Life Expectancy, Human Capital Formation, and Per-Capita Income

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1. Introduction

A fairly strong positive association exists between per capita income and life expectancy across developing countries.[1] Even though associations do not reveal causality, in this case one explanation of the association is transparent as the association itself: countries that master means and resources to provide more and higher-quality health and health related services end up having longer-lived residents. The possibility that causality runs in exactly the opposite direction, that is, that longer life expectancy translates into higher per capita income is less well recognized. This possibility is taken up in the current paper. Specifically, we study the chain that longer life expectancy encourages larger investments in human capital which in turn facilitates the attainment of higher income per capita. Although in itself this chain is not novel, the proposed microeconomic rationale which underlies the observed macroeconomic relationship is novel.

When education and skills are more abundant, countries produce more. Although the close link between investment in human capital, per capita income, and growth is well documented (e.g., Lucas (1988), Romer (1989), Azariadis and Drazen (1990), Ehrlich and Lui (1991), Mankiw, Romer, and Weil (1992) and Galor and Zeira (1993)) the underlying mechanism is not yet fully understood. Recently, Becker, Murphy, and Tamura (1990) suggested an explanation that draws on the role of fertility behavior: higher fertility is assumed to raise the rate of discount in the intertemporal utility function, thereby discouraging investment in human capital. Just as changes in fertility behavior modify the incentive structure that impinges on investment behavior, holding life expectancy constant, according to our approach changes in life expectancy account for changes in human capital investment, holding fertility behavior constant.

[1] For a group of 75 developing countries in 1989 (World Bank, 1991) the Pearson correlation coefficient between life expectancy and income per capita is 0.7421. The coefficient for the same countries in 1977 (World Bank, 1979) is 0.7567. The change is not significantly different from zero (using conventional levels of significance).

To illustrate how different life expectancies bring about different levels of investment in human capital, consider a world where assets are fully transferred through bequests. If life expectancy is 40, and if a child is capable of making productive use of familial assets at the age of 20, then bequests occur exactly when the child is ready to receive and make a productive use of the assets, assuming that the parent was 20 when the child was born. However, if life expectancy is 70, then, retaining other assumptions as above, the child must wait on average 30 years to receive familial assets. The incentive then for the child to invest in the acquisition of human capital would be greater, provided that both forms of capital enhance earnings.

The links between life expectancy and per capita income, on the one hand, and per capita income and human capital, on the other hand, however modeled, do not convert easily into a causal relationship between life expectancy, human capital formation, and per capita income.[2] In this paper we offer a microeconomic-based model that provides such a relationship – to our knowledge, for the first time. Specifically, we demonstrate that in an economy where life expectancy is long and the transfer to offspring of the familial productive resource – land – takes place late in life, individuals invest more in human capital formation than if life expectancy is short and the parental transfer takes place early in life. Since the timing of the transfer is not known with certainty, a decision to invest in human capital formation must factor in the possibility that acquired human capital will not be used or that it will be used only a little. That is, if the earnings arising from combining labor with a productive physical asset – land – are higher than the earnings arising from assetless application of labor amplified by human capital, the individual will switch from the latter to the former engagement, and this possible shift has to be considered in deciding to acquire human capital. We develop the model to show that the productivity implications arising from human cap-

[2]It is of interest to note that the "Basic Indicators" table in the World Development Reports of the World Bank provides data on only three measures of development: Per-capita income, life expectancy, and adult literacy – a measure of human capital.

ital formation are such that (economy-wide) per capita income is higher when parental life expectancy is longer.

2. The Model

Consider an overlapping-generations economy in which economic activity is conducted over infinite discrete time. In every period t, $t = 0, 1, 2, \ldots,$ the economy produces a single good in two sectors: a nonfarm sector in which the production technology requires efficiency units of labor, and a farm sector that uses land and physical units of labor in the production process.

2.1 Production

2.1.1 The Nonfarm Sector

Production in the nonfarm sector occurs within a period according to a constant returns to scale production technology which is stationary across time. The output of the nonfarm sector produced at time t, Y_t^{nf}, is

$$Y_t^{nf} = f(L_t) = L_t f(1), \tag{1}$$

where L_t is the quantity of labor, measured in efficiency units, employed at time t. The production function $f : \mathbf{R}_+ \rightarrow \mathbf{R}_+$ is twice continuously differentiable, $f'(L_t) > 0$ and $f''(L_t) = 0$ $\forall L_t \geq 0$, and $f(0) = 0$. The market for efficiency units of labor is perfectly competitive. Given constant returns to scale in production the wage rate per efficiency unit of labor is therefore stationary at a level $\overline{w}$, where

$$\overline{w} = f'(L_t) = f(1). \tag{2}$$

2.1.2. The Farm Sector

Production in the farm sector occurs within a period and allows individuals who own a unit of land to combine it with their own physical unit of labor to produce $\tilde{y}$ units of output (regardless of the number of efficiency units embodied in this unit of physical labor).[3] The marginal productivity of an additional unit of labor is lower than that in the nonfarm sector. Furthermore, land changes hands only through intra-familial, intergenerational transfers.

