Does Longevity Cause Growth? A Theoretical Critique*

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Abstract

This paper challenges conventional wisdom by arguing that greater longevity may have contributed less than previously thought for the significant accumulation of human capital during the transition from stagnation to growth. This is because when parents make choices over the quantity and quality of their offspring, greater longevity positively affects not only the returns to quality but also the returns to quantity, leaving the relative return between quality and quantity unaffected. This paper also provides evidence that despite gains in longevity, the lifetime labor input of individuals has been declining, at least since the mid nineteenth century. Hence, the mechanism that stresses the impact of a longer horizon over which investment in education is paid off is inconsistent with this evidence. Finally, in contrast to longevity, improvements in health can generate quantity-quality tradeoff and hence the paper shows the importance of controlling for fertility when empirically examining the impact of children's health on their education.

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1 Introduction

Recent studies have focused on the role of longevity in explaining economic growth through investment in education. These studies have utilized the mechanism of the seminal work of Yoram Ben-Porath (1967), according to which prolonging the period in which individuals may receive returns on their investment spurs investment in human capital (Soares 2005, Cervellati and Sunde 2005).[1] Given the historical relationship among longevity, education, and per-capita output, which have been increasing simultaneously and monotonically since the middle of nineteenth century, it is appealing to suggest that causality runs from longevity to growth through education. This literature, however, has assumed that individuals invest in their own human capital.[2]

Prior to the second half of the nineteenth century, however, education was not widespread. In England, the average years of schooling of the cohort born between 1801-1805 was 2.3 years and rose to 5.2 years for the cohort born between 1852-56 (Matthews, Feinstein and Odling-Smee 1982). Similar patterns are observed for other European countries and the US.[3] Furthermore, the high rates of child labor in Europe and the US during the nineteenth century, suggest that parents have had much control over the allocation of their children's time.[4] Hence, at that period, a more reasonable framework would be one in which education choices are made by parents.[5]

Our paper shows that the Ben-Porath (1967) mechanism is less robust than it seems. Moving the decision on education from the individual herself to her parents changes the way households conceive the role of education. When individu-

[1] See also de la Croix and Licandro (1999), Kalemli-Ozcan, Ryder and Weil (2000), Boucekkine, de la Croix and Licandro (2002, 2003), among others.

[2] In Soares (2005) parents invest in their children's human capital as well as in their own. We compare his work to ours below.

[3] See Flora, Kraus and Pfenning (1983) for Europe and US Bureau of the Census (1975) for the US.

[4] See Basu (1999) and the references therein. All the empirical literature that investigate the phenomenon of child labor, either in the past of the nowadays developed economies or in contemporary developing economies, assumes that parents allocate the time of their children between child labor and schooling.

[5] This is not to say that individuals do not invest in their own human capital. However, we argue that the major part of investment in human capital at that time was done by parents.

als choose their own level of education, they do so in order to maximize lifetime utility from consumption, i.e., they conceive education as an investment good. However, when parents choose the level of education of their children, they conceive the education of their children as a consumption good, as parents enjoy seeing their children educated. Since the utility function of the parents exhibits some degree of substitutability among all consumption goods, it is not necessary that an increase in the longevity of the children induces parents to choose more education for their children.[6]

Moreover, parents do not choose the level of education of their children solely, but in combination with fertility choice. Indeed, the vast majority of the literature that emphasizes the role of human capital as the prime cause for the transition from stagnation to growth have assumed such a framework.[7] Within this framework, several papers have conjectured that the Ben-Porath mechanism would remain valid. In particular, Galor and Weil (1999) write,

> A fall in mortality, raises the rate of return on investments in child's human capital and thus can induce households to make quality-quantity trade-offs. (p. 153)

Similarly, Kalemli-Ozcan et al. (2000) have modeled the relationship among life expectancy and human capital by assuming that individuals invest in their own human capital. Yet, they conjecture,

> In a more complex model, education choices would be made by parents who maximize an intergenerational utility function, and choices over education would be integrated with the fertility decision. The key effect on which we focus − that increasing life expectancy would raise the period over which investments in schooling are paid off, and thus raise the optimal quantity of schooling would still be present in such a model. (p. 4)

[6]In section 2.1 we formally derive the conditions under which the Ben-Porath (1967) mechanism holds in the framework in which parents choose the level of education of their children.

