginal increase in its level results in so much more human capital in the next generation that the growth rate of human capital rises rather than falls.

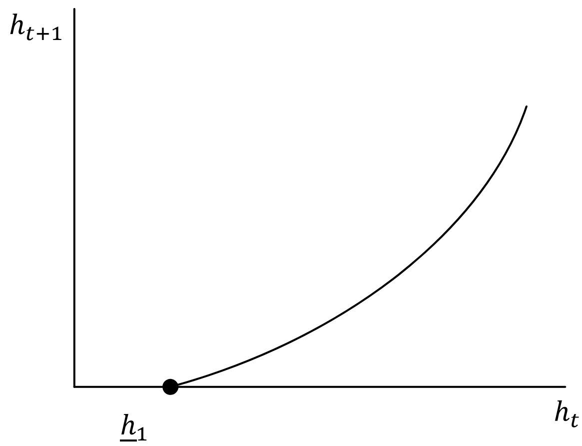

Figure 2-1. The dynamic of human capital growth in private healthcare system

2.3 Public healthcare system

In the case of out-of-pocket healthcare spending, individuals have to measure the benefit of more children and benefit of human capital investment to maximise their utility subject to budget constraint. This may generate inefficiency in the economy as the poor have less incentive for human capital investment and the rich prefer to have fewer children. It is noted that healthcare services have some 'public good' characteristics. For example, one person's access to information on malaria control does not leave that information less available for others (Behrman 1996). Although positive externalities for health investment exist, the private incentives to invest in child health may not be socially desirable from a pure efficiency perspective. The difference in private and social incentives for investing in child health is likely to be much larger for the poor due to imperfect capital market (Behrman 1996). Public health investment may overcome this inefficiency by internalizing the aforementioned externality. In a public healthcare system, reduction in mortality rate is due to increased public healthcare funding. With the certainty of survival probability, individuals may not necessarily face the trade-off between quantity and quality.

Under the public healthcare system, the government levies a proportional tax τ_t on all adults to finance a common level of health spending $\overline{g}$ at time t and keep a certain level of child survival $\pi(\overline{g})$. Using the same approach as with the private case, the probability of survival is given as

$\pi(\overline{g}) = \pi_0(1 + a_1\tau_t)$. Similarly, we also assume $\pi_0 \in (0, \frac{1}{2})$ and $a_1 \in (0, \frac{1}{2})$ to ensure $\pi(\overline{g}) \in (0,1)$. Since the agent does not choose the health expenditure for children, the budget constraint of the agent is expressed as the following,

$$c_t = (1 - \tau_t)h_t(1 - \theta n_t) - e_t n_t \pi_0(1 + a_1\tau_t)\,. \qquad (17)$$

And the human capital of a child during adulthood is modified from (7) and now is given by

$$h_{t+1} = b\tau^{\alpha} {e_t}^{\beta} h_t. \qquad (18)$$

Substituting the Eq. (17) and (18) into the utility function, the maximization problem of an agent of generation t is given by

$$U_t = \gamma ln[(1 - \tau_t)h_t(1 - \theta n_t) - e_t n_t \pi_0(1 + a_1\tau_t) - \bar{c}] + (1 - \gamma) ln\left[\pi_0(1 + a\tau_t)n_t b\tau^{\alpha} {e_t}^{\beta} h_t\right],$$

$$\text{s.t.} \qquad (n_t, e_t) \geq 0\,. \qquad (19)$$

The optimal choices for decision variables are obtained as follows:

$$n_t = \frac{(1-\beta)(1-\gamma)[(1-\tau_t)h_t - \bar{c}]}{(1-\tau_t)h_t\theta}, \qquad (20)$$

$$e_t = \frac{\beta(1-\tau_t)h_t\theta}{(1-\beta)\pi_0(1+a_1\tau_t)}. \qquad (21)$$

Equation (20) requires that $h_t \geq \frac{\bar{c}}{1-\tau}$, otherwise when income is so low that it cannot sustain an agent's lowest consumption, the agent chooses not to have any children and hence no human capital accumulated.

As average health spending in the society is determined by tax rate τ_t which is assumed to be exogenously chosen by the government, the comparative statics of the above decision variables with respect to τ_t and h_t are given by:

$$\frac{\partial n_t}{\partial h_t} = \frac{(1-\gamma)(1-\beta)\bar{c}}{{h_t}^2\theta} > 0 \qquad (22)$$

$$\frac{\partial n_t}{\partial \tau_t} = -\frac{(1-\gamma)(1-\beta)\bar{c}}{h_t\theta(1-\tau)^2} < 0 \qquad (23)$$

$$\frac{\partial e_t}{\partial h_t} = \frac{\beta(1-\tau_t)\theta}{(1-\beta)\pi_0(1+a\tau_t)} > 0 \qquad (24)$$

$$\frac{\partial e_t}{\partial \tau_t} = -\frac{\beta h_t\theta(1+a_1)}{(1-\beta)\pi_0(1+a_1\tau_t)^2} < 0 \qquad (25)$$

The signs of comparative statics are similar to the private case except the impact of τ_t on e_t. Different from the private health spending which is used on agents themselves, though τ_t is levied specifically on public health spending to reduce child mortality, there is no difference among individuals. The direct response of agents to the tax is the decrease of disposable income and they will invest less on child's education.

Based on these results we state the following lemma.

Lemma 3. *Under a public healthcare system, fertility and education investment will rise with income while decrease with tax-funded public health spending.*

Substituting (21) into (18), the next generation will accumulate human capital according to

$$h_{t+1} = b{\tau_t}^{\alpha}\left[\frac{\beta(1-\tau_t)\theta}{(1-\beta)\pi_0(1+a_1\tau_t)}\right]^{\beta}{h_t}^{1+\beta}. \qquad (26)$$

Linearizing the above equation, the impact of tax-funded health spending on child's human capital can be obtained as

$$\frac{\partial lnh_{t+1}}{\partial \tau_t} = \frac{\alpha}{\tau_t} - \frac{\beta}{1-\tau_t} - \frac{a_1\beta}{1+a_1\tau_t} = \frac{\alpha\left(1-a_1{\tau_t}^2\right)-(\alpha-\beta)(1-a_1)\tau_t}{\tau_t(1-\tau_t)(1+a_1\tau_t)} > 0 \qquad \text{for } \alpha < \beta \quad (27)$$

The above result implies that the sufficient condition for positive impact of public health spending on human capital accumulation for the next generation is that returns to education must be larger than the efficiency of health investment.

