Parental health and the education of their offspring: examining the trade-off

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ABSTRACT

We develop an overlapping generations model where adults educate their offspring and undertake certain health expenditures to improve their own longevity. For agents with incomes exceeding a certain threshold level, health expenditure is a necessity, while it is a luxury for others. When income is below another threshold level, health and education expenditures are substitutes, but are complements otherwise. If the intertemporal elasticity of substitution is below a particular value, parental longevity and offspring's human capital are positively associated for all agents. Otherwise, parental longevity and offspring human capital may be negatively related for poorer agents, resulting in intergenerational inequalities in longevity.

Keywords: health expenditures; longevity; education expenditures; human capital

JEL codes: I14, I24, E24, J24

1. Introduction

Extant economic literature, both theoretical and empirical, suggests that investments made by parents on educating their children can have important implications for intergenerational inequality and long run growth outcomes (see, among others, Becker & Tomes, 1979; Haveman & Wolfe, 1995; Houtenville & Conway, 2008; Mauldin, Mimura, & Lino, 2001). However, investing time and money on children's education invariably entails certain tradeoffs upon parents. These tradeofffs could potentially have implications for their health and longevity. For instance, parents may work longer hours to pay school fees or private tutors, which could cause their health to deteriorate. Furthermore, expenditures on children's education may result in parents foregoing expenses on health and longevity enhancing activities such as diagnostic testing, nutritional supplementation and exercise. Especially in developing countries, where, despite the presence of public education systems, parental expenditures are a crucial determinant of the educational achievements of children, such tradeoffs could create intergenerational inequalities in longevity and educational achievement.

Generally, parents from richer households are able to invest more in their own health and also spend more on their children's education. Empirical evidence regarding the former observation is provided in studies like Raab et al. (2002), Van Bebber et al. (2007), Kopits, Chen, Roberts, Uhlmann, and Green (2011) and Neumann et al. (2012), which show that people from higher socio-economic backgrounds generally have a higher willingness to pay for tests that could help towards the early detection of diseases. Evidence suggesting that richer households spend more on children's education is provided, for instance, by Foko, Tiyab, and Husson (2012), who show that households belonging to the poorest income quintile in the African region spend 2.6% of their income on education, the second, third and fourth quintiles spend 2.9%, 3.3% and 3.9% of income on education respectively, while expenditure by the richest income quintile is 5.4%. A number of other studies such as Glick and Sahn (2000) and Tansel and Bircan (2006) also reveal a positive association between spending on children's education and parental income, wealth and education levels.

Closely related to these observations is the noticeable positive link between parental life expectancy and the educational levels of their offspring observed in the interdisciplinary literature for several countries including USA (Friedman & Mare, 2010), Taiwan (Zimmer, Martin, Ofstedal, & Chuang, 2007), and Sweden (Torssander, 2013, 2014). The explanation for this link that these studies provide is the child-to-parent transmission of healthy behaviours. For instance, Friedman and Mare (2010) suggest that educated children can influence their parents' health directly because they possess the financial capability to provide their parents with appropriate care, information and medication, as well as indirectly because educated children are more likely to display healthy behaviours which encourages parents to adopt similar behaviours. According to these authors, children can influence their parents' health-related behaviours even when parents do not cohabit with their children in old age, because adult children form a major part of their elderly parents' social networks.

Although the child-to-parent transmission of healthy behaviours may be a valid explanation for the presence of a strong link between parental longevity and children's human capital, it is unlikely to be the *only* one. In fact, in modern societies, the strength of this mechanism may be adversely affectd due to a number of reasons. Firstly, an increasing proportion of old people around the world now live independently (United Nations, 2005). Table 1, which shows where older people in Australia live, is a typical profile of the living arrangements of the elderly in a developed country. In Australia, only 8.2% of elderly persons live with their children or relatives. Even in developing countries, there has been a decline in the proportion of the elderly cohabiting with their children. This is evident from Figure 1, which shows how living arrangements of the elderly in India have changed over time.

Table 1. *Living Arrangements of Australian Aged 65 and over in 2011*

Type of living arrangement	Percentage of people aged 65 and over
Living with spouse or partner	55.6
Living with children or other relatives	8.2
Group household	1.7
Lone person	25.4
Non-private dwelling	6.4

Source: Australian Bureau of Statistics (2013)

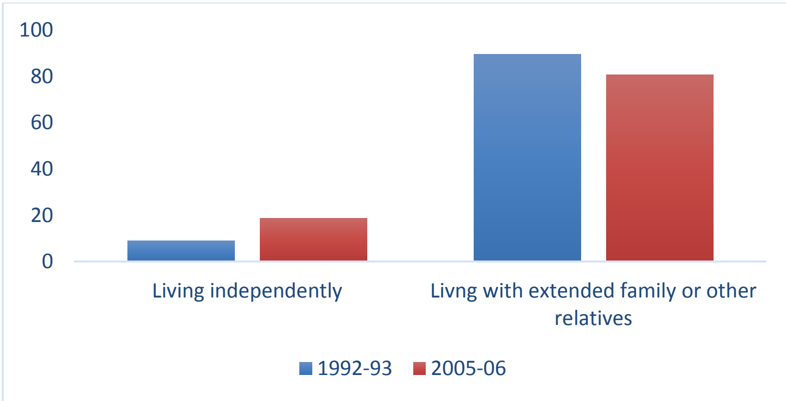

Figure 1. Changes in living arrangements of the elderly in India

Source: Sathyanarayana, Kumar, and James (2014)

When elderly parents live independently, their children's ability to influence their health behaviours, either directly or indirectly, is likely to be limited. The possible presence of a considerable geographical distance between parents who live independently and their adult children may impact the proximity of parent-offspring ties adversely, which restricts the transmission of healthy behaviours from children to parents (Lawton, Silverstein, & Bengtson, 1994). Another factor that may weaken this mechanism may be the strain in the relations between elderly parents and children that parental divorce may cause (Amato & Booth, 1996; Silverstein & Bengtson, 1997) Finally, while direct financial or physical assistance is perhaps the most effective means by which children can influence their parents' health, in contemporary societies, it is becoming increasing difficult for adult children to extend financial or other practical assistance to their parents (Lye, 1996).

