Heterogenous Human Capital: Life Cycle Investment in Health and Education

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1 INTRODUCTION

During the last forty years, economists have devoted a great deal of effort to developing the concept of human capital and applying it to explain investment in education, income inequality, and life-time earning profiles. Early contributions to the human capital theory (Schultz 1961, Mushkin 1962, Becker 1964, Fuchs 1966) suggested that there might exist several forms of human capital. However, theoretical models of human capital (Becker 1964, Ben-Porath 1967) modelled it as a one-dimensional stock variable, which was typically interpreted as education. Even though in the empirical work both education and experience were usually included in the earning equation (Mincer 1997), experience was usually interpreted as a continuation of education at the job place in the spirit of Ben-Porath's model.

The concept of health capital was developed by Grossman (1972). Stock of health in his model determines the total amount of time an individual can spend producing money earnings and commodities.[1] It also directly affects the utility of the individual. The major drawback of this model is that in order to explain an empirically observed correlation between education and the stock of health (Grossman, 1970) one has to assume that education

[1] For the distinction between market goods and commodities, see Becker (1965).

increases the efficiency with which gross investments in health are produced. This assumption is not very intuitive and there is no compelling empirical evidence to support it.

In this paper I propose that a positive correlation between education and health stock arises from their complementarity in the individual's utility function. This complementarity arises due to an insurance motive for health accumulation, which was largely overlooked in the literature. The basic idea is that an individual invests in health to increase the probability of survival in order to enjoy the fruits of the investment in education. Vice versa, a healthy person will have higher incentives to invest in education, since she is more likely to survive long enough to enjoy the results.

The insurance motive can explain not only the positive correlation between education and health, but also a positive correlation between the saving rate and health. It means that the health status of the population has an unambiguously positive effect on the growth rate of economy.

A positive causal effect of health on economic growth was reported for 18 Latin American countries by Mayer (2001) and for some of the OECD countries by Devlin and Hansen (2001). The primary importance of the health capital for the LDCs was confirmed by McDonald and Roberts (2002).

This result is of a great potential importance, since it suggests that for these countries a trade-off between health enhancing policies and economic growth need not exist.

Existing theoretical explanations of the connection between health and productivity (e.g., Fogel 1994, Chang 1996) emphasize the direct effect of health on the individual's ability to participate in the production process. The effects of better health include, for example, an increased ability to perform complex physical tasks and a decrease in sick hours. They largely ignore the fact that better health increases the incentives to invest in future earning capacity. If improved health stimulates more education investment, part of the effect of an improvement of health status on the rate of economic growth will be realized with a lag (especially, in poor countries). This implies that a regression of growth rate on the current health stock will underestimate the effect of health on growth.

To formalize the insurance motive for health accumulation, I purpose a life-cycle model of human capital accumulation, in which human capital has two dimensions: education and health. At each point of their lives credit-constrained individuals divide their income between consumption, saving, and investments in health and education. I assume that education affects the wage rate, while health determines the probability of survival till the next period. These assumptions are made not because I believe that individuals do not value health or health does not affect earning capacity, but because I am want to isolate the insurance motive for the investment in health and study its consequences.

I show that if the health level of an individual is high enough her investment in education is independent of health and she will equate the marginal product of investment in education with the return to physical assets. This result is standard in human capital theory. However, for individuals with poor health, educational investment is positively related with their health. To get an intuitive understanding of this result note that individuals with poor health would like to consume as much as possible in the current period, since they are unlikely to survive till the next one. Hence, the borrowing constraint will bind. This, in turn, implies that the opportunity cost of the investment in education will be determined not by the actual interest rate, but by the effective interest rate equal to the lowest interest that will make the borrowing constraint slack. This effective interest rate will increase with the demand for borrowing, which in turn will decrease with probability of survival and hence, with current health. Hence, the investment in education will increase with health.

Even though investment in education for an individual with good health is independent of the current stock of health, investment in health does depend on the current stock of education. This will create a positive correlation between the stocks of health and education across individuals if income effects are small enough.

The paper is organized as follows. In Section 2 I develop a simple two-period model of optimal investment in physical capital and various forms of human capital. Section 3 generalizes the model for a life-cycle of indefinite length. Section 4 concludes.