Based on the analysis of (26) and (27), we state the following statements.

Lemma 4. *In a public health system, if the returns to education are larger than the efficiency of health investment human capital accumulation rises with tax-funded health spending.*

Proposition 2. *When the initial human capital in an economy starts with a level above $\underline{h}_2$, human capital grows with parents' income (human capital) at an increasing rate. It implies that inequality persists in the long run.*

Proof. Human capital accumulated by next generation increases at an increasing rate with the initial human capital above a level $\underline{h}_2 = b^{-\frac{1}{\beta}} \tau_t^{-\frac{\alpha}{\beta}} \frac{(1-\beta)\pi_0(1+a_1\tau_t)}{\beta(1-\tau_t)\theta}$, shown in Figure 2-2.

For a poor agent, the accumulation of human capital is given as

$$h_{t+1}{}^p = b^p \tau_t{}^\alpha \left[\frac{\beta(1-\tau_t)\theta}{(1-\beta)\pi_0(1+a_1\tau_t)}\right]^\beta (h_t{}^p)^{1+\beta} .$$

For a rich agent,

$$h_{t+1}{}^r = b^r \tau_t{}^\alpha \left[\frac{\beta(1-\tau_t)\theta}{(1-\beta)\pi_0(1+a_1\tau_t)}\right]^\beta (h_t{}^r)^{1+\beta} .$$

The difference of human capital accumulation process between the rich and the poor can be expressed by the following ratio,

$$\frac{h_{t+1}{}^r}{h_{t+1}{}^p} = \frac{b^r}{b^p}\left(\frac{h_t{}^r}{h_t{}^p}\right)^{1+\beta} .$$

If we ignore the differences in the ability of individuals, we have $\frac{h_{t+1}{}^r}{h_{t+1}{}^p} > \frac{h_t{}^r}{h_t{}^p}$ with $\frac{h_t{}^r}{h_t{}^p} > 1$, which implies that the wedge in human capital stock between the rich and the poor is increasing over time.■

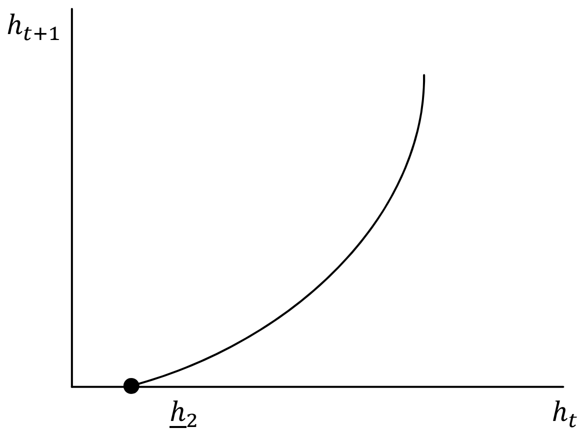

Figure 2-2. The dynamic of human capital growth in public healthcare system

The intergenerational transmission of human capital occurs through the impact of health on education investment. Under the public health system, agents do not need to consider the mortality risk of their children, thus they can pay more attention to education investment in children. However, tax-funded health spending reduce the disposable income of households and hence the incentives to education investment. With no difference in health spending which may contribute to higher learning abilities, education investment in this case mainly depends on income level. Rich parents comparative to poor parents are less affected by the tax and likely to invest more in child's education. With more human capital accumulated, the income of a child during adulthood will be higher which will have similar influence on next generations. Hence, the returns to education for the rich will be higher than for the poor which implies that inequality will grow over generations. In fact, this is the case in most developed countries when child mortality is no longer a problem. Generally, rich people will live in districts called "school zone" or send their children to high quality private schools.

2.4 A hybrid healthcare system

The previous two systems we have considered are extreme cases. In a stand-alone form these systems appear to have some problems. For example, in the United States' private insurance system, most of the population is insured by their employers, some buy health insurance on their own, and the poor cannot afford, resulting in high prevalence of obesity, infant mortality and other transmitted infections relative to other OECD countries. In the same vein, the public healthcare system in some OECD countries such as Denmark, Norway, and Germany may not suit different needs and results in inefficiency of resources allocation.

One way to tackle these problems is to have a hybrid system that combines both private and public healthcare systems. This is a system that provides all medically necessary services to the public, but also allows those who wish to pay for expanded or faster services the ability to do so, thereby freeing scarce resources for others. In particular, the deficit of healthcare system in the OECD countries has led to the emergence of hybrid systems. Australia is a good example of implementing a hybrid healthcare system. Similarly, Sweden has experienced many developments from a government-funded system to a more open system that includes the private sector.

In a hybrid healthcare system, people pay tax τ_t to get some basic level of healthcare, but some may choose to pay extra for a private health insurance for better quality of services. The probability of survival is given as $\pi(g) = \pi_0(1 + ag_t + a_1\tau_t)$. With the assumption of $\pi_0, a, a_1 \in (0, \frac{1}{2})$, it is easy to guarantee that $\pi(g) \in (0,1)$.

The budget constraint in the hybrid case becomes

$$c_t = (1 - \tau_t)h_t[1 - (\theta + g_t)n_t] - e_t n_t \pi_0(1 + ag_t + a_1\tau_t), \qquad (28)$$

The interplay between public and private health spending has been identified by Cigno (1998) in which he argues that public and private health expenditure may be either complements or substitutes depending on parents' decision. Bhattacharya and Qiao (2007) and Varvarigos and Zakaria (2013) assume that higher public health expenditure may enhance the effectiveness of private health spending as an increase in the public provision of health services induces individuals to reduce their saving and hence devote more resources towards health improvement. In this paper, somewhat similar to the above authors, we assume that the marginal impact of private health spending on survival rate decreases with public health investment. This implies that a higher public health investment forms a safer health net and encourages individuals to increase investment in other aspects. In light of this, we assume that public and private health expenditures are imperfect substitutes; hence, the human capital of children is now given by

$$h_{t+1} = b(\tau_t + g_t)^{\alpha} {e_t}^{\beta} h_t. \qquad (29)$$

In the optimisation problem, with the tax rate τ_t given, the agents choose g_t, e_t, n_t. By substituting (28) and (29) to utility function and solving the optimisation problem yield the optimal values of decision variables:

$$n_t = \frac{(1-\beta)(1-\gamma)[(1-\tau_t)h_t - \bar{c}]}{(\theta + g_t)h_t} \qquad (30)$$

$$e_t = \frac{\beta(1-\tau_t)(\theta + g_t)h_t}{(1-\beta)\pi_0(1 + a g_t + a_1\tau_t)} \qquad (31)$$

For non-negative n_t and e_t, it is necessary for $h_t \geq \frac{\bar{c}}{1-\tau_t}$ to exist.