Since these observations indicate that the transmission of healthy behaviours from children to parents may not be as strong a determinant of the positive link between parental health and children's educational levels as suggested in the interdisciplinary literature, we are naturally motivated to explore alternative channels that may create a link between parental longevity and their children's human capital. Hence, we propose that *expenditures* undertaken by parents on educating their children and enhancing their own longevity may be an important mechanism that could create a link between parental longevity and the human capital of their offspring.

To this end, we develop an overlapping generations model where agents potentially live for three periods: childhood, adulthood and old age. Childhood is spent studying. At the beginning of adult age, the agent gives birth to a single offspring whose education has to be funded by the parent. In addition to educating her child, the adult agent spends her wage income on household consumption, savings to finance old age consumption, and health expenditures aimed at improving her probability of survival into old age. Educating her child gives the agent a warm glow utility. We abstract from physical capital, and assume that the agent's wage is equal to her stock of human capital in adult age, which depends on her parent's human capital and the education she acquired in childhood. While agents survive during childhood and adulthood for certain, the probability of survival into old age is a strictly concave function of health expenditures undertaken in adulthood.

The key results of our model reveal that for individuals with incomes below a certain threshold value, the income elasticity of demand for health expenditure is above 1, and health expenditure is therefore a luxury good. On the other hand, agents with incomes exceeding this threshold value consider it to be a necessity. Hence, a given increase in income causes a proportionately higher increase in health expenditure among the poorer agents with health expenditures falling below the threshold value. On the other hand, the health expenditure of the richer agents with incomes exceeding this threshold is less responsive to a rise in income.

We also show that longevity enhancing health expenditure and expenditure on educating offspring are gross substitutes for agents whose incomes fall below a particular threshold value, but for the remaining agents with incomes above this threshold, the two expenditures are complementary. Although the set-up of our model is such that longevity enhancing health expenditures and education expenditure compete for a given household budget, this result shows that only the poorer agents in the economy, with income below the threshold value, face a trade-off between educating their children and improving their likelihood of living longer. Conversely, as suggested by the extant empirical literaure, richer agents can simultaneously increase spending on the education of their offspring and also undertake higher longevity enhancing expenditures.

As long as the intertemporal elasticity of substitution is below a certain threshold, there is a positive association between expected parental longevity and offspring's human capital for all agents in the economy. However, if the intertemporal elasticity of substitution is above this threshold, a negative association between expected parental longevity and offspring's human capital may emerge for the poorest agents in the economy. Given that a higher intertemporal elasticity of substitution improves the ability of agents to shift expenditures between periods, this result suggests that, driven by their altruism, the poorer agents in the economy may make use of the greater flexibility created by a higher intertemporal elasticity of substitution to increase expenditures on their children's education whilst foregoing their own expected longevity.

When the poorer agents forego their longevity enhancing health expenditures to educate their children, they face a reduced probability of surviving into old age. In turn however, their offspring now possess higher levels of human capital, which enables them to undertake higher longevity enhancing health expenditures, and consequently enjor a higher survival probability. As a result, a possible negative link between parental and offspring *longevity* may also emerge for the poorer agents in the economy when the intertemporal elasticity of substitution is high. Hence, our results suggest that extant empirical evidence should be interpreted with caution, and further empirical work, particularly in the context of a larger set of economies, with due consideration of economic factors, is needed.

The key contribution of our study is that it provides an explanation for the link between parental longevity and offspring's human capital via a channel that has received sparse attention in the extant theoretical and empirical economics literature. By initiating an explanation for this link that rests on expenditure decisions made by households, our study makes a novel addition to the literature on human capital accumulation and intergenerational inequality. lThe rest of the paper is organised as follows: the model is presented in Section 2, the dynamics of the model are discussed in Section 3 and Section 4 concludes. Several proofs are provided in the Appendix.

2. The Model

We consider a three period overlapping generations model, where an individual spends her childhood studying, works in adulthood and is retired in old age. At the beginning of adult age, each individual gives birth to a single offspring whose education is funded by the parent. In adult age, the agent also undertakes certain health expenditures that determine her probability of survival into old age. Time is discrete and is given by *t=0,1,2,3…*. We assume that at time *t=0*, the economy is populated with a generation of adult individuals whose distribution of human capital is $H_0(.)$.

An individual's stock of human capital in adult age is determined by education acquired in childhood as well as parental human capital, according to the following increasing returns human capital accumulation function:

$$h_{t+1} = h_t^{\psi} e_t^{\alpha}, \quad 0 < \psi, \alpha < 1, \ \psi + \alpha > 1 \tag{2.1}$$

Where h_t and e_t are the stock of human capital and education in period t.