2 A TWO-PERIOD MODEL

Assume that an individual lives for at most two periods. The preferences of the individual over a consumption stream (c_1, c_2) are given by

$$U(c_1, c_2) = u(c_1) + \delta u(c_2), \tag{1}$$

where $u(\cdot)$ is twice differentiable and strictly concave,

$$\lim_{c \to +0} u'(c) = \infty$$

and $\delta \in (0,1)$. Assume that the individual is endowed with T units of time each period, which can be divided between working, schooling, and health enhancing activities.[2] In addition, the investment in health and education involves monetary resources, q_e and q_h for a unit of time invested in health and education, respectively. I also assume that the individual is endowed with e_0 units of education and h_0 units of health at her birth.[3]Similar to the model of Ben-Porath (1967), the education level at the beginning of period two and health capital at the end of period one are produced using the existing stock of capital and time. Production technology exhibits decreasing returns to scale. The wage of the individual is always equal to her education, $w = e$. The probability to survive period one is given by a strictly increasing, concave function $p(\cdot)$ where $p(0) = 0$ and

$$\lim_{h \to \infty} p(h) = 1. \tag{2}$$

[2]We assume that the individual has no preferences for leisure.

[3]The educational endowment can be interpreted as the innate ability of the individual.

Finally, the interest rate is equal to r.

Since the individual is always alive in period one and is alive in period two with probability $p(h)$ her ex-ante expected utility is given by

$$p(h)(u(c_1) + \delta u(c_2)) + (1 - p(h))(u(c_1) + \delta u(D)) \tag{3}$$

where $u(D)$ is the utility of death.

The individual solves

$$\max[u(c_1) + \delta p(h)(u(c_2) - u(D))] \tag{4}$$

$$s.t. \;\; c_1 + s + q_e i_e + q_h i_h = e_0(1 - i_e - i_h) \tag{5}$$

$$c_2 = s(1 + r) + eT \tag{6}$$

$$\begin{aligned} e &= (1 - d_1)e_0 + Q_e, \;\; h = (1 - d_2)h_0 + Q_h & (7) \\ Q_e &= e_0^{\alpha_1} i_e^{\alpha_2}, \;\; Q_h = h_0^{\beta_1} i_h^{\beta_2} & (8) \end{aligned}$$

Equations (8)-(9) specify production technologies for health and education. Here d_i $(0 \leq d_i \leq 1)$ are the depreciation rates of education and health respectively, and α_i and β_i are positive constants such that $\alpha_1 + \alpha_2 < 1$ and $\beta_1 + \beta_2 < 1$. Note that the production of education depends on the stock of education, but not on the health stock, and vice versa. Again, this is done not because I believe that the health stock does not affect production of education, but in order to keep the model as parsimonious as possible.

Define an imputed utility over period one consumption, savings, health and education by

$$W(c_1, s, e, h) = u(c_1) + \delta p(h) u(s(1 + r) + eT).$$

Note that the health and education capital and savings are complements in the imputed utility function. This implies that if the income effects are small all these variables move in the same direction in response to a change in the exogenous parameters of the model.

Let us normalize the initial stock of education, amount of time and monetary costs of investments by

$$Te_0 = 1,\ e_0 + q_e = 1,\ e_0 + q_h = 1. \tag{9}$$

To proceed further we need some technical assumptions.

Assumption 1 The individuals capacity to borrow is limited, that is there exists $M > 0$ such that $c_1 + i_e + i_h \leq M$.

Define

$$\kappa = (\frac{T\alpha_2}{1+r})^{\frac{1}{1-\alpha_2}},\ \rho = \frac{1-(\alpha_1+\alpha_2)}{1-\alpha_2}$$

Assumption 2 $1 \leq M < \min\{(2+r-d_1)/(1+r),\, 1-\kappa(e_0^{\rho}+e_0^{1-\rho})/(2+r)\}$.

Assumption 3 There exists such a level of health h_* that $p(h_*) = 1$.

Assumption 4 The social discount factor equals the private discount factor $\delta = 1/(1+r)$.