2.2 Consumption and Investment in Human Capital

In every period t a generation is born. A generation consists of a continuum of individuals of measure N.[4] Each member of generation t has a single parent in generation $t-1$ and each parent of generation $t-1$ has a single offspring in generation t. The economy consists, therefore, of a continuum of dynasties of measure N. Each dynasty is endowed with a unit of land that is transferred across generations. By the existing social code land is transferred from parent to child upon the death of the parent.

The duration of life is uncertain. Individuals may live either two or three periods. They face a probability $\alpha \in [0,1)$ of dying at the end of the second period. If they survive, with probability of $(1-\alpha)$, they die at the end of the third period. Population size is thus $N + N + N(1-\alpha) = N(3-\alpha)$.

Individuals of generation t are characterized by their intertemporal utility func-

[3] This simplification is not essential for our results; we can allow for $\tilde{y}$ to be somewhat sensitive to coupling with human capital. For four developing countries for which comparable evidence is available, the effect of an additional year of schooling on both wages and farm output is positive, although the percentage increase in wages is 3 to 5 2/3 times the percentage increase in farm output, with the former being as high as 17 percent (World Bank (1991), Table 3.2).

[4] For simplicity, there is no population growth. The qualitative nature of the analysis will not be affected by allowing nonzero population growth.

tion defined over consumption in the three periods of their life.

$$U^t = \sum_{i=1}^{3} \beta^{i-1} u(c_i^t) \tag{3}$$

where $\beta < 1$ is the individual's discount factor and

$$u'(c) > 0 \text{ and } u''(c) \leq 0 \ \ \forall c \geq 0; \ u(0) > -\infty. \tag{4}$$

Thus, $u : \mathbf{R}_+ \rightarrow \mathbf{R}$ is strictly monotonic increasing, concave, and bounded from below. Furthermore, it satisfies the expected utility axioms.

In the first period of their lifetime (youth), individuals of generation t are endowed with a unit of labor but with no land. Individuals allocate their unit endowment of labor between work in the nonfarm sector at the competitive market wage $\overline{w}$ and investment in human capital. Given the absence of capital markets or the availability of storage technology, individuals consume their entire wage income in the first period. Thus, the first period consumption of a member of generation t is $c_1^t = \overline{w}\ell$, where $\ell \in [0,1]$ is the proportion of the unit endowment of labor that an individual chooses to allocate to work, and $(1-\ell)$ is therefore the proportion allocated to investment in human capital. The amount of human capital, h, (measured in efficiency units of labor that are available for usage in the second period of the individual's lifetime) generated by this investment in human capital is

$$h = \phi(1-\ell) \tag{5}$$

where

$$\phi(0) = 1, \ \phi(1-\ell) > 1, \ \phi'(1-\ell) > 0 \text{ and } \phi''(1-\ell) < 0 \quad \forall \ell \in (0,1). \tag{6}$$

Thus, if investment in human capital does not take place (i.e., $(1-\ell) = 0$) the number of efficiency units available for the individual in the second period is equal to the initial endowment of 1. Otherwise, the number of efficiency units available in the second period is increasing in the level of investment in human capital, but at a decreasing rate.[5] Furthermore,

$$\lim_{\ell \to 1} \phi'(1-\ell) = \infty \quad \text{and} \quad \lim_{\ell \to 0} \phi'(1-\ell) = 0. \tag{7}$$

In the second period of their lifetime (middle age) individuals of generation t are endowed with $\phi(1-\ell)$ efficiency units of labor, and with probability $\alpha \in [0,1)$ (i.e., in case of a parent's death at the end of the second period of the parent's lifetime) with a unit of land. If the parent does not die and consequently no land inheritance is obtained, individuals supply inelastically their efficiency units of labor, generating a wage income of $\overline{w}\phi(1-\ell)$. This wage income is subsequently consumed. However, if the parent does die, the individual inherits a unit of land. Individuals, therefore, may utilize the technology which combines a unit of land and a physical unit of labor to produce $\tilde{y}$ units of output. Since transfer of the property rights to land is not allowed, this technology will be employed as long as $\tilde{y} > \overline{w}\phi(1-\ell)$.[6] Suppose that this inequality indeed holds and that the distribution of earnings is fairly compact, that is,

$$\tilde{y} = \overline{w}\phi(1-\ell) + \epsilon, \tag{8}$$

where $\epsilon > 0$ is sufficiently small. It follows that regardless of the level of investment in human capital individuals who inherit land find it beneficial to utilize the traditional technology and to produce $\tilde{y}$ units of output which is subsequently consumed. Thus, second period consumption of an individual of generation t, c_2^t, is

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[5]Direct outlays in connection with human capital investment are disregarded. The investment costs consist only of foregone earnings.