The optimal level for private child health investment is given as:

$$g_t = \frac{\sqrt{[(a\theta(1+\alpha-\beta)+(\alpha+\beta-1)(1+a_1\tau_t)]^2+4a\alpha[(1+a_1\tau_t-a\theta)(1-\beta)\tau_t-\alpha\theta(1+a_1\tau_t)]}-[(a\theta(1+\alpha-\beta)+(\alpha+\beta-1)(1+a_1\tau_t)]}{2a\alpha} \qquad (32)$$

Eq. (32) underlies the interplay between public and private health spending. If $\alpha\theta(1 + a_1\tau_t) = (1 - \beta)(1 + a_1\tau_t - a\theta)\tau_t$, then $g_t = 0$. Agents may choose not to invest in child health privately, and the optimal levels of n_t and e_t fall into the same as the public case. When $(1 - \beta)(1 + a_1\tau_t - a\theta)\tau_t > a\theta(1 + a_1\tau_t)$, then $g_t > 0$. However, it is complex to determine the relationship between g_t and τ_t. On one hand, when tax τ_t rises, the disposable household income is reduced and hence private health investment is lower. On the other hand, a higher tax τ_t means higher survival probability of children, agents prefer quality to quantity of children by invest more on children's health in order to take advantage of public health investment. From (32), the derivative of g_t with respect to τ_t depends the returns to education and health investment

$\alpha + \beta$ (for technical details, see Appendix). When $\alpha + \beta > 1$, we have $\frac{\partial g_t}{\partial \tau_t} > 0$, which implies that public and private health investments are imperfect substitutes. This means that when the cost of providing public health service is high, individuals resort to private health care. Otherwise, $\frac{\partial g_t}{\partial \tau_t} < 0$ if $\alpha + \beta < 1$. This implies when the price public health service is increased the demand for private health investment is decreased as both health services are complements.

With the assumption of $\frac{\partial g_t}{\partial \tau_t} > 1$, we can derive the comparative statics of decision variables with respect to h_t and τ_t as below:

$$\frac{\partial n_t}{\partial h_t} = \frac{(1-\beta)(1-\gamma)\bar{c}}{{h_t}^2(\theta+g_t)} > 0 \qquad (33)$$

$$\frac{dn_t}{d\tau_t} = -(1-\beta)(1-\gamma)\left[\frac{1}{\theta+g_t} + \frac{\partial g_t}{\partial \tau_t}\frac{(1-\tau_t)h_t-\bar{c}}{h_t(\theta+g_t)^2}\right] < 0 \qquad (34)$$

$$\frac{\partial e_t}{\partial h_t} = \frac{\beta(1-\tau_t)(\theta+g_t)}{(1-\beta)\pi_0(1+ag_t+a_1\tau_t)} > 0 \qquad (35)$$

$$\frac{de_t}{d\tau_t} = \frac{\beta h_t}{(1-\beta)\pi_0}\frac{(1-\tau_t)(1+a_1\tau_t-a\theta)\frac{\partial g_t}{\partial \tau_t}-(\theta+g_t)(1+a_1+ag_t)}{(1+ag_t+a_1\tau_t)^2} > 0 \qquad (36)$$

From the above comparative statics of decision variables, we obtain the derivatives of fertility and education investment with respect to g_t, given the tax rate τ_t,

$$\frac{dn_t}{dg_t} = -\frac{(1-\beta)(1-\gamma)\left[\frac{\partial \tau_t}{\partial g_t}(\theta+g_t)+(1-\tau_t)h_t-\bar{c}\right]}{h_t(\theta+g_t)^2} < 0 \qquad (37)$$

$$\frac{de_t}{dg_t} = \frac{\beta h_t}{(1-\beta)\pi_0}\frac{(1-\tau_t)(1+a_1\tau_t-a\theta)-(\theta+g_t)(1+a_1+ag_t)\frac{\partial \tau_t}{\partial g_t}}{(1+ag_t+a_1\tau_t)^2} > 0 \qquad (38)$$

The following lemma is stated based on the above derivatives.

Lemma 5. *Under a hybrid healthcare system, when income reaches above a certain level* $h_t > \frac{\bar{c}}{(1-\tau_t)}$, *fertility and private education investment increase with income. With elastic demand,* *fertility decreases with both public and private health spending while private education investment increases with public or private health spending.*

The intuition behind choices of fertility and education investment in the hybrid healthcare system is different from public or private health system. Specifically, there is no fertility and education investment when the agent has very low income. When income increases above a certain level $\frac{\bar{c}}{(1-\tau)}$, fertility and education investment increase with income. The negative impact of health spending on fertility is easy to see. With a higher tax rate which is to fund public health spending the number of children to be born is discouraged as it reduces the disposable household income. Moreover, with high average survival rate of children in the society, there exist a trade-off between quantity and quality, so we have seen the decrease of fertility with private health spending.

The impact of health spending on education investment is complicated. First, whether public or private health spending will crowd out the expenditure on child's education investment. However, as quality of child is regarded more important, private health investment contributes to child's learning ability and hence the preference for higher education investment, especially when returns to education β is high. For the impact of public health spending, when τ_t is increased, the disposable income is lower for agents, and they may reduce the spending on child's education. With a higher survival rate of children in the society, the agent chooses to rely on public-funded health services with private and public health investment being substitutable especially when income is low, which releases some resources spent on education investment. This outcome indicates a very important social and economic effect of healthcare in terms of increasing productive capacity of an economy at the early stages of development.