The last assumption is made for analytical convenience. It will help us to obtain closed form solutions, but does not alter results significantly. To analyze problem (5)-(9) first note that the individual maximizes a continuous function over a compact set. Hence, a solution exists. Assume that $p(\cdot)$ is differentiable for any h different from h_*. Then, the following first order conditions should hold at the solution of problem (5)-(9):

$$u'(c_1) = p(h)u'(c_2) + \lambda \tag{10}$$

$$u'(c_1) = T\delta\alpha_2 e_0^{\alpha_1} i_e^{\alpha_2 - 1} p(h)u'(c_2) \tag{11}$$

$$u'(c_1) = h_0^{\beta_1}\beta_2 i_h^{\beta_2 - 1} p'(h)(u(c_2) - u(D)) \tag{12}$$

$$\lambda(s - 1 + M) = 0,\ \lambda \geq 0,\ s \geq 1 - M. \tag{13}$$

Here λ is the Lagrange multiplier for a borrowing constraint. The first result I am going to prove is that there is a cutoff level of initial health below which the borrowing constraint becomes binding.

Proposition 1 *The exists a positive level of initial health $h_{\min} > 0$ such that for any $h_0 < h_{\min}$ the borrowing constraint binds.*

Proof. From (10) one obtains
$\lambda = u'(c_1) - p(h)u'(c_2) \geq u'(M) - p((1-d_2)h_0 + h_0^{\beta_1}M^{\beta_2})u'((1-d_1) + (1+r)(1-M))$. For $h_0 = 0$ one obtains $\lambda \geq u'(M) > 0$. By the continuity of $p(h)$, there exists $h_{\min} > 0$ such that $\lambda > 0$ for any $h < h_{\min}$. But then the complementary slackness condition (13) implies $s = 1 - M$. ■

If $h_0 = 0$ the the solution to system (10)-(13) is

$$c_1 = M,\ c_2 = 2 + r - d_1 - (1 + r)M^4,\ i_e = i_h = 0. \tag{14}$$

For small h_0 the approximate solution is given by

$$\begin{aligned} c_1 &= M,\ c_2 = 2 + r - d_1 - (1 + r)M, & (15)\\ i_e &= (\frac{T\alpha_2\delta p(h_0)e_0^{\alpha_1}u'(c_2)}{u'(c_1)})^{\frac{1}{1-\alpha_2}}, & (16)\\ i_h &= (\frac{\beta_2\delta p'(h_0)h_0^{\beta_1}(u(c_2) - u(D))}{u'(c_1)})^{\frac{1}{1-\beta_2}}. & (17)\end{aligned}$$

Note that if the initial health is small enough, the investment in education is increasing in the initial stock of health. This means that more healthy individuals will tend to obtain higher education. Since investment in health is also increasing in the initial stock of health this will provide a positive correlation between education and health in agreement with Grossman's results.

Next I will look at education investment when the borrowing constraint does not bind. Combining (10) and (11) one observes that

$$i_e = \kappa e_0^{\frac{\alpha_1}{1-\alpha_2}}, \tag{18}$$

Hence, investment in education is independent of the initial stock of health and is determined only by the interest rate and the initial stock of education. It can be found from the condition that the return to the marginal dollar invested in education equals the rate of return on the investment in the physical assets.

So far I obtained investment in education assuming the borrowing constraint does not bind. Next, I am going to argue that if the initial health stock is sufficiently high this is indeed the case.

Proposition 2 *There exists an initial stock of health* $h_{\max} > 0$ *such that for any* $h_0 > h_{\max}$ *the borrowing constraint is slack. If the borrowing constraint is slack investment in education is independent of the initial stock of health and is given by (19).*

Proof. Let h_0 be such that $(1 - d_2)h_0 \geq h_*$, where h_* is defined in Assumption 3. Then $i_h = 0$, $h = (1 - d_2)h_0$ and $p(h) = 1$. Assume that the borrowing constraint does not bind. Then equation (10) implies $c_1 = c_2$, equation (11) implies

$$i_e = (\frac{T\alpha_2 e_0^{\alpha_1}}{1+r})^{\frac{1}{1-\alpha_2}}, \tag{19}$$

and the budget constraint allows us to solve for savings

$$s = -\frac{\kappa}{2+r}(e_0^{\rho} + e_0^{1-\rho}).$$

Assumption 4 ensures that the borrowing constraint is satisfied, hence it does not bind at the optimum. ■

Note that since the borrowing constraint is slack at $h_0 = h_*/(1-d_2)$ it will be slack in a open neighborhood of this point. Hence, though perfect consumption smoothing implies that the borrowing constraint is slack, the reverse is not true and $h_{\max} < h_*/(1-d_2)$.