[6]The qualitative nature of the analysis will not be affected if the land can be rented as long as $\tilde{y} > \overline{w}\phi(1-\ell)$ + land rent, namely, as long as the owner of the land is significantly more productive than potential renters in cultivating the land. Rosenzweig and Wolpin (1985) provide strong evidence that such productivity differentials do exist.

$$c_2^t = \begin{cases} \overline{w}\phi(1-\ell) & \text{with probability } 1-\alpha \\ \tilde{y} & \text{with probability } \alpha. \end{cases} \tag{9}$$

Individuals reach the third period of their lifetime with probability $(1-\alpha)$. At that time they are endowed with a unit of land (inherited from the deceased parent) and with $\phi(1-\ell)$ efficiency units of labor. Given (8), individuals in this case employ the traditional technology which generates $\tilde{y}$ units of output that is subsequently consumed. Thus, $c_3^t = \tilde{y}$.

Individuals allocate their first-period endowment of labor between work and investment in human capital so as to maximize their expected utility from consumption. Thus,

$$\ell(\alpha) \;=\; argmax\{u(\overline{w}\ell) + \beta\{(1-\alpha)u[\overline{w}\phi(1-\ell)] + \alpha u(\tilde{y})\} + \beta^2(1-\alpha)u(\tilde{y})\}. \tag{10}$$

Given the properties of the ϕ function as stated in (6) and (7), and since $\alpha \in [0,1)$, the solution to (10) is interior (that is, the level of investment in human capital $(1-\ell) \in (0,1)$) and is given by the first-order condition

$$(1-\alpha)\phi'(1-\ell) = \frac{u'(\overline{w}\ell)}{\beta u'[\overline{w}\phi(1-\ell)]}. \tag{11}$$

Proposition 1. *Under (4), (6), and (7), an increase in the parent's life expectancy increases the investment in human capital by the child (that is,* $\partial(1-\ell)/\partial(1-\alpha) > 0 \;\; \forall \ell \in (0,1)$*).*

Proof: See Appendix. □

2.3 Stationary Output

In every period t, each young individual supplies ℓ efficiency units of labor to the nonfarm sector. In addition, with probability $(1-\alpha)$, each middle-aged individual supplies $\phi(1-\ell)$ efficiency units of labor to this sector. Thus, the aggregate supply of labor to the nonfarm sector in efficiency units, L_t, is

$$L_t = [\ell + (1-\alpha)\phi(1-\ell)]N. \tag{12}$$

Given (1), the output produced in the nonfarm sector is $Y_t^{nf} = L_t f(1)$. The output produced in the farm sector at time t is $Y_t^f = \tilde{y}N$. The aggregate output produced in the economy at time t, Y_t, is therefore stationary at a level $\hat{Y}$, where

$$\hat{Y} = \hat{Y}^{nf} + \hat{Y}^f = \{[\ell + (1-\alpha)\phi(1-\ell)]f(1) + \tilde{y}\}N. \tag{13}$$

Given that the population size is $(3-\alpha)N$, the per-capita aggregate output, $\hat{y}$, is

$$\hat{y} = \frac{[\ell + (1-\alpha)\phi(1-\ell)]f(1) + \tilde{y}}{3-\alpha}. \tag{14}$$

Thus, the following results can be derived:

Proposition 2. *Under (4), (6) - (8), an increase in life expectancy increases the stationary per-capita output in the economy (that is, $\partial\hat{y}/\partial(1-\alpha) > 0$).*

Proof: See Appendix. □

Corollary. *Consider a world that consists of countries which are identical in all respects except for the life expectancy of their populations. Under (4), (6) - (8), the per-capita income is higher in countries in which life expectancy is longer.*

As follows from (13), (14) and (A2), aggregate as well as the per-capita output in the nonfarm sector increases with life expectancy. The aggregate output in the farm sector is constant, however, given the constant supply of land. Furthermore, since an increase in life expectancy increases the number of individuals in the economy at any point in time, in per-capita terms the output in the farm sector decreases with life expectancy. Thus, the proposition holds as long as the increase in the per-capita output in the nonfarm sector outweighs the decrease in the per-capita output in the farm sector. As follows from (A2), if (8) is not satisfied proposition 2 and the corollary are less likely to hold the larger the share of farm output in total output.