Now, we consider the impact of child health spending on human capital accumulation under a hybrid healthcare system. Substitute (31) into (29), human capital accumulated by generation at time $t+1$ under a hybrid healthcare system is

$$h_{t+1} = b(\tau_t + g_t)^{\alpha} \left[\frac{\beta(1-\tau_t)(\theta+g_t)}{(1-\beta)\pi_0(1+ag_t+a_1\tau_t)}\right]^{\beta} h_t^{\ 1+\beta} \qquad (39)$$

Linearizing (39), the impact of child's health investment on human capital accumulation can be obtained as

$$\frac{\partial lnh_{t+1}}{\partial g_t} = \alpha \frac{1+\frac{\partial \tau_t}{\partial g_t}}{\tau_t+g_t} + \beta \frac{de_t}{dg_t} > 0 \qquad \text{for } a, a_1 \in (0,\tfrac{1}{2}) \ \& \ \theta \in (0,1) \quad (40)$$

Lemma 6. *Under a hybrid healthcare system, human capital accumulation rises with private child health investment when the returns to education and health investment are high with* $\alpha + \beta > 1$*.*

From the growth of human capital in (39), there exists a steady state $\underline{h}_3 = b^{-\frac{1}{\beta}}(\tau_t + g_t)^{-\frac{\alpha}{\beta}} \frac{(1-\beta)\pi_0(1+ag_t+a_1\tau_t)}{\beta(1-\tau_t)(g_t+\theta)}$.

Based on the result of (39), we state a proposition as follows.

Proposition 3. *In a hybrid healthcare system, an economy starting with a human capital level below* $\underline{h}_3$ *converges to an equilibrium where* $h_{t+1} = 0$*. When the initial human capital in an economy starts with a human capital level above* $\underline{h}_3$*, human capital is accumulated at an increasing rate.*

The implication of proposition 3 lies in the fact that in a hybrid healthcare system everyone receives public health services, there is no difference in survival rate between individuals except for the available resources and preference. When income rises above a certain level, it relaxes the restrictions of consumption and leaves more resources for child, and hence higher education expenditure. Meanwhile, higher income raises agents' preferences for private health care in order to take advantage of public health investment, leaving the impact to education investment more complex. On one hand, preferences for private health care crowd out the spending on education. On the other hand, with private health investment and public health care being complementary, survival probability of children is largely raised which requires more educational investment for high quality of children. As the effect of private investment in child's health may be enhanced by the advantages of public health system, this implies that the better the public health system, the larger the impact of additional private health investment on child's human capital accumulation.

The dynamic of human capital accumulation under the hybrid healthcare system is shown in Figure 2-3. With a low human capital stock at the beginning, an agent prefers not to have any children and hence there is no human capital accumulation in the next generation. When agent's human capital increases above a certain level $\underline{h}_3$ and continues to rise, the agent cares more about the child health status, so that he or she increases health investment privately, for example, spends more on private health insurance to get better quality of health services. Although a higher spending on private health investment will crowd out the investment on education, the health investment raises the child's learning abilities, which may result in a higher preference of education investment. With the assumption of high returns to education and health investment, there exist a positive relationship between education investment and private health spending. This will result in an increase in human capital accumulation for next generation.

An important aspect of the hybrid system is that it overcomes the shortages of public and private healthcare systems. Under the hybrid healthcare system, individuals with low income may rely on public health services to reduce mortality rate of children and they can still spend limited resources to improve the quality of children. Taking advantage of public health service the rich can invest extra on child's health for a more significant growth in human capital accumulation.

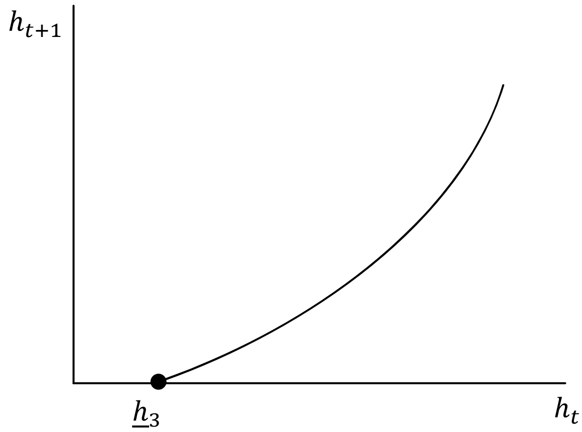

Figure 2-3. The dynamic of human capital growth in hybrid healthcare system

3. Empirical investigation

In this section, we will undertake an empirical investigation regarding to the impact of child health investment on human capital accumulation. We mainly examine the case for a hybrid healthcare system in which the individual's decision on child health investment is considered while basic healthcare needs are guaranteed.

3.1 Model specification

Based on the solutions in (39), the human capital accumulation is determined by parent's human capital, child care cost and child health spending as well as child's ability. We may linear Eq. (39) as the following dynamic empirical formation:

$$h_{it+1} = \beta_0 + \beta_1 h_{it} + \beta_2 \theta_{it} + \beta_3 g_{it} + \beta_4 b_{it} + \varepsilon_{it} \qquad (41)$$

Where i=1……n represents individuals. It is noted from the theoretical model that h_{t+1} is also determined by τ_t, but τ_t is invariant for all individuals so it is captured by the constant item. We assume that child's ability b_{it} is a linear function of parents' education and lifestyle.

Recall that h_{it+1} represents the human capital that a child accumulates when he/she reaches adulthood. Unfortunately, there is no data spanning over two generations. To address this issue, we shorten the period from infants to juniors or from juniors to adolescents. We justify this approach by the rationale that knowledge accumulation is a continuous process and the final stock of knowledge depends on the intermediate levels of knowledge one accumulates.[6] Thus, the human capital stock accumulated by one h_{it+1} is represented (proxied) by educational outcomes as the education is the main element of human capital. In other words, educational outcome is assumed to be an indicator of the human capital accumulation, which drives children's future income. In light of this discussion, we estimate the effect of parent's investment in child health on their children's school performance based on Eq. (41).

3.2 Data

This study uses data from the Longitudinal Study of Australian Children (LSAC). The LSAC is a long-term research project following a large group of children and their families over the years as they grow and learn in Australia. The LSAC survey began in 2004 and collects data on these children every 2 years. The main topics include health, parenting, education, child care, family socioeconomic status. A key strength of LSAC is its longitudinal design in which information is collected from the same sample at multiple time points. There are currently 5 waves of data collection for two cohorts of children (B-Cohort born between 2003 and 2004; K-Cohort born between 1999 and 2000). Each cohort contains approximately 5000 children. This design allows us to track developmental changes over the life span using the same people, which is especially suitable for application in the OLG model developed in this study.