3 A LIFE-CYCLE MODEL

In this section I will extend the model of the previous section assuming individuals live indefinitely. The value function for an individual with health

h, education e, and asset holding a is given by

$$\begin{aligned}
V(e,h,a) &= \max_{e',h',a'}(u(c)+\delta p(h')V(e',h',a')) && (20)\\
s.t.e' &= (1-d_1)e+e^{\alpha_1}i_e^{\alpha_2}, && (21)\\
h' &= (1-d_2)h+h^{\beta_1}i_h^{\beta_2}, && (22)\\
a' &= (1+r)(a-i_e-i_h)+e' && (23)\\
i_e+i_h &\leq 1 && (24)
\end{aligned}$$

Define an imputed instantaneous utility by

$$W(c,s,e',h')=u(c)+\delta p(h')u(s(1+r)+e'T)$$

The triple of variables (e',h',s) are complements in the instantaneous utility function. This implies that if income effects are small these variables will move in the same direction in response to a change in an exogenous parameter of the model. The income effect will be small if income level is big. Since income increases with education and asset holdings these variables will always move together for an individual with enough assets or for an individual who has attained a high enough level of education.

Assuming (24) does not bind[5], we obtain the system of Euler equations

$$
\begin{aligned}
u'(c_t) &= p(h_t)u'(c_{t+1}) + \lambda_t && (25)\\
u'(c_t) &= T\delta\alpha_2 e_t^{\alpha_1} i_{et}^{\alpha_2 - 1} p(h_t) u'(c_{t+1}) && (26)\\
u'(c_t) &= h_t^{\beta_1}\beta_2 i_{ht}^{\beta_2 - 1} p'(h_t)(u(c_{t+1}) - u(D)) && (27)\\
\lambda_t(s_t - e_t + M) &= 0,\ \lambda_t \geq 0,\ s_t \geq e_t - M. && (28)
\end{aligned}
$$

System (25)-(28) to define policy functions $i_e(h_t, e_t, a_t)$, $i_h(h_t, e_t, a_t)$, $c(h_t, e_t, a_t)$ such that

$$
\begin{aligned}
i_{et} &= i_e(h_t, e_t, a_t), && (29)\\
i_{ht} &= i_h(h_t, e_t, a_t), && (30)\\
c_t &= c(h_t, e_t, a_t). && (31)
\end{aligned}
$$

One readily obtains propositions similar to Propositions 1 and 2.

Proposition 3 *The exists a positive level of initial health* $h_{\min} > 0$ *such that*

[5] In a two-period this constraint will never bind provided the initial asset holding is zero. In Ben-Porath (1967) a similar constraint typically binds for some period at the beginning of life. It happens, because Ben-Porath has a fixed life span and hence the value of an investment in education decreases with time. This period is usually interpretted as schooling.

for any $h_t < h_{\min}$ *the borrowing constraint binds.*

Proposition 4 *There exists an initial stock of health* $h_{\max} > 0$ *such that for any* $h_t > h_{\max}$ *the borrowing constraint is slack. If the borrowing constraint is slack investment in education is independent on the initial stock of health and is given by*

$$i_{et} = \kappa e_t^{\frac{\alpha_1}{1-\alpha_2}}. \tag{32}$$

The proofs verbatim repeat the proofs of Propositions 1 and 2 respectively. At a low level of health the policy functions are approximately given by

$$\begin{aligned}
c_t &= M, &(33)\\
i_{et} &= \left(\frac{T\alpha_2\delta p(h_t)e_t^{\alpha_1}u'(c_2)}{u'(c_1)}\right)^{\frac{1}{1-\alpha_2}}, &(34)\\
i_{ht} &= \left(\frac{\beta_2\delta p'(h_t)h_t^{\beta_1}(u(c_2)-u(D))}{u'(c_1)}\right)^{\frac{1}{1-\beta_2}}. &(35)
\end{aligned}$$

Note that both i_{et} and i_{ht} increase in h_t. This generates a positive correlation between health and education. Though the mechanism is very different than the one for high income individuals, the correlation between health and education in this case is also positive.

Let us study some dynamics of the model. Assume that $e_0 > 0$ and $h_0 > 0$. Then if

$$T(\frac{\kappa}{d_1})^{\frac{\alpha_2}{\rho}} + (1+r)(1 - d_1(\frac{\kappa}{d_1})^{\frac{\alpha_2}{\rho}} - d_2 h_*) \leq (2+r)M. \tag{36}$$

individual's health and education stocks and the consumption level will eventually converge to

$$h^* = h_*,\ e^* = (\frac{\kappa}{d_1})^{\frac{\alpha_2}{\rho}}, c^* = \frac{T(\frac{\kappa}{d_1})^{\frac{\alpha_2}{\rho}} + (1+r)(1 - d_1(\frac{\kappa}{d_1})^{\frac{\alpha_2}{\rho}} - d_2 h_*)}{2+r}. \tag{37}$$

provided she survives long enough. If

$$T(\frac{\kappa}{d_1})^{\frac{\alpha_2}{\rho}} + (1+r)(1 - d_1(\frac{\kappa}{d_1})^{\frac{\alpha_2}{\rho}} - d_2 h_*) > (2+r)M \tag{38}$$

define μ by

$$T(\frac{\kappa\mu}{d_1})^{\frac{\alpha_2}{\rho}} + (1+r)(1 - d_1(\frac{\kappa\mu}{d_1})^{\frac{\alpha_2}{\rho}} - d_2 p^{-1}(\mu)) = (2+r)M. \tag{39}$$

Then (h^*, e^*, c^*) are given by

$$p(h^*) = \mu, \; e^* = (\frac{\kappa\mu}{d_1})^{\frac{\alpha_2}{\rho}}, \tag{40}$$

$$c^* = \frac{T(\frac{\kappa\mu}{d_1})^{\frac{\alpha_2}{\rho}} + (1+r)(1 - d_1(\frac{\kappa\mu}{d_1})^{\frac{\alpha_2}{\rho}} - d_2 p^{-1}(\mu))}{2+r}. \tag{41}$$

Note that when the health level h_* is reached individuals leave forever after it. This result can be relaxed in two ways. First, one may assume that the probability of survival asymptotes to some value smaller then one. Second, it is possible to introduce aging assuming that the depreciation rate of health increases with age. In this case it will become eventually too costly to maintain the health level and the individual will allow it to depreciate.

4 DISCUSSION AND CONCLUSIONS

In this paper I proposed a simple model that allows us to incorporate health-investment decisions into a life-cycle framework. The complementarity between savings, health, and education is created by an insurance motive for the accumulation of health. The model predicts a positive correlation between the health stock, education and savings rate for both high income countries and poor countries. I showed that investments in education are independent of health status for sufficiently high levels of health and increases in health if the health status is low.

Assuming that the growth rate of a country is determined by its education capital, this result suggests an explanation for the observation that the growth rates of LDCs are much more sensitive to health status than is the case for OECD countries. This, in turn, leads to some interesting policy implications. For example, we are used to think that there is a trade-off between economic growth and clean environment. The results of this paper suggest that for LDCs such a trade-off need not exist. Indeed, environmental policy can improve the health status of population, which would result in higher education investment. The positive effect of an increase of education investment on growth rates can out-weight the negative direct effect of the environmental policy.

The model also suggests that the positive correlation between health and education at high levels of income is due to their complementarity in the individual's utility function. It can also be used to study the effect of religious beliefs, as captured by utility of death, on human capital accumulation. It can be readily extended to incorporate social risks coming from a poor environment or crime. One has only to replace $p(h)$ by $q(h) = q_* p(h)$ where

$q_* \leq 1$ is a measure of social risk.

The most important drawback of the model is that is does not allow for aging. Even though it can be done in a straightforward way discussed above, a model becomes much less tractable. Introducing aging in a tractable way represents a considerable challenge, however, I believe that the main conclusions of the paper will survive such an extension.

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