For simplicity, we abstract from physical capital accumulation so that the output produced by a person in period t is equal to her human capital, which, for simplicity, we assume is also equal to her wage. Therefore,

$$y_t = w_t = h_t \tag{2.2}$$

In period $t+1$, each individual allocates her adult age wage between family consumption c_{t+1}, health expenditure m_{t+1} to enhance her probability of surviving into old age, expenditure on her child's education e_{t+1} and savings s_{t+1}. Therefore, her budget constraint in adult age is given by:

$$c_{t+1} + m_{t+1} + e_{t+1} + s_{t+1} = w_{t+1} \tag{2.3}$$

Her savings, which accumulate an exogenous interest of $\bar{r}$, are used to finance her old age consumption c_{t+2} if she survives. Following Yaari (1965), we assume that the agent invests all her savings in a life insured annuity which pays her an allowance while she is alive, and is cancelled upon her demise. This means that if she does not survive into old age, her savings cannot be inherited by her offspring. Therefore, her budget constraint in old age is given by:

$$c_{t+2} = \left(1+\bar{r}\right)s_{t+1} \tag{2.4}$$

An agent derives utility from consumption in each period as well as a "warm glow" utility from educating her child. Her probability of survival into old age is given by $\phi\left(m_t\right)$. This probability satisfies the conditions $\phi'\left(m_t\right)>0$ and $\phi''\left(m_t\right)<0$ so that it is strictly concave in health expenditure m_t. The individuals' utility at time t is given by:

$$U_t = U(c_{t+1}) + \theta V(e_{t+1}) + \phi(m_{t+1})U(c_{t+2}) \tag{2.5}$$

We assume CIES utility such that $U(c_i) = \frac{c_i^{1-\sigma}}{1-\sigma}$, where $i = t+1, t+2$,

and $V(e_{t+1}) = \frac{e_{t+1}^{1-\sigma}}{1-\sigma}$.

Like in Chakraborty (2004) we take a survivial probability function of the following form:

$$\phi(m_{t+1}) = \frac{m_{t+1}}{1+m_{t+1}} \tag{2.6}$$

This survival probability function satisfies the properties $\phi(0) = 0$, $\phi'(m_{t+1}) = \frac{1}{(1+m_{t+1})^2} > 0$, $\phi''(m_{t+1}) = -\frac{2}{(1+m_{t+1})^3} < 0$ mentioned above, and $\phi(m_{t+1}) \to 1$ as $m_{t+1} \to \infty$.

Maximizing utility subject to the budget constraints gives us the following FOCs:

$$U'(c_{t+1}) = \theta U'(e_{t+1}) \Rightarrow e_{t+1} = \gamma c_{t+1}, \text{where } \gamma = \theta^{1/\sigma} \tag{2.7}$$

$$U'(c_t) = (1+r)\phi(m_t)U'(c_{t+1}) \Rightarrow c_{t+1} = \left[(1+\bar{r})\left(\frac{m_t}{1+m_t}\right)\right]^{-1/\sigma} c_{t+2} \tag{2.8}$$

$$\phi'(m_{t+1})U(c_{t+2}) = (1+r)\phi(m_{t+1})U'(c_{t+2}) \Rightarrow c_{t+2} = (1-\sigma)(1+\bar{r})(1+m_{t+1})m_{t+1} \tag{2.9}$$

The FOC given by equation (2.7) tells us that when the agent maximises utility, the marginal utility she gets from spending a dollar of her income on adult age consumption should be equal to the marginal utility associated with a dollar spent on her offspring's education. Similarly, the optimality condition given by (2.8) shows that the marginal utility she derives from a dollar spent on adult age consumption should be equal to the marginal utility she gets from a dollar spent on expected old age consumption. Finally, equation (2.9) indicates that the marginal benefit she acquires by spending an extra dollar on longevity enhancing health expenses should be equal to the marginal utility she gains from spending an extra dollar on old age consumption.

Substituting (2.7)-(2.9) into the budget constraint gives us the following implicit equation for the optimal health expenditure m^*_{t+1}:

$$(1+\gamma)(1-\sigma)(1+\bar{r})^{1-1/\sigma} m_{t+1}^{1-1/\sigma}(1+m_{t+1})^{1+1/\sigma} + (1-\sigma)(1+m^*_{t+1})m^*_{t+1} + m^*_{t+1} = h_{t+1} \tag{2.10}$$

Given the optimal health expenditure m^*_{t+1} which satisfies equation (2.10), the expressions for the optimal values of c_{t+1}, e_{t+1}, s_{t+1} and c_{t+2} as functions of m^*_{t+1} are:

$$c^*_{t+1} = \frac{h_{t+1} - \backslash(1-\sigma)(1+m^*_{t+1})m^*_{t+1} - m^*_{t+1}}{1+\gamma} \tag{2.11}$$

$$e^*_{t+1} = \frac{\gamma\left[h_{t+1} - \backslash(1-\sigma)(1+m^*_{t+1})m^*_{t+1} - m^*_{t+1}\right]}{1+\gamma} \tag{2.12}$$

$$s^*_{t+1} = h_{t+1} - m^*_{t+1} - (1+\gamma)(1-\sigma)(1+\bar{r})^{1-1/\sigma} m^{*\,1-1/\sigma}_{t+1}(1+m^*_{t+1})^{1+1/\sigma} \tag{2.13}$$

$$c^*_{t+2} = (1+\bar{r})\left\{h_{t+1} - m^*_{t+1} - (1+\gamma)(1-\sigma)(1+\bar{r})^{1-1/\sigma} m^{*\,1-1/\sigma}_{t+1}(1+m^*_{t+1})^{1+1/\sigma}\right\} \tag{2.14}$$

Equations (2.11)-(2.14) can be used to glean further insights into the key features of some of the optimal values. Since the motivation for the study emerges from the notion that longevity enhancing medical expenditure and expenditure on educating offspring may compete for a given household budget, a primary consideration is whether all agents in the economy consider the two types of expenditure to be gross substitutes for one another. Proposition 1, the proof for which is provided in Appendix A, shows us that this may not necessarily be the case for all agents:

Proposition 1: A threshold value of human capital h^S exists such that for agents with adult age human capital/income $h_{t+1} > h^S$, longevity enhancing medical expenditure and the expenditure on their offspring's education are gross complements, while for agents with $h_{t+1} < h^S$, these two expenditures are gross substitutes.