To reflect an intergenerational transmission impact, we use wave 1 and wave 5 of the data for two cohorts of children. That is, for B-Cohort we examine parent's decision when child is a 0-1 year old infant in wave 1 and the child's schooling performance in primary school at 8-9 year old in wave 5. We also look at 4-5 year old children in wave 1 of K-Cohort and their academic results in junior high school generally at 12-13 year old in wave 5 to see if there exists consistent impact of child health investment for different age cohorts.

[6] There are substantial studies showing a positive correlation between education performance and future income such as Rivkin (2000), Zax and Rees (2002), Pischke (2007), French *et al.* (2014). Since, the earning capacities depends on the level of human capital, one can relate the school performance to the level of human capital one possesses.

In our empirical analysis, income is represented by weekly income earned by the mother and the father. We use "how many hours per week spent on child caring" to proxy child care cost. In the survey, parents are required to answer three possible types of child care. The child care type means child being looked after by others rather than themselves each week. The more hours for child care by others imply a higher opportunity cost of looking after child by parents themselves. As a majority of parents do not choose the second or the third type, we only use the first child care type in this paper.

In the health production model proposed by Grossman (1972), it is assumed that the individual inherits an initial stock of health that depreciates over time. The individual may, however, positively influence the stock of health capital via gross investments such as medical care, diet, exercise and lifestyle. The same as the child health production, parents invest their own time and available market goods in child health to maximize their utility. All these resources are actually determined by parents' social-economic status. In the case of Australia, except for government-funded medical service, people may choose to purchase private health insurance for better medical care service. Therefore, the use of private health insurance can reflect the child health investment for both cohorts.

Here we only consider cognitive skills for school performance, which is based on the NAPLAN (National Assessment Program – Literacy and Numeracy) data for children from each interviewed family. NAPLAN is an annual assessment for students in Years 3, 5, 7 and 9. It is made up of tests in the four areas of reading, writing, language conventions and numeracy. In wave 5 LSAC NAPLAN release includes B & K cohort NAPLAN results for 2008 to 2012. For B-Cohort, there is only NAPLAN results for Year 3 (8-9 year old) students conducted in 2011 and 2012. For K-Cohort, we use the average scores of Years 3, 5 and 7 for each child conducted from 2008 to 2012 to reflect a stable learning ability.

Since there are no good indicators of ability, we choose parents' education level and lifestyle including smoking and drinking habit to proxy child's ability as these factors are good predictor of genetic transmission of intellectual ability. For smoking, we use "How many cigarettes do you usually smoke in one day?" Drinking habit is represented by average daily alcohol consumption. Parents' education is represented by the level of the highest qualification completed by mother and father which is divided into high education level (including postgraduate, graduate diploma, bachelor and diploma) and low education level (certificate and below). The summary statistics of chosen variables for B-Cohort and K-Cohort are shown below.

Table 3-1. Summary statistics of variables

	Mean		Std. Dev.		Minimum		Maximum	
	B	K	B	K	B	K	B	K
NAPLAN score	422.360	495.919	69.843	66.588	116.400	196.400	644.660	703.600
Income ($)	1140.976	1230.604	866.317	886.622	0	0	10,000	8624.159
Childcare (hours)	6.189	11.695	11.632	10.549	0	1	72	73
Private health insurance	0.460	0.460	.498	0.498	0	0	1	1
Smoke (number)	2.090	2.508	5.251	5.976	0	0	40	42
Alcohol (number)	0.373	0.483	0.570	0.744	0	0	5.5	8.5
Mother's qualification (certificate or below)	0.375	0.412	0.484	0.492	0	0	1	1
Father's qualification (certificate or below)	0.511	0.503	0.500	0.500	0	0	1	1

3.3 Estimation Results

With the suspicion that health investment suffers from omitted variable biased, we choose parents' exercise and vegetable consumption as instrumental variables. These two variables explain a person's choice of purchasing private health insurance to some extent. We use Durbin-Wu-Hausman test to ascertain whether the health investment variable is endogenous. For both cohorts, the null hypothesis that variable g_{it} is endogenous is rejected at 5% level. So we use OLS estimation in the regression. The estimation results for B-Cohort and K-Cohort are reported as below.

Table 3-2. The effect of health investment on educational outcome

	B-Cohort (0-1 yr)		K-Cohort (4-5 yr)	
	Coef.	Std. Err.	Coef.	Std. Err.
Income	8.097***	1.653	4.016**	1.734
Child care	-0.246*	0.135	0.003	0.13
Private health insurance	3.055	3.079	5.923*	3.412
Smoke	-0.487	0.397	-1.040***	0.384

Alcohol	0.092	2.600	0.909	2.147
Mother's qualification (certificate or below)	-19.975***	3.640	-14.455***	3.525
Father's qualification (certificate or below)	-28.121***	3.422	-28.910***	3.373

Note: As the coefficients for income are too small in equation 2, we divide family income by 1,000 to report a clear result. *** denotes significant at 1% level, ** and * represent statistical significance at 5% level and 10% level separately.

For B-Cohort with 4191 observations, income has a positive impact on children's school performance, and the coefficient of income is statistically significant at 5%, which implies that if parents' income rises by $1,000, the NAPLAN score of their child will increase by 8 points. Although private health insurance positively affects child's educational results, the coefficient is not statistically significant. One of the reasons for insignificant impact of health investment may be due to multicollinearity. It is noted from Eq. (32) that health investment is determined by childcare cost. The other reason is that children in B-Cohort are 0-1 year old, investment in health services may raise the survival probability but health effect may take time to have influence on the learning abilities of children in this cohort.

The coefficient for child care is negative and statistically significant at 10% level. Child raising cost is the fraction of a parent's income, in another word, it is an opportunity cost of looking after children. Generally the opportunity cost of raising a child is higher for high income earners. Given the income level, theoretical model suggests that the more time you spend on childcare, the higher human capital the child accumulates. In the regression, the variable childcare represents the number of hours a child being looked after by someone other than parents each week, so it negatively affects children's school performance. This implies that the less time you spend with your child in early days of his or her life, the poorer academic performance the child may have later on.

For the ability predictors that affect child's school performance, whether parents smoke or drink alcohol do not have a significant impact. However, parents' education level does play an important role in child's educational outcomes possibly through genetic transmission of intellectual ability and knowledge spill-over.