[7]See Becker, Murphy and Tamura (1990), Ehrlich and Lui (1991), Galor and Weil (2000), Galor and Moav (2002), Greenwood and Seshadri (2002), Hazan and Berdugo (2002), Lucas (2002), Doepke (2004), Doepke and Zilibotti (2005), among others.

Our paper shows that this intuition is misleading and that the Ben-Porath mechanism may fail to hold once parents make choices over education and fertility. An important contribution of the paper is to point out that greater longevity of children increases not only the returns to eduction but also the returns to fertility as each child lives longer. We show that if parental preferences are defined over the full income of their children, as in Galor and Weil (2000), an increase in children's longevity increases each child's income proportionally, irrespective of her level of education. Thus, it does not change the relative return between education (quality) and fertility (quantity) and, hence, does not cause any increase in the level of education chosen by the parents.[8] We call this the "neutrality result."

The question mark on the Ben-Porath (1967) mechanism is strengthened by a careful examination of the data. In particular, this mechanism implies that as individuals live longer, their total labor input over their lifetime increases. Hazan (2006) estimates the expected working hours over the lifetime of nine consecutive cohorts of American men born between 1840 and 1920. He assumes that individuals calculate their expectations at age 5, the age at which formal education begins, under the assumption that the age of entry to the labor market is 20 years old.[9] His results, presented in figure 1, show that despite a gain of nearly 13 years in the expectations of life at age 5 (51.67 for the oldest cohort, vs. 64.55 for the youngest cohort), the expected working hours over the lifetime have declined from nearly 108,000 hours to less than 87,000 between the oldest and the youngest cohorts, a decline of more than 20 percent in total labor input. Hence we argue that the Ben-Porath (1967) mechanism fails to meet its necessary condition.

Ehrlich and Lui (1991) and Soares (2005) explore the effect of longevity on growth via investment in education in models where fertility is endogenous. In Ehrlich and Lui (1991), the optimal number of surviving children is the minimum that one can obtain, which they assume to be one. As the surviving probability of children increases, the required number of births decreases to assure one survivor

[8] Moav (2005) discusses this result without formalizing it.

[9] Note that this assumption introduces a *downward* bias if the average age of entry to the labor market is less than 20 years old. Since average age of entry to the labor market was well below 20 for most of the cohorts at study and has been increasing over time, Hazan (2006) *underestimates* the change in total labor input across the cohorts.

child. The resources freed are allocated to all normal goods, among them consumption at old age. Since the later is provided by the survivor child, the parent increases the investment in the eduction of her child. In Soares (2005) longevity affects investment in eduction via three channels. First, since individuals invest in their own human capital, gains in longevity induce higher investment in education as in the classic mechanism of Ben-Porath. Second, as parents become more educated they also become more productive in educating their children. Finally, Soares assumes that as children's longevity increases, the elasticity of altruism with respect to quantity decreases and therefore parents reduce fertility. The freed resources may be channelled to children's education.

Formal evidence on the casual effect of longevity on growth in general and on fertility and education in particular is given by two recent papers by Acemoglu and Johnson (2005), and Lorentzen, McMillan and Wacziarg (2005). Acemoglu and Johnson (2005) build an instrument for life expectancy using the pre-intervention distribution of mortality from various diseases around the world and the dates of global health interventions that began in the 1940s. Interestingly, Acemoglu and Johnson (2005) find a positive effect of life expectancy on fertility and no effect of life expectancy on schooling. Lorentzen et al. (2005) pursue a structural econometric approach to explore the effect of adult mortality on economic development. In contrast to Acemoglu and Johnson (2005), they find that adult mortality positively affect fertility. Nonetheless, they too find that "human-capital investments, as measured by enrollment levels, do not seem to play a substantial role" (p. 28).

The discussion above weakens the argument that longevity have had a positive effect on the acquisition of human capital during the transition from stagnation to growth. However, the strong positive correlation among the two variables suggests that there might have been a third variable that has affected both education and longevity. One such variable may be health.[10] Health as a determinant of growth has been analyzed in two strands in the literature. The first strand as-

[10]Although longevity and health have been used by the empirical literature interchangeably, at the theoretical level they are differentiated because longevity measures the length of life while health measures one's physiological condition at a given point in time. In the context of this paper, longevity measures the length of productive life whereas health measures labor productivity per unit of time.

sesses the direct effect of health on productivity. Seminal contributions are Fogel (1994) and Shastry and Weil (2003).[11] The second strand is closer to our argument as it assesses the indirect effect of health on income through education. Alderman, Behrman, Lavy and Menon (2001), Bleakley (2003), Miguel and Kremer (2004) and Behrman and Rosenzweig (2004) estimate the impact of health on education. Most of this literature finds positive causal effect running from health to education. Closest to our argument comes the paper by Bleakley and Lange (2005) that finds that the eradication of hookworm disease in the American South circa 1910 led to an increase in school attendance and literacy rates, substantial gains in income and a reduction in fertility.