Proposition 1 demonstrates that the cross elasticity between longevity enhancing medical expenditure and offspring's education expenditure is dependent upon the agent's income/human capital. Although the budget constaint may create the perception that an increase in one type of expenditure should entail a concurrent reduction in the other, it is interesting to see that such a tradeoff is only present for the poorer individuals in the economy with incomes below the threshold level h^S. There is no such tradeoff for the richer individuals in the economy with incomes exceeding the threshold h^S. From the expression for h^S (which is provided in Appendix A), we can see that this threshold level of human capital/wage is affected by several factors. Firstly, a higher interest rate on savings reduces the threshold, implying that more agents in the economy will consider health and education expenditures to be gross complements. Recall that $\gamma = \theta^{1/\sigma}$. Hence, a higher value of the altruism factor will be reflected in an increased value of the parameter γ, which causes the threshold value of human capital to rise. Therefore, as expected, greater the value of the warm glow parameter, there will be more agents willing to substitute longevity enhancing health expenditures to educate their children. However, the manner in which the term $1/\sigma$, which is the elasticity of intertemporal substitution associated with the agent's utility function , impacts on the threshold is unclear.

Another issue of interest is whether consumers consider longevity enhancing health expenditure to be a necessity or luxury. The merit goods argument motivates one to consider healthcare as a necessity in any modern society, and is the primary reason for government intervention in the healthcare industry in the form of direct provision, social insurance schemes and regulation of the different components of healthcare systems. Such views suggest that the income elasticity for healthcare in general should be income inelastic. Our model reveals the following:

Proposition 2: A certain threshold level of human capital/income h^Y exists such that for agents with $h_{t+1} < h^Y$, longevity enhancing health expenditure is a luxury good. For agents with $h_{t+1} > h^Y$, it is a necessity.

According to Proposition 2, the poorer agents in the economy whose incomes fall below the threshold level specified above have an income elasticity of demand for medical expenditure which is above 1, and therefore consider it to be a luxury good, while richer agents with incomes above this threshold have an income elasticity of demand which is below 1.

There is considerable variation in the extant estimates of the income elasticity for healthcare in general, and some longevity enhancing health expenses in particular. To illustrate this point, we present the income elasticity estimates from a large number of studies in Table 2 below. If one considers the recent studies presented in Table 2, the range of income elasticity estimates for the African region obtained by Murthy and Okunade (2009) is higher than the range obtained by Narayan et al. (2011) for the OECD countries, possibly suggesting that developing regions have a higher income elasticity for healthcare than developed countries. In contrast, the estimates provided in Farag et al. (2012), point in the direction of a non-monotonic relationship between the income elasticity of demand for healthcare and the level of economic development. However, given the differences in methodology and data quality, cross-study as well as cross-country comparisons of this nature should be treated with considerable caution, and should not be regarded as conclusive evidence to support or refute any contention on the income elasticity of demand for healthcare. If any, the only concrete observation emanating from Table 2 is that differences in these estimates makes it difficult to reach any consensus on whether the demand for healthcare at the aggregate level is income elastic or not.

Table 2. *Income Elasticity Estimates for Health*

Study	Context	Type of expenditure considered	Elasiticity estimates
Feldstein (1971)	USA	Hospital admissions and mean length of stay	hospital admissions 0.078 Mean length of stay 0.465
Newhouse (1977)	13 developed countries	Per capital medical expenditure	1.13-1.31
Fogel (1999)	USA	Household health expenditure	1.6
Freeman (2003)	USA	Health expenditure for different states	0.817-0.844
Yu and Chu (2007)	Taiwan	Per capita healthcare expenditure	0.261
Murthy and Okunade (2009)	44 African countries	Per capital healthcare expenditure	0.69-2.677
Ang (2010)	Australia	Per capita healthcare expenditure	1.207-1.252
Narayan, Narayan, and Smyth (2011)	OECD	Per capita healthcare expenditure	0.2425-0.9886
Zhou, Su, Gao, Xu, and Zhang (2011)	Rural China	Outpatient and inpatient health services	Outpatient services 0.098 Inpatient services 0.521
Farag et al. (2012)	Global (173 countries)	Per capita healthcare expenditure	Low income 0.52 Middle income 0.87 High income 0.64
Yavuz, Yilanci, and Ozturk (2013)	Turkey	Per capita health expenditure	0.75
Khan and Mahumud (2015)	Southeast Asia	Public and private sector health expenditure	Public sector 0.412 Private sector 1.128

It is important to note that the health expenditures that are incorporated in our model are those that are directly associated with longevity improvements, while the estimates given in Table 2.1 refer to health expenditures in general. Hence, these estimates, while highlighting the considerable variations in income elasticities for health expenditure, provide us with limited insights into the income elasiticity specific to longevity enhancing health expenditures of the type we consider. Nevertheless,there is considerable variation in the estimates for the income elasticity for longevity enhancing health expenditure as well. For instance, Johannesson, Johannsson, Kristrõm, Borgquist, and Jõnsson (1993) provide an estimate of aproximately 0.2 for the income elasticity of demand for the willingness to pay for lipid and high blood pressure lowering treatments that contribute towards longevity by helping to reduce the risk of cardiovascular disease. According to Bouis and Haddad (1992), different studies conducted in a number of developing countries estimate that the income elasticity of calorie consumption, which may also be regarded as a determinant of old age health and longevity, varies between 0.34 and 1.18.