For K-Cohort which has 1675 observations, a $1,000 rise in income could result in an increase of 4 points in child's NAPLAN result. Health investment is a significant determinant of child's school performance. It shows that purchasing private health insurance will raise child's NAPLAN result by 5 points. This is consistent with our theoretical model. Health investment improves child health status and hence learning capacity of children through many ways in line with the literature (Mayer-Foulkus 2005, Currie et al 2010, Bloom and Canning 2009, Howitt 2005). However, a positive sign of the coefficient for *childcare* implies that the more hours looked after by others the better academic performance the child has. For 4-5 year preschoolers, there are more versatile childcare types including pre-school program, gym, leisure or community centre which provides a variety of activities for children's physical and mental development. But the large standard error means that childcare cost appears to be a weak determinant of child's academic result in K-Cohort.

Furthermore, the negative coefficient for 'smoke' means that parent's smoking behaviour has a strong impact on child's academic outcome. Children may breathe second hand smoke when their parents smoke, which may cause health problems. In addition, Vuolo and Staff (2013) have found that children of current and former smokers are more likely to smoke than those whose parents are nonsmokers. Youth smoking can biologically reduce learning productivity and can also reduce youths' expected returns to education and lower their motivation to go to school (Zhao et al 2012). This intergenerational association matches with the academic results obtained by teenagers in Wave 5 of K-Cohort. However, alcohol consumption is not a statistically significant impact factor. Similar to the B-Cohort result, parents' education level is a good indicator of child's ability which affects educational outcome.

4 Conclusion and policy implications

This paper proposes a new theoretical framework to study the links between child health investment and human capital accumulation. An overlapping-generations model is developed to investigate how child health investment affects human capital accumulation from the behaviour of households. Different from current literature (Kalemli-Ozcan, 2003; Ehrlich and Kim, 2005; and Fioroni; 2010) we integrate child health investment in individual's optimization problem and hence child health investment has become a decision making problem endogenously determined by individual's socioeconomic status and their preferences.

The theoretical analysis is undertaken in three healthcare systems (private, public and hybrid) separately. Under a private healthcare system, individuals face the trade-off between quality and quantity when decide fertility. When income cannot sustain agents' subsistence level of consumption, the adults choose not to have any children. When income rises above a certain level, the opportunity cost of child bearing increases, individuals are more willing to exchange quality for quantity by having fewer children and more investment in child, therefore human capital accumulation will grow. In a public healthcare system, individuals no longer worry about mortality risk of their children. With exogenous government health spending and mortality rate, the intergenerational transmission of wealth is through education investment which depends on parent's income. Rich parents are inclined to invest more in children's education, the income during their children's adulthood will be higher, which will have similar influence on next generations. It is expected that in inequality will persist over generations in the long run. Under a hybrid healthcare system, private and public health expenditures are complementary to some extent. With a decline in fertility along the economic growth, a better public health system enhances the positive impact of private child health investment on human capital accumulation. This system works well for individuals with low income. They may rely on public health services and spend limited resources to improve the quality of children. Moreover, the rich can take advantage of public health service to invest extra on child's health for more human capital accumulation.

An empirical investigation has been conducted to estimate the impact of child health investment on human capital accumulation. Our empirical specification is closely based on the theoretical model. We base our analysis on the Australian data where a hybrid healthcare system exists. Specifically, we examine the impact of child health investment on academic results which reflect human capital level to some extent for two cohorts of Australian children. One (B-Cohort) includes 0-1 year old infants in wave 1 and their Year 3 school results in wave 5; the other (K-Cohort) is made up of 4-5 year old children in wave 1 and their average school results of Year 3, 5 and 7 in wave 5 are examined. Regression results have shown that child health investment has significant impact on child's academic performance for K-Cohort but not B-Cohort.

Finally, the results in this paper have some important policy implications. For low income countries, child health problem has been ignored with low income and poor health services, leading to high mortality and malnourished children. With low human capital accumulation, those countries become poorer. Behrman et al. (2004) have outlined several policies to reduce the prevalence of malnutrition in early childhood. For fast developing countries, lack of public health spending and high opportunity cost of child bearing often discourage fertility. Without demographic dividend, economic growth could not be sustainable. Even in developed countries, little attention is paid to the impact of child health on education and human capital accumulation. Part of the reason could be the perception that child health is but a by-product of education rather than a factor that could determine educational outcomes (Suhrcke and de Paz Nieves, 2011). Stressing the importance of child health investment in human capital formation, this paper provides some insights for the ways to raise national income and promote economic growth.

Compliance with Ethical Standards:

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Conflict of Interest: The authors declare that they have no conflict of interest.

Appendix

A. Optimization with private healthcare system

Given agent's maximization problem by (8), the first-order conditions yield the equations below for the optimal level of number of children and child's education spending.

$$\frac{\partial U}{\partial n_t} = \frac{-\gamma[h_t(g_t+\theta)+e_t\pi_0(1+ag_t)]}{h_t(1-(g_t+\theta)n_t)-e_tn_t\pi_0(1+ag_t)-\bar{c}} + \frac{1-\gamma}{n_t} = 0; \quad (A.1)$$

$$\frac{\partial U}{\partial e_t} = \frac{-\gamma n_t\pi_0(1+ag_t)}{h_t(1-(g_t+\theta)n_t)-e_tn_t\pi_0(1+ag_t)-\bar{c}} + \frac{(1-\gamma)\beta}{e_t} = 0; \quad (A.2)$$

B. Optimization with hybrid healthcare system

Given maximization problem by Eqs (4), (28) and (29), the first order conditions yield Eqs. (B.1), (B.2) and (B.3) for the optimal level of decision variables n_t, e_t and g_t.

$$\frac{\partial U}{\partial n_t} = \frac{-\gamma[(1-\tau_t)h_t(g_t+\theta)+e_t\pi_0(1+ag_t+a_1\tau_t)]}{(1-\tau_t)h_t[1-(\theta+g_t)n_t]-e_tn_t\pi_0(1+ag_t+a_1\tau_t)-\bar{c}} + \frac{1-\gamma}{n_t} = 0; \quad (B.1)$$

$$\frac{\partial U}{\partial e_t} = \frac{-\gamma n_t\pi_0(1+ag_t+a_1\tau_t)}{(1-\tau_t)h_t[1-(\theta+g_t)n_t]-e_tn_t\pi_0(1+ag_t+a_1\tau_t)-\bar{c}} + \frac{(1-\gamma)\beta}{e_t} = 0; \quad (B.2)$$

$$\frac{\partial U}{\partial g_t} = \frac{-\gamma[(1-\tau_t)h_tn_t+e_tn_t\pi_0 a]}{(1-\tau_t)h_t[1-(\theta+g_t)n_t]-e_tn_t\pi_0(1+ag_t+a_1\tau_t)-\bar{c}} + \frac{a(1-\gamma)}{1+ag_t+a_1\tau_t} + \frac{\alpha(1-\gamma)}{\tau_t+g_t} = 0; \quad (B.3)$$