4. Summary, Implications, and Predictions

Human capital theory predicts that, holding all else constant, a longer life expectancy encourages individuals to invest more in human capital formation because of the prolongation of the payoff period. Our model expands the human capital framework to incorporate the case where the prolongation of life expectancy of cohort t induces more human capital formation by cohort $t+1$ because of the resulting postponement of the transfer of familial productive assets. We prove that as a consequence, per capita income in the economy with the longer-lived generation t is higher.

The model expands the human capital framework in yet another way: the acquisition of human capital serves not only as a means of enhancing productivity but also as a form of insurance. In the event that land will not be transferred in the second period, earnings are guaranteed to be higher than those that would have accrued to bare labor.

The analysis helps explain a number of stylized facts. Several empirical studies point to absence of a trend toward equality across countries except among the subset of the very wealthy countries (Romer (1986, 1989) and Lucas (1988)). One reason for this nonconvergence could be that poor economies are locked in an incentive structure that operates to discourage human capital formation. And low levels of human capital formation translate into low levels of per-capita income. If human capital not only enhances the productivity of those who accumulate it but also confers *external* benefits on the productivity of others, economies that form large quantities of human capital will increasingly distance themselves from economies that form small quantities. Income equality may not come about simply in the natural course of events. Our model thus predicts that as long as disparities in life expectancy across countries exist, disparities in the levels of per-capita income between countries will exist as well. Evidence suggesting that some converges does occur (e.g., Barro (1991), Barro and Sala-i-Martin (1992), and Mankiw, Romer and Weil (1992)) is not inconsistent with our model, however. If life expectancy is endogenized, then convergence in life expectancy *may* take place and lead, in conjunction with other factors, to convergence in per-capita income.

The model may hint at an interesting association between the behavior of parents, the well-being of their children, and social welfare. Especially if children cannot borrow against expected terminal assets, the timing of the transfer of parental wealth impinges not only on their behavior toward their parents but apparently also on allocative decisions. This, in turn, affects the children's own well-being, and hence the well-being of society. A social rationale for the postponement of the transfer of familial resources to the time of death – or very close to that time – may thus be that this pattern results in a higher per-capita output. Our model may then be read "inside out"; if a society were to adopt a rule of conduct as assumed, would it be better off in the long run in comparison to a society that pursues an alternative norm? The apparent advantage of postponing the timing of intergenerational transfers may explain the evolution and sustainability of a social code that so mandates.

In the 60's and 70's, the Moshav movement in Israel prohibited breaking up family plots. Consequently one child, usually the elder son, inherited the family farm. Whereas typically the heir-designate did not acquire a college or university degree, the other children did. For them, the low probability of receipt of the family land (an event which could have taken place had the elder son died prematurely) served as an inducement to acquire other earning-enhancing capital. This pattern mimics the experience of European societies in the middle ages in which military activity was a means to secure wealth. In England, for example, under the institution of primogeniture – the exclusive right of the eldest son to inherit his father's estate – *younger* sons who declined to become clergymen had to resort to the art of warfare as the only socially acceptable means to make their fortunes. Baumol (1990) reports that in a good many cases this resulted in spectacular success and quotes the case of "William Marshal, fourth son of a minor noble, who rose through his military accomplishments to be one of the most powerful and trusted officials under Henry II and Richard I, and became one of the wealthiest men in England."

Prior to listing a number of testable implications, we consider two issues that could work against our approach. First, we have assumed a constant fertility behavior. Yet parents may offset the effect of their anticipated prolonged life by delaying childbearing so that the familial pool of work-years is unchanged. A child born in this adaptive state will then face exactly the same planning horizon and thereby the same incentive structure as a child born in the early years of a short parental life expectancy. Consequently, our model will not bite. We know though of no fertility model nor any empirical study that predicts or produces such possible full adjustment. And if anything less than full adjustment takes place, our sign hypothesis clearly remains unchanged. Moreover, in the present paper we model the behavior of the offspring, not the parent. Endogenization of fertility decisions mandates a different modeling approach (possibly a bargaining game framework) where *both* child and parent optimize. Future work may nonetheless expand beyond our framework by tracing the implications arising from cases with more than one child per parent, and cases in which parents' life expectancy affect the number of children in the family and possibly the timing of the birth of the children.