Nevertheless, the presence of two groups with distinct income elasticities for longevity improving health expenditures is a plausible outcome, given the heterogeneity of human capital endowments inherent to the model. Such heterogeneity in the income elasticity between different groups is observed by Parker and Wong (1997), who estimate that for the richer 50% of the population without health insurance in Mexico, the income elasticity of demand for paid health services is 0.956 and for the poorer 50% of the uninsured population, it is 1.60. In our model, the division of agents into two distinct groups is essentially an outcome emerging due to the strict concavity of the survival probablity function, which means that the marginal gain from additional expenditure on longevity improving health expenditures for people with lower health expenditures is higher than for those who spend more on health. Hence, an increase in income is likely to induce poor agents to increase their expenditure on health proportionately more than those who already undertake relatively high health expenditures.

3. Dynamics

Having looked at some key features of the model, we can now look at the dynamics emerging from it. Our main focus is on the relationship between the offspring's human capital and parental longevity. To explore the nature of this link, we first we lag the human capital accumulation function given by equation (2.1) by one period to express the offspring's adult age human capital (in period *t+2*) in terms of parental adult age human capital and education expenditure. This results in the following human capital accumulation equation:

$$h_{t+2} = h_{t+1}^{\psi} e_{t+1}^{\alpha} \tag{3.1}$$

Recall that the implicit equation (2.9) gives us an expression for h_{t+1} in terms of optimal longevity enhancing medical expenditure m_{t+1}^{*}, and equation (2.11) gives us an expression for optimal education expenditure in terms of m_{t+1}^{*}. Then, substituting equations (2.9) into equation (2.11) enables us to express (optimal) education expenditure also in terms of m_{t+1}^{*}. Substituting these equations back into (3.1) above gives us the offspring's human capital as a function of optimal health expenditure. While we relegate all the related calculations and derivations to Appendix C, we can characterise the association between expected parental longevity and offspring's human capital as follows:

Proposition 3: A sufficient condition under which there is a positive relationship between expected parental longevity and offspring's human capital for *all* agents in the economy is $\sigma > \frac{\alpha}{\alpha+\psi}$. When $\sigma < \frac{\alpha}{\alpha+\psi}$, a certain threshold value of human capital h^L exists such that, for agents with human capital/income below this value, a negative relationship may emerge between expected parental longevity and the human capital of their offspring.

Under the assumption of CIES utility, the elasticity of intertemporal substitution is given by $\varepsilon = 1/\sigma$. Hence, the sufficient condition which guarantees a positive association between expected parental longevity and the human capital of their offspring given in Proposition 3 can be expressed as: $\varepsilon < \frac{\alpha + \psi}{\alpha}$. As long as the elasticity of intertemporal substitution is below this threshold value, there is a positive association between expected parental longevity and the human capital of their offspring. A lower elasticity of intertemporal substitution implies that it is difficult for the agent to shift expenditure between periods and causes the curvature of the intertemporal indifference curve to rise. In the utility function we consider in our model, the adult agent enjoys the utility associated with educating her child immediately, but she realises the benefit of health expenditure only in the next period, in the form of higher expected utility in old age. Hence, a lower elasticity of intertemporal substitution is most likely to cause the two types of expenditure to rise (or fall) hand in hand in response to a change in income or the interest rate, thereby leading to a positive association between parental longevity and the human capital of their offspring. Also notice that a higher value of ψ causes the threshold value of ε to rise while a higher value of α causes the threshold value to fall. Recall that ψ is the share of parental human capital in the human capital accumulation function and α is the share of education. Hence, a smaller share of education relative to the share of parental human capital in the human capital accumulation function increases the value of this threshold value, thereby implying that even in the presence of a relatively high elasticity of intertemporal substitution, all the agent in the economy can experience a positive link between their own longevity and the human capital of their offspring.

Since $\varepsilon < \frac{\alpha+\psi}{\alpha}$ is only a sufficient condition for the emergence of a positive link between expected parental longevity and the human capital of their offspring, we cannot deduce that if $\varepsilon > \frac{\alpha+\psi}{\alpha}$ there is necessarily a negative relationship. Nevertheless, in Appendix C, we derive a threshold value of human capital, which we denote with h^L such that, for agents with human capital/income above this threshold, we can state that a positive association between expected parental longevity and offspring's human capital would be present. However, since we have relied on a sufficient condition for our analysis, we can only infer that a negative link *may* be present for agents with human capital/income below this threshold.

This possible presence of a negative link implies that the strong positive association between parental longevity and the socio-economic status of their offspring revealed in the interdisciplinary literature may not be present for the poorer agents of the economy. As discussed earlier, these studies suggest that this positive link emerges due to child to parent transmission of healthy behaviours. Generally, it is possible to infer that if parents cohabit with their adult children, the socio-economic status of their children would impact on their longevity positively, as the financial capability of their children is likely to be a key determinant of their ability to supply appropriate geriatric care for their aged parents by providing them, among other things, with nutrious food and food supplements, taking them for regular medical check-ups and organizing the physical environment of the household to minimise the risk of accidents.