B.1 The relationship between g_t and τ_t

Divide (B.2) by (B.3) and substitute the expression for optimal education spending in (31), we obtain the following equation for the optimal level of private health spending:

$$\alpha a {g_t}^2 + [a\theta(1+\alpha-\beta)+(\alpha+\beta-1)(a_1\tau_t+1)]g_t + (a\tau_t\theta - \tau_t - a_1{\tau_t}^2)(1-\beta) + \alpha\theta(1+a_1\tau_t) = 0 \quad (B.4)$$

Differentiate (B.4) with respect to g_t, we have

$$2\alpha a g_t + [a\theta(1+\alpha-\beta)+(\alpha+\beta-1)(a_1\tau_t+1)] + a_1(\alpha+\beta-1)g_t\frac{\partial\tau_t}{\partial g_t} + (1-\beta)\left[a\theta\frac{\partial\tau_t}{\partial g_t} - \frac{\partial\tau_t}{\partial g_t} - 2a_1\frac{\partial\tau_t}{\partial g_t}\right] + a_1\alpha\theta\frac{\partial\tau_t}{\partial g_t} = 0 \quad (B.5)$$

Rearrange (B.5) to obtain

$$-[a_1(\alpha+\beta-1)g_t + (1-\beta)(a\theta-1-2a_1) + a_1\alpha\theta]\frac{\partial\tau_t}{\partial g_t} = 2\alpha a g_t + [a\theta(1+\alpha-\beta) + (\alpha+\beta-1)(a_1\tau_t+1)] \quad (B.6)$$

And $$\frac{\partial\tau_t}{\partial g_t} = \frac{2\alpha a g_t + [a\theta(1+\alpha-\beta)+(\alpha+\beta-1)(a_1\tau_t+1)]}{(1-\beta)(2a_1+1-a\theta)-a_1(\alpha+\beta-1)g_t-a_1\alpha\theta} \quad (B.7)$$

As , $a_1 \in (0,\frac{1}{2})$, the denominator is positive. The sign of $\frac{\partial\tau_t}{\partial g_t}$ depends on the nominator. When $\alpha+\beta<1, \frac{\partial\tau_t}{\partial g_t}<0$; when $\alpha+\beta>1, \frac{\partial\tau_t}{\partial g_t}>0$.

Reference

Ahrendt, J. (2005) Does education cause better health? A panel data analysis using school reform for identification. *Economics of Education Review* 24(2): 149-160.

Albouy, V. and Lequien, L. (2009) Does compulsory education lower mortality? *Journal of Health Economics* 28(1):155–168.

Arrow, K. J., Dasgupta, P., Goulder, L. H., Mumford, K. J. and Oleson, K. (2012) Sustainability and the measurement of wealth. *Environment and Development Economics* 17(3): 317-353.

Azarnert, L. V. (2006) Child mortality, fertility and human capital accumulation. *Journal of Population Economics* 19(2):285–297.

Behrman, J. R. (1996) The impact of health and nutrition on education. *The World Bank Research Observer* 11(1): 23-37.

Behrman, J. R., Alderman, H. and Hoddinott, J. (2004) The Challenge of Hunger and Malnutrition, Copenhagen Consensus Challenge Paper.

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

Bloom, D.E. and Canning, D. (2009) Population health and economic Growth, in Spence, M. and Lewis, M. (eds.), *Health and Growth*, NW, Washington DC: The World Bank, 53-75.

Case, A., Fertig, A. and Paxson, C. (2005) The lasting impact of childhood health and circumstance. *Journal of Health Economics* 24(2): 365-389.

Cigno, A. (1998) Fertility decisions when infant survival is endogenous. *Journal of Population Economics* 11(1): 21-28.

Clark, D., and Royer, H. (2010) The effect of education on adult mortality: Evidence from the United Kingdom. NBER Working Paper 16013.

Currie, J. (2008) Healthy, wealthy and wise: Socioeconomic status, poor health in childhood and human capital development. NBER Working Paper No. 1398.

Currie, J., Stabile, M., Manivong, P. and Ross, L.L. (2010) Child health and young adult outcomes. *Journal of Human Resources* 45(3): 517-548.

Cutler, D. and Lleras-Muney, A. (2006) Education and health: evaluating theories and evidence. NBER Working Paper 12352.

Cutler, D. and Lleras-Muney, A. (2010) Understanding differences in health behaviors by education. *Journal of Health Economics* 29(1): 1-28.

de la Croix, D. & Doepke, M. (2003) Inequality and growth: Why differential fertility matters. *American Economic Review* 93: 1091-1013.

Deaton, A. and Paxson, C. (2001) Mortality, education, income and inequality among American cohorts, in David Wise (eds.) *Themes in The Economics of Aging*, Chicago University Press for NBER, 2001, 129-170.

Ding, W.L., Lehrer, S. F., Rosenquist, J.N. and Audrain-McGovern, J. (2009) The impact of poor health on academic performance: New evidence using genetic markers. *Journal of Health Economics* 28(3): 578–597.

Doepke, M. (2004) Accounting for fertility decline during the transition to growth. *Journal of Economic Growth* 9: 347-383.

Ehrlich, I. and Kim, J. Y. (2005) Endogenous fertility, mortality and economic growth: Can a Malthusian framework account for the conflicting historical trends in population? NBER Working Paper No. 11599.

Fioroni, T. (2010) Child mortality and fertility: public vs private education. *Journal of Population Economics* 23: 73-97.

French, M. T., Homer, J. F., Popovici, I. and Robins, P. K. (2014) What you do in high school matters: high school GPA, educational attainment, and labor market earnings as a young adult. *Eastern Economic Journal.* doi: 10.1057/eej.2014.22

Galal, O. M., Neumann, C. G. and Hulett, J. (2005) International workshop on articulating the impact of nutritional deficits on the education for all agenda. *Food and Nutrition Bulletin* (United Nations University), 26(2), supplement 2.