We incorporate health into the model by assuming that it joins education as an input in the production of human capital. We assume that the production function exhibits positive and decreasing marginal product in health and education and that the two inputs are complements. A naïve conclusion would be that the complementarity assumption is sufficient to assure that improvements in health would increase the investment in quality. Health improvements, however, not only increase the return on quality but also raise the level of human capital, i.e., the return on quantity. Consequently, the optimal level of education will rise only if the return on quality increases by more than the return on quantity. Specifically, this would be the case if the degree of complementarity between health and education is sufficiently high. Although the effect of health improvements on schooling is an empirical matter, our contribution here is to show the importance of controlling for fertility choice when empirically investigating this question. Notably, all of the aforementioned papers have ignored the endogeneity of fertility but Bleakley and Lange (2005) who explicitly examine the effect of health improvement on education and fertility.

Finally, our analysis suggests a plausible explanation for the observed positive

[11] Fogel (1994) estimates the increase in energy available to the British population between 1790 and 1980 and argues that the increase in caloric intake boosted labor-force participation and the intensity of work per hour. Fogel traces roughly one-third of per-capita income growth in England during that period to this increase in labor input. Similarly, using current cross-country data, Shastry and Weil (2003) estimate the direct contribution of health to cross-country differences in per-capita output and find that health may account for one-third of the variation that is left unexplained by other measures of factor accumulation.

correlation among longevity and education. Indeed, if the improvements in children's health affect the returns to quality by more than the returns to quantity, then our theory suggests a causal effect, running from better health to higher investment in education. At the same time, evidence suggests that better health at childhood promotes longer life (Costa and Steckel 1997).

The rest of the paper is organized as follows. Section 2 formalizes our arguments, Section 3 portrays the evolution of the economy along the transition form stagnation to growth, building on the economic relations presented in section 2. Section 4 presents some concluding remarks.

2 The Model

The model consists of two periods, t and $t+1$, and there is no discounting of the future by any agent. It is assumed that a representative adult possesses linear technology, making marginal productivity constant and is set equal to 1. At the beginning of period t, she decides how much to consume, c_t, how many children to have, n_t, and how much education to give each child, e_{t+1}. The adult lives a fraction π_t of period t and is endowed with h_t units of human capital. Thus, she divides her full income, between childraising and consumption.[12]

Let $\tau + e_{t+1}$ be the time cost for an adult of producing a child with education level e_{t+1}. That is, τ is the time needed to raise a child irrespective of quality and e_{t+1} is the time devoted to each child's education. Hence, the time-cost of raising n_t children at education level e_{t+1} is $(\tau + e_{t+1})n_t$. In period $t+1$, each child becomes an adult who lives a fraction π_{t+1} of the period.

Each level of education is translated into human capital according to the production function $h(e)$, where $h(\cdot)$ is assumed to be twice continuously differentiable, strictly increasing, and strictly concave.

[12]Kalemli-Ozcan (2002) argues that when there is a precautionary demand for children, declining child mortality-another important aspect of increase in life expectancy-may have a strong negative effect on fertility and a positive effect on education. Doepke (2005) shows quantitatively that the incorporation of sequential fertility choice eliminates the impact of the decline in child mortality on fertility. We abstract from uncertainty in order to focus on the (deterministic) effect of longer productive lives of children on the decisions of their parents.

Parental utility is denoted by $W_t = W(c_t, n_t\pi_{t+1}h(e_{t+1}))$, i.e., the parent's preferences are defined over household consumption as well as the full income of her offspring. Following Becker (1991), we assume that W_t is separable. Thus:

$$W_t = U(c_t) + V(n_t\pi_{t+1}h(e_{t+1})) \tag{1}$$

where U and V are both twice continuously differentiable, strictly increasing, and strictly concave.[13]