However, in our model, we focus on a nuclear family setting where only two generations—the young and the adult age agents—cohabit. The old agent lives alone, financing her consumption by investing her savings in a life insured annuity. The motivation to consider such a setting emerges from the global trend towards elderly people living independently which was noted in the Introduction. In contrast to the child to parent transmission of healthy behaviours suggested in the extant interdisciplinary literature, in our model, parents can influence their children's human capital, but children cannot influence their parents' longevity. Due to this difference in the direction of causality we consider, we observe that if the elasticity of intertemporal substitution is higher than the threshold value noted in Proposition 3, a negative asssociation may emerge between parental longevity and their offspring's human capital for the poorest agents in the economy.

The possible emergence of such a negative association for the poorest agents in the economy could translate into intergenerational inequalities in *longevity*. If the poorer parents undertake lower health expenditures in order to educate their children, they will face a reduced probability of survival into old age. However, their children will be able to enjoy a higher level of human capital/income as a result, which enables them to enjoy a higher probability of survival into old age. Hence, this may result in a negative relationship between parental and offspring longevity for the poorest agents in the economy. Extant literature suggests that a relationship between parental and offspring longevity could arise due to genetics and behavioural factors (see Pörtner and Wong, 2013 and references therein). However, we suggest that decisions made by parents regarding expenditures on education of their children and their own health could be another mechanism that could yield an association between parental and offspring longevity.

4. Conclusion

Interdisciplinary literature reveals the presence of a positive link between parental longevity and the human capital of their offspring. This link is often explained by the child-to-parent transmission of healthy behaviours; educated, affluent children can provide direct financial and practical assistance to their elderly parents and also influence their behaviour if they maintain close ties with their parents. However, in modern societies, due to several reasons like the increasing proportion of parents living independently, the geographical distance between parents and their children and emotional distance between parents and adult children caused by problems such as parental divorce, this mechanism may not be as strong as the interdisciplinary literature suggests. We therefore develop a model to explore an alternative mechanism that could explain this link. In our model, adults undertake expenditures to enhance their own longevity and simultaneously spend on their offspring's education, leading to an association between parental longevity and the human capital of their children.

Contrary to the extant literature, our model reveals that, under certain conditions, a negative link between human capital of offspring and longevity of parents could emerge for agents with incomes/human capital below a certain threshold value. As higher human capital enables an agent to afford higher outlays on health, this could consequently lead to a negative association between parental and offspring longevity. In a society characterised by high initial inequality, there will be a high proportion of agents with incomes below the threshold mentioned above. These results indicate that redistribution of income may help reduce the persistence of a negative association between parental and offspring longevity for these agents.

In addition, our model also shows that for the poorer agents in the economy, whose human capital lies below a particular threshold value, longevity enhancing health expenditures and expenditure on educating offspring are gross substitutes while for the richer agents, the two expenditures are complementary. Furthermore, longevity enhancing health expenditure is a luxury for poorer agents while it is a necessity for others.

In our model, we abstract from behavioural and genetic impacts on longevity. However, modelling the survival probability function to incorporate these aspects could lead to richer insights into the issues investigated herein.. Another possible extension is considering a reciprocal arrangement where, in return for educating them in childhood, The non-monotonicity of the relationship betweeen children's human capital and parental longevity revealed in our study is worthy of further investigation in relation to a larger set of economies.

Appendices

Proof of Proposition 1

Substituting for h_{t+1} from equation (2.9) into equation (2.11), we get the following expression for e^*_{t+1}:

$$e^*_{t+1} = \frac{\gamma(1-\sigma) {m^*_{t+1}}^{1-1/\sigma} \left(1+m^*_{t+1}\right)^{1+1/\sigma}}{\left(1+\bar{r}\right)^{1/\sigma - 1}} \tag{A1}$$

Differentiating (A1) gives us:

$$\frac{de^*_{t+1}}{dm^*_{t+1}} = \frac{\gamma(1-\sigma) {m^*_{t+1}}^{-1/\sigma} \left(1+m^*_{t+1}\right)^{1/\sigma} \left(2m^*_{t+1} + 1 - 1/\sigma\right)}{\left(1+\bar{r}\right)^{1/\sigma - 1}} \tag{A2}$$

From (A2) above, we can see that if $m^*_{t+1} < \frac{1/\sigma - 1}{2}$, $\frac{de^*_{t+1}}{dm^*_{t+1}} < 0$, i.e. health and education are gross substitutes, while if $m^*_{t+1} > \frac{1/\sigma - 1}{2}$, $\frac{de^*_{t+1}}{dm^*_{t+1}} > 0$, and they are gross complements.