Galor, O. and Mayer-Foulkes, D. (2002) Food for thought: basic needs and persistent educational inequality, mimeo.

Gan, L. and Gong, G. (2007) Estimating interdependence between health and education in a dynamic model. NBER Working Paper No. 12830.

Glewwe, P. and Jacoby, H. G. (1995) An economic analysis of delayed primary school enrolment in a low income country: the role of early childhood nutrition. *The Review of Economics and Statistics* 77(1): 156-169.

Glewwe, P., Jacoby, H. G. and King, E. M. (2001) Early childhood nutrition and academic achievement: a longitudinal analysis. *Journal of Public Economics* 81(3): 345-368.

Grimard, F. and Parent, D. (2007) Education and smoking: Were Vietnam draft avoiders also more likely to avoid smoking? *Journal of Health Economics* 26: 896-926

Grossman, M. (1972) On the concept of health capital and the demand for health. *Journal of Political Economy* 82(2): 223-255.

Grossman, M. (2000) The human capital model. In: Culyer, A.J. and Newhouse, J.P. (Eds.), *Handbook of Health Economics*, Elsevier Science, Volume 1, pp. 347-408.

Grossman, M. (2005) Education and nonmarket outcomes. NBER Working Paper No. 11582.

Howitt, P. (2005) Health, human capital, and economic growth: A Schumpeterian perspective, In Lopez-Casasnovas, G., Rivera, B. and Currais, L. (eds.) *Health and Economic Growth: Findings and Policy Implications,* Cambridge, MA: MIT Press, 19-40.

Kalemli-Ozcan, S. (2003) A stochastic model of mortality, fertility, and human capital investment. *Journal of Development Economics* 70: 103-118.

Kenkel, D., Lillard, D. and Mathios, A. (2006) The roles of high school completion and GED receipt in smoking and obesity. *Journal of Labor Economics* 24 (3): 635-659.

Knowles, S. and Owen, P.D. (1997) Education and health in an effective-labour empirical growth model. *The Economic Record* 73(223): 314-328.

Lleras-Muney, A. (2005) The relationship between education and adult mortality in the US. *Review of Economic Studies* 72: 189-221.

Jürges, H., Reinhold, S. and Salm, M. (2011) Does schooling affect health behavior? Evidence from the educational expansion in Western Germany. *Economics of Education Review* 30: 862-872.

Lundborg, P. (2008). The health returns to education: what can we learn from twins? Bonn, Forschungsinstitut zur Zukunft der Arbeit (Working Paper 3399).

Madsen, J. (2012) Health, human capital formation and knowledge production: two centuries of international evidence. NBER Working Paper No. 18461.

Mayer-Foulkus, D. (2005) Human development traps and economic growth. In Lopez-Casasnovas, G., Rivera, B. and Currais, L. (eds.) *Health and Economic Growth*, Cambridge, MA: MIT Press, 115-141.

Meltzer, D. (1992) *Mortality Decline, the Demographic Transition, and Economic Growth*. Ph.D. Dissertation, University of Chicago, Department of Economics.

Nayga, R.M. (2000) Schooling, health knowledge, and obesity. *Applied Economics* 32: 815-832.

Pincus, T., Callahan, L. F. and R. V Burkhauser (1987) Most chronic diseases are reported more frequently by individuals with fewer than 12 years of formal education in the age 18-64 us population. *Journal of Chronic Diseases* 40: 865-874.

Pischke, J. S. (2007) The impact of length of the school year on student performance and earnings: evidence from the German short school years. *The economic journal* 117(523): 1216-1242.

Rivkin, S. G. (2000) School desegregation, academic attainment, and earnings. *The Journal of Human Resources* 35(2): 333-346

Shultz, T. P. (1993) Mortality decline in the low-income world: causes and consequences. *American Economic Review* 83(2): 337-342.

Silles, M. (2009) The causal effect of education on health: Evidence from the United Kingdom. *Economics of Education Review* 28: 122-128

Smith, J. P. (2008) The impact of childhood health on adult labor market outcomes. Dublin, UCD Geary Institute, Labor and Population Working Paper 14/2008.

Stenberg, K., Axelson, H., Sheehan, P., Anderson, I., Gülmezoglu, A. M., Temmerman, M., Mason, E., Friedman, H. S., Bhutta, Z.A., Lawn, J. E., Sweeny, K., Tulloch, J., Hansen, P., Chopra, M., Gupta, A., Vogel, J. P., Ostergren, M., Rasmussen, B., Levin, C., Boyle, C., Kuruvilla, S., Koblinsky, M., Walker, N., de Francisco, A., Novcic, N., Presern, C., Jamison, D. and Bustreo, F. (2014) Advancing social and economic development by investing in women's and children's health: a new Global Investment Framework. *Lancet* 383(9925): 1333-1354.

Strauss, J. and Thomas, D. (1998) Health, nutrition and economic development. *Journal of Economic Literature* 36(2): 766-817.

Suhrcke, M. and de Paz Nieves, C. (2011). The impact of health and health behaviours on educational outcomes in high income countries: a review of the evidence. Copenhagen, WHO Regional Office for Europe.

van Zon, A. and Muysken, J. (2001) Health and endogenous growth. *Journal of Health Economics* 20:169-185.

Varvarigos, D. and Zakaria, I. Z. (2013) Endogenous fertility in growth model with public and private health expenditures. *Journal Population Economics* 26: 67-85.

WHO, UNICEF, World Bank (2009) State of the world's vaccines and immunization, 3rd ed. Geneva, World Health Organization.

Wisniewski, S. L. W. (2010) Child nutrition, health problems, and school achievement in Sri Lanka. *World Development* 38(3): 315-332.

Zax, J. S. and Rees, D. I. (2002) IQ, academic performance, environment, and earnings. *Review of economics and statistics* 84(4): 600-616.

Zhang, J. and Zhang, J. S. (2005) The effect of life expectancy on fertility, saving, schooling and economic growth: theory and evidence. *Scandinavian Journal of Economics* 107(1): 45-66.

Zhao, M., Konishi, Y. and Glewwe, P. (2012) Does smoking affect schooling? Evidence from teenagers in rural China. *Journal of Health Economics* 31(4): 584-598.

Vuolo, M. and Staff, J. (2013) Parent and child cigarette use: a longitudinal, multigenerational study. *Pediatrics* 132(3): 568-577.