The adult in period t faces the following budget constraint:

$$\pi_t h_t = c_t + (\tau + e_{t+1})n_t h_t \tag{2}$$

2.1 Longevity and Exogenous Fertility

In order to examine the mechanism proposed in Ben-Porath (1967) in a framework in which the parent chooses the level of education of her children, we assume in this section that fertility is exogenous. To simplify, we set $n_t = 1$. Maximizing (1) with respect to (2) yields the following first-order condition:[14]

$$U'(c_t)h_t = V'(\pi_{t+1}h(e_{t+1}))\pi_{t+1}h'(e_{t+1}) \tag{3}$$

The left-hand side (henceforth: LHS) of (3) is the marginal cost of educating a child, measured in terms of the loss of utility from foregone consumption, and the right-hand side (henceforth: RHS) of (3) is the marginal utility of educating a child in terms of the utility gain from an increase in the child's full income. Note that the LHS of (3) is continuously increasing in e_{t+1} while the RHS of (3) is continuously decreasing in e_{t+1}. We assume the existence of an interior solution, denoted by e^*_{t+1}, that satisfies (3).

The LHS of (3) is independent of the longevity of the child, π_{t+1}, whereas the RHS of (3) may decrease, increase, or be independent of π_{t+1}. Note that the RHS of (3)

[13] Note that nothing hinges on the separability of U and V.

[14] To highlight the role of longevity, we focus on an interior solution for e throughout section 2.

is composed of two elements. The first element, $V'(\pi_{t+1}h(e_{t+1}))$, is the marginal utility that a parent derives from the child's full income. The second element, $\pi_{t+1}h'(e_{t+1})$, is the change in the child's full income for a marginal increase in education as life prolongs. Since the two elements act in opposite directions, the Ben-Porath mechanism is not robust to the assumption who chooses the optimal level of education. The rationale is that when individuals choose their own level of education, they do so in order to maximize lifetime utility from consumption, i.e., they conceive education as an investment good. However, when parents choose the level of education of their children, they conceive the education of their children as a consumption good, as parents enjoy seeing their children educated. Since the utility function of the parents exhibits some degree of substitutability among all consumption goods, it is not necessary that an increase in the longevity of the children induces parents to choose more education for their children.

Therefore, an increase in the longevity of the child has a positive effect on education if and only if:

$$-V''(\pi_{t+1}h(e_{t+1}))\frac{(\pi_{t+1}h(e_{t+1}))}{V'((\pi_{t+1}h(e_{t+1}))} < 1.^{15} \tag{4}$$

This elicits the following proposition:

Proposition 1 *"The Modified Ben-Porath Mechanism." When fertility is exogenous, an increase in children's longevity increases the optimal educational level if and only if Inequality* (4) *holds.*

2.2 Longevity and Endogenous Fertility

By treating education and fertility as a parental choice, we obtain the following first-order conditions:

[15] Note that the LHS of Inequality (4) is the elasticity of $V'(\cdot)$ with respect to $\pi_{t+1}h(\cdot)$. Therefore, Inequality (4) implies that the percentage change in $\pi_{t+1}h(\cdot)$ is greater than that of $V'(\cdot)$ for a marginal increase in education. For example, the CRRA utility function, $W_t = \frac{1}{1-\gamma}c_t^{1-\gamma} + \frac{1}{1-\gamma}(\pi_{t+1}h(e_{t+1}))^{1-\gamma}$ with $\gamma < 1$ satisfies Inequality (4).

$$U'(c_t)n_t h_t = V'(n_t\pi_{t+1}h(e_{t+1}))n_t\pi_{t+1}h'(e_{t+1}) \tag{5}$$

and

$$U'(c_t)(\tau + e_{t+1})h_t = V'(n_t\pi_{t+1}h(e_{t+1}))\pi_{t+1}h(e_{t+1}) \tag{6}$$

Note that (5) resembles (3) except that fertility is endogenous. The LHS of (6) is the marginal cost of children, measured in the utility loss from foregone consumption, and RHS of (6) is the marginal utility from children, measured in the utility gain from an increase in the children's full income. Solving (5) and (6) yields:

$$\frac{1}{\tau + e_{t+1}} = \frac{h'(e_{t+1})}{h(e_{t+1})} \tag{7}$$

where the LHS of (7) is the relative price of education in terms of fertility and the RHS of (7) is the marginal rate of substitution between education and fertility. Note that the marginal rate of substitution between education and fertility is independent of children's longevity because longevity has a symmetrical effect on the marginal utility from fertility and the marginal utility from education. This leads us to the following proposition:

Proposition 2 *"The Neutrality Result." When fertility is endogenous, an increase in children's longevity has no effect on the optimal level of education.*

Proposition 2 suggests that the positive effect of the prolongation of productive life on the acquisition of human capital obtained in growth models is dependent either on the assumption that fertility is exogenous when inequality (4) holds, or on non-homothetic preferences of parents.[16] Notice that even if parental preferences are non-homothetic, the neutrality result suggests that quantitatively, the

[16] The result derived here relies on the homothetic preferences of parents with respect to the quantity and quality of their children. Specifically, we could rewrite the utility function as $W_t = U(c_t) + V(\pi_{t+1}n_t, \pi_{t+1}h(e_{t+1}))$. If (V_1/V_2) is independent of π_{t+1} the neutrality result follows.

effect of greater longevity is less than previously emphasized in the literature. This is because the literature has ignored the positive effect of longevity on the returns to quantity. Increases in longevity may also affect the wage profile over the life cycle. A well known fact from the labor literature is that labor earnings over the life cycle are hump-shaped. In contrast, for simplicity, our model assumes that wages are constant over the life cycle. Notice, however, that as long as wages increase proportionally over the life cycle for all levels of education, our analysis remains valid.[17]

2.3 Health and Endogenous Fertility

In this part we examine whether improvements in health can account for the accumulation of human capital. In view of the evidence surveyed in the Introduction, the most general way to incorporate health into our analysis is to assume that health is an input in the production of human capital. Technically, $h = h(e_{t+1}, \theta_{t+1})$ where θ_{t+1} is the level of health of each child and $h(e_{t+1}, \theta_{t+1})$ is an increasing and strictly concave function of both arguments. Furthermore, we assume that education and health are complements in the production of human capital, i.e., $h_{e\theta}(e_{t+1}, \theta_{t+1}) > 0$. By solving the maximization problem in section 2.2 with the modified human-capital production function, we obtain:

$$\frac{1}{\tau + e_{t+1}} = \frac{h_e(e_{t+1}, \theta_{t+1})}{h(e_{t+1}, \theta_{t+1})} \tag{8}$$

Note that for a given value for θ_{t+1}, (8) has a unique solution for e_{t+1}. Inspection of the solution suggests another counterintuitive result. While one may think that the complementarity of health and education suffices to ensure that improvements in health will tip the coin in favor of quality at the expense of quantity, this is not necessarily so. Inspection of the RHS of (8) suggests that although improvement in health increases the marginal return on quality, it also increases the marginal return on quantity. Thus, the marginal rate of substitution between the

[17] Formally, suppose one posits the following Mincer wage regression: $lnw_i = \alpha_0 + \alpha_1 schooling_i + \alpha_2 age_i + \alpha_3 age_i^2 + \alpha_4(schooling_i \cdot age_i) + \epsilon_i$. As long as $\alpha_4 = 0$, the neutrality result holds.

two may increase, decrease, or remain unchanged. Thus, our theory shows the importance of controlling for fertility when empirically examining the impact of health on education.

Formally, health improvements will have a positive effect on education investment if and only if:

$$\frac{\partial[h_e(e_{t+1}, \theta_{t+1})/h(e_{t+1}, \theta_{t+1})]}{\partial\theta} > 0 \tag{9}$$

This leads us to the following proposition:

Proposition 3 *When fertility is endogenous, improvements in children's health have a positive effect on education investment if and only if Inequality* (9) *holds.*

Inequality (9) states that the percentage increase in h_{t+1} due to a marginal increase in e_{t+1} is increasing in θ_{t+1}. Technically, Condition (9) holds if the degree of complementarity between education and health is sufficiently high. In turns out that Inequality (9) holds for any constant return to scale (CRS) human capital production function in the range in which the elasticity of substitution between education and health is less than 1. The findings in Bleakley and Lange (2005) are consistent with a sufficiently high complementarity between education and health. As discussed in the introduction, they find that improvements in children's health induce parents to substitute education for fertility. Hereafter, we assume that (9) holds.

Thus far, our theory argues that longevity does not have a causal effect on education, despite the strong positive correlation between longevity and education among many European countries and Western Offshoots which has been observed since the second half of the eighteenth century. However, our theory proposes a way to reconcile this positive correlation among longevity and education with the proposed neutrality result. Assuming that better health promotes longer lives, our theory suggests that on the one hand, improvements in children's health promotes higher investment in education, while on the other hand, it induces greater longevity. In the next section, we portray the evolution of the economy from stagnation to growth that emphasizes the role of health and longevity in that process.

3 The Evolution of the Economy from Stagnation to Growth

By the economic relations among longevity, health, fertility and education described in the previous section, we provide an alternative explanation for the transition from stagnation to growth.[18] In this respect, the current paper is related to the strand of the literature that explains the long run transition from stagnation to growth.[19]

To portray the the evolution of the economy, we build on three fundamental elements. The first element, as was established in (8) and (9), describes how health improvements raise the relative rate of return to human capital and hence induce parents to substitute quality for quantity of children. The second element relates the choice of parents regarding household consumption to the health of their children. Formally, assume that $\theta_{t+1} = \theta(c_t)$ with $\theta'(\cdot) > 0$ and $\theta''(\cdot) < 0$. These two elements generate a positive feedback loop inducing a rapid improvement in health accompanied by accelerated output growth via both: investments in education and reductions in fertility. The third element of the model is that better health at childhood positively affects longevity which generates more resources to be allocated to consumption as well as to children. Formally, assume that $\pi_{t+1} = \pi(\theta_{t+1})$ with $\pi'(\cdot) > 0$ and $\pi''(\cdot) < 0$.

Consider an economy in its early stages of development. The level of health is low, and the relative return to human capital is low as well. Parents have no incentives to invest in child quality and thus the optimal educational level is

[18] The formal derivation of the dynamic system and its properties are available for the authors upon request.

[19] The economic development of Western Europe and the Western Offshoots over the long-run has been analyzed in the literature by Galor and Weil (2000), Jones (2001), Stokey (2001), Galor and Moav (2002), Lucas (2002), Hansen and Prescott (2002), Doepke (2004), among others. See Galor (2005) for a summary of these theories.

stuck at a corner solution.[20] Hence, parents channel all the resources allocated to their children to quantity only.

However, along the transitional dynamics health improves through generations and so does longevity. As a result, households' budget constraints are being relaxed by the increase of the full income of parents. This higher full income enables parents to choose higher household consumption as well as higher investment in children. As long as the level of health is low enough to prevent investment in quality: $\theta \leqslant \hat{\theta}$, all the resources are allocated to quantity. Therefore, fertility increases along with a slight increase in the standard of living. As the standard of living grows, the health level in the economy grows as well, which, in turn, causes individuals to live longer.

As health improves sufficiently to induce positive investment in education: $\theta > \hat{\theta}$, health improvements have two effects on fertility. On the one hand, improved health eases household's budget constraints through greater longevity, allowing parents to spend more resources on raising children. On the other hand, it induces a reallocation of these increased resources toward child quality. Thus, our model can provide an explanation for the concurrent increase in both: fertility and education observed in most of Western European countries circa the end of the nineteenth century. However, as the health status of the population becomes sufficiently high due to the growth in consumption, it triggers the modern growth regime: fertility starts its long run decline causing growth rates to accelerate.

4 Concluding Remarks

Contrary to conventional wisdom, we argue that greater longevity may have contributed less than previously thought for the significant accumulation of human

[20] So far, we have assumed an interior solution for education. However, when focusing on the transition from stagnation to growth, it is desirable to widen the discussion to include corner solution in which education is zero. Formally, under some conditions on $h(e, \theta)$, for sufficiently low levels of θ, $\frac{1}{\tau} > \frac{h_e(0,\theta_{t+1})}{h(0,\theta_{t+1})}$. By (9), there exists $\hat{\theta}$ such that for $\theta \leqslant \hat{\theta}$ the optimal level of education is zero, while for $\theta > \hat{\theta}$ the optimal level of education is positive and increasing in θ.

capital during the transition from stagnation to growth. Two reasons are pointed out. First, we argue theoretically that greater longevity of children increases not only the returns on eduction but also the returns on fertility, leaving the relative return between quality and quantity unaffected. Therefore, longevity fails to induce a quantity quality tradeoff. Second, we provide evidence that despite the major gains in longevity that have been achieved over the last 150 years, the lifetime labor input of individuals has been declining. This evidence further questions the relevance of the Ben-Porath mechanism.

In contrast to longevity, we show that improvements in children's health can generate a quantity-quality tradeoff. This result has two implications. First, it suggests a new guideline for the empirical investigation of the relationship between health and education. In particular, our theory suggests that abstracting from fertility choice hides the true impact of health improvements on investment in education. Second, it proposes a way to reconcile the positive correlation among longevity and education by suggesting that on the one hand, improvements in children's health promotes higher investment in education, while on the other hand, it induces greater longevity. Finally, we demonstrate how an economy can evolve from stagnation to growth by emphasizing the role