Let the corresponding threshold value of human capital be h^S_{t+1}. Substituting the threshold value of health expenditure derived above into equation (2.9) and simpliying gives us:

$$h^S_{t+1} = \frac{(1+\gamma)(1-\sigma)}{\left(1+\bar{r}\right)^{1/\sigma - 1}} \left(\frac{1/\sigma^2 + 1}{4}\right) \left(\frac{1/\sigma + 1}{1/\sigma - 1}\right)^{1/\sigma} + (1-\sigma)\left(\frac{1/\sigma^2 + 1}{4}\right) + \left(\frac{1/\sigma - 1}{2}\right) \tag{A3}$$

Proof of Proposition 2

Using equation (2.9), we can write the following implicit function:

$$F\left(h_t, m_t^*\right) = \left\{(1+\gamma)\left[\left(1+\bar{r}\right)\left(\frac{m_t^*}{1+m_t^*}\right)\right]^{1/\sigma} + \frac{1}{1+\bar{r}}\right\}(1-\sigma)\left(1+\bar{r}\right)\left(1+m_t^*\right)m_t^* + m_t^* - h_t \qquad \text{(B1)}$$

Using the implicit function theorem, we have:

$$\frac{\partial m_t^*}{\partial h_t} = \frac{-f\left(h_t\right)}{f\left(m_t^*\right)} = \frac{1}{(1+\gamma)(1-\sigma)\left(1+\bar{r}\right)^{1-1/\sigma} m_{t+1}^{-1/\sigma}\left(1+m_{t+1}^*\right)^{1/\sigma}\left(1+2m_{t+1}-\frac{1}{\sigma}\right)+1+(1-\sigma)\left(1+2m_{t+1}\right)}$$

(B2)

From (B2), The income elasticity for longevity enhancing health expenditure is:

$$\xi = \frac{\partial m_t^*}{\partial h_t} \times \frac{h_t}{m_t^*} = \frac{(1+\gamma)(1-\sigma)\left(1+\bar{r}\right)^{1-1/\sigma} m_{t+1}^{1-1/\sigma}\left(1+m_{t+1}\right)^{1+1/\sigma}+(1-\sigma)\left(1+m_{t+1}^*\right)m_{t+1}^*+m_{t+1}^*}{(1+\gamma)(1-\sigma)\left(1+\bar{r}\right)^{1/\sigma+1} m_{t+1}^{*\ 1-1/\sigma}\left(1+m_{t+1}^*\right)^{1/\sigma}\left(1+2m_{t+1}^*-\frac{1}{\sigma}\right)+(1-\sigma)\left(1+2m_{t+1}^*\right)m_{t+1}^*+m_{t+1}^*}$$

Health care is a luxury/income elastic good if $\xi > 1$. This occurs when

$$(1+\gamma)(1-\sigma)\left(1+\bar{r}\right)^{1-1/\sigma} m_{t+1}^{1-1/\sigma}\left(1+m_{t+1}\right)^{1+1/\sigma}+(1-\sigma)\left(1+m_{t+1}^*\right)m_{t+1}^*+m_{t+1}^* >$$

$$(1+\gamma)(1-\sigma)\left(1+\bar{r}\right)^{1-1/\sigma} m_{t+1}^{*\ 1-1/\sigma}\left(1+m_{t+1}^*\right)^{1/\sigma}\left(1+2m_{t+1}^*-\frac{1}{\sigma}\right)+(1-\sigma)\left(1+2m_{t+1}^*\right)m_{t+1}^*+m_{t+1}^*$$

Which simplifies to:

$$(1+\gamma)\left(1+\bar{r}\right)^{1-1/\sigma}\left(1+m_{t+1}^*\right)^{1/\sigma}\left(1/\sigma-m_{t+1}^*\right)m_{t+1}^{*\ -(1+1/\sigma)} > 1$$

Rearranging, we get:

$$(1+\gamma)\left(\frac{1}{m^*_{t+1}}+1\right)^{1/\sigma}\frac{1}{(1+\bar{r})^{1/\sigma-1}}\left(\frac{1}{\sigma m^*_{t+1}}-1\right)>1$$

In the above inequality, as $0<\sigma<1$ and $\gamma > 0$, it is evident that $(1+\gamma)\left(\frac{1}{m^*_{t+1}}+1\right)^{1/\sigma}>1$

Hence, a necessary condition under which the above inequality holds is:

$\frac{1}{(1+\bar{r})^{1/\sigma-1}}\left(\frac{1}{\sigma m^*_{t+1}}-1\right)>1,$ which can be rearranged as:

$$m^*_{t+1}<\frac{1}{\sigma\left[(1+\bar{r})^{1/\sigma-1}+1\right]}$$

Conversely, if $m^*_{t+1}>\frac{1}{\sigma\left[(1+\bar{r})^{1/\sigma-1}+1\right]}$, it is a necessity.

Let h^Y_{t+1} be the threshold value of human capital/wage that corresponds to this threshold value of health expenditure. We thus have:

$$h^Y_{t+1}=(1+\gamma)(1-\sigma)(1+\bar{r})^{1-1/\sigma}\left\{\frac{1}{\sigma\left[(1+\bar{r})^{1/\sigma-1}+1\right]}\right\}^{1-1/\sigma}\left\{1+\frac{1}{\sigma\left[(1+\bar{r})^{1/\sigma-1}+1\right]}\right\}^{1+1/\sigma}+\frac{(1-\sigma)}{\sigma\left[(1+\bar{r})^{1/\sigma-1}+1\right]}\left\{1+\frac{1}{\sigma\left[(1+\bar{r})^{1/\sigma-1}+1\right]}\right\}+\frac{1}{\sigma\left[(1+\bar{r})^{1/\sigma-1}+1\right]}$$

Proof of Proposition 3

From equation (3.1), we can find the derivative of h_{t+2} with respect to m^*_{t+1}:

$$\frac{dh_{t+2}}{dm^*_{t+1}}=\psi h^{\psi-1}_{t+1}e^{\alpha}_{t+1}\frac{dh_{t+1}}{dm_{t+1}}+\alpha h^{\psi}_{t+1}e^{\alpha-1}_{t+1}\frac{de_{t+1}}{dm_{t+1}}=h^{\psi-1}_{t+1}e^{\alpha-1}_{t+1}\left[\psi e_{t+1}\frac{dh_{t+1}}{dm_{t+1}}+\alpha h_{t+1}\frac{de_{t+1}}{dm_{t+1}}\right] \quad \text{(C1)}$$

We see that $\frac{dh_{t+2}}{dm^{*}_{t+1}} > 0$ if $\psi e_{t+1}\frac{dh_{t+1}}{dm_{t+1}} + \alpha h_{t+1}\frac{de_{t+1}}{dm_{t+1}} > 0$, which can be rearranged as:

$$\frac{dh_{t+1}/dm_{t+1}}{de_{t+1}/dm_{t+1}} + \frac{\alpha h_{t+1}}{\psi e_{t+1}} > 0$$

From equations (A2) and (B2) we have:

$$\frac{dh_{t+1}/dm_{t+1}}{de_{t+1}/dm_{t+1}} = \frac{1+\gamma}{\gamma} + \frac{1+(1-\sigma)(1+2m_{t+1})}{\gamma(1+\bar{r})^{1-1/\sigma}(1-\sigma)m_{t+1}^{-1/\sigma}(1+m_{t+1})^{1/\sigma}\left(1+2m_{t+1}-1/\sigma\right)} \qquad \text{(C2)}$$

Then, from equations (2.9) and (A1), we have:

$$\frac{\alpha h_{t+1}}{\psi e_{t+1}} = \left(\frac{\alpha}{\psi}\right)\left[\frac{1+\gamma}{\gamma} + \frac{1+(1-\sigma)(1+m_{t+1})}{\gamma(1+\bar{r})^{1-1/\sigma}(1-\sigma)m_{t+1}^{-1/\sigma}(1+m_{t+1})^{1/\sigma+1}}\right] \qquad \text{(C3)}$$

Then,

$$\frac{dh_{t+1}/dm_{t+1}}{de_{t+1}/dm_{t+1}} + \frac{\alpha h_{t+1}}{\psi e_{t+1}} = \left(\frac{1+\gamma}{\gamma}\right)\left(1+\frac{\alpha}{\psi}\right) + \frac{\frac{(1+m_{t+1})[1+(1-\sigma)(1+2m_{t+1})]}{\left(1+2m_{t+1}-1/\sigma\right)} + \alpha/\psi\,[1+(1-\sigma)(1+m_{t+1})]}{\gamma(1+\bar{r})^{1-1/\sigma}(1-\sigma)m_{t+1}^{-1/\sigma}(1+m_{t+1})^{1/\sigma+1}}$$

From (C4) above, we can see that a sufficient condition under which $\frac{dh_{t+1}/dm_{t+1}}{de_{t+1}/dm_{t+1}} + \frac{\alpha h_{t+1}}{\psi e_{t+1}} > 0$ is:

$$\frac{(1+m_{t+1})[1+(1-\sigma)(1+2m_{t+1})]}{\left(1+2m_{t+1}-1/\sigma\right)} + \alpha/\psi\,[1+(1-\sigma)(1+m_{t+1})] > 0$$

This condition can be rearranged to take the form of the following quadratic inequality:

$$am_{t+1}^2 + bm_{t+1} + c > 0,$$

Where, $a = 2(1-\sigma)\left(1 + \alpha/\psi\right)$,

$b = (2-\sigma)\left(1 + 2\alpha/\psi\right) + (1-\sigma)\left[2 + \alpha/\psi\left(1 - 1/\sigma\right)\right]$,

and $c = (2-\sigma)\left[1 + \alpha/\psi\left(1 - 1/\sigma\right)\right]$

Hence, $\frac{dh_{t+2}}{dm_{t+1}^*} > 0$ if $m_{t+1} > \frac{-b + \sqrt{b^2 - 4ac}}{2a}$ or $m_{t+1} < \frac{-b - \sqrt{b^2 - 4ac}}{2a}$.

If $c > 0$, the inequality $am_{t+1}^2 + bm_{t+1} + c > 0$ is always satisfied.

Since $2 - \sigma > 0$, $c > 0$ if $1 + \alpha/\psi\left(1 - 1/\sigma\right) > 0$, which simplifies to: $\sigma > \frac{\alpha}{\psi + \alpha}$.

On the other hand, if $c < 0$, which occurs in the range $\sigma < \frac{\alpha}{\psi + \alpha}$, the condition $m_{t+1} > \frac{-b + \sqrt{b^2 - 4ac}}{2a}$ is binding.

Hence, when $\sigma < \frac{\alpha}{\psi + \alpha}$, for all agents with longevity enhancing health expenditures $m_{t+1} > \frac{-b + \sqrt{b^2 - 4ac}}{2a}$, $\frac{dh_{t+2}}{dm_{t+1}^*} > 0$. By substituting this threshold level of health expenditure into equation (2.9), we can get the corresponding threshold level of human capital/income, which we will denote with h_{t+1}^L. For all agents with incomes above h_{t+1}^L, there is a positive association between expected parental longevity and children's human capital. On the other hand, for some agents with incomes below this threshold, it *may* be possible that $\frac{dh_{t+2}}{dm^*_{t+1}} < 0$ (since we only looked at the sufficient condition for $\frac{dh_{t+2}}{dm^*_{t+1}} < 0$, we cannot say for certain that when this condition is not met, $\frac{dh_{t+2}}{dm^*_{t+1}}$ is necessarily negative.

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