Second, if the extra years arising from prolonged life expectancy accrue at older ages and if, therefore, these years do not fully translate into extra work-years on the farm, enhanced longevity will result in only a partial postponement of the transfer of the family land to the offspring. Only in the unlikely case that prolonged life leads to no additional work-years will our effect possibly wash out. We say possibly because longer-lived parents control their land longer. Thus, relinquishing title to their offspring at some transfer price prior to their death is, incentive-wise, equivalent to a delayed transfer.

Our model gives rise to several testable predictions. One such prediction is that the parental life expectancy effect has a positive impact on the level of the investment in human capital undertaken by the children, an effect which is separate from the one arising from the prolongation of life of the children themselves (the children's life expectancy effect). The empirical difficulty here is that children who observe a longer life expectancy of their parents may infer that their own life expectancy would also be longer, so that their human capital investment decisions may be fully explained by the traditional human capital framework. To overcome this difficulty, though, we can think of a situation where the life expectancy of the parents rises while that of the children falls, yet human capital formation by the children is larger. Such an outcome can only arise from the operation of the parental life expectancy effect since the negative children's life expectancy effect implies reduced investment in human capital by the children. We can likewise think of a situation where the life expectancy of the parents falls, that of the children rises, yet investment in human capital by the children declines. Any one of these scenarios then could provide a discriminating test between our model and the traditional human capital model.

More concretely though, our model predicts that in a country such as India, where typically daughters do not inherit the family's land but sons do, a rising life expectancy of the parents – even if interpreted by the children as a signal that their own life expectancy will be longer – has a stronger effect on human capital formation by boys (two effects are operative) than by girls. Furthermore, consider the case of societies characterized by "perfect primogeniture" – the eldest son receiving all the bequest. Since all other children are then immune to the timing of transfer, their human capital investment behavior will not be sensitive to a change in the life expectancy of the parent. Thus, if the life expectancy of the parent rises then, again, even if all children were to infer that their own life expectancy will be longer, human capital investment by the eldest child will increase by more than will human capital investment by the other children.

The number of individuals who either engage in human capital formation or work in the nonfarm sector is an increasing function of life expectancy.[7] Suppose these activities are carried out in the urban economy. Then, a prediction of the model is that longer life expectancy is positively correlated with the porportion of the population residing off the farm.

Finally, the procedure employed in the construction of our model gives rise to the following testable prediction: the higher the share of the farm sector in total output, the smaller the impact of life expectancy on per-capita output.

[7]Since N out of the $(3-\alpha)N$ members of the population are tilling the N farms, for the remainder $(2-\alpha)N$, $\partial[(2-\alpha)N]/\partial\alpha < 0$.

Appendix

Proof of Proposition 1. Using the implicit function theorem, it follows from (11) that

$$\frac{\partial \ell}{\partial \alpha} = \frac{-\beta u'[\overline{w}\phi(1-\ell)]\phi'(1-\ell)}{\overline{w}u''(\overline{w}\ell) + \beta(1-\alpha)\{u''[\overline{w}\phi(1-\ell)]\overline{w}[\phi'(1-\ell)]^2 + u'[\overline{w}\phi(1-\ell)]\phi''(1-\ell)\}} \tag{A1}$$

Noting (4), (6) and (7), the proposition follows. □

Proof of Proposition 2. Using (14),

$$\frac{\partial \hat{y}}{\partial \alpha} = \frac{\{[1-(1-\alpha)\phi'(1-\ell)]\frac{\partial \ell}{\partial \alpha} - \phi(1-\ell)\}(3-\alpha)f(1) + \{[\ell + (1-\alpha)\phi(1-\ell)]f(1) + \bar{y}\}}{(3-\alpha)^2}, \tag{A2}$$

$$= \frac{[1-(1-\alpha)\phi'(1-\ell)]\frac{\partial \ell}{\partial \alpha}(3-\alpha)f(1) - [\phi(1-\ell)f(1) - \bar{y}] - [\phi(1-\ell) - \ell]f(1)}{(3-\alpha)^2}.$$

As follows from (6) $\phi(1-\ell) > 1 > \ell \quad \forall \ell \in (0,1)$. Furthermore, $(1-\alpha)\phi'(1-\ell) > 1$ as follows from (11), (4) and (6), and $\phi(1-\ell)f(1) = \phi(1-\ell)\overline{w} = \bar{y} - \epsilon$, where $\epsilon > 0$ is sufficiently small, as follows from (2) and (8). Thus, noting (A2) and Proposition 1, the proposition follows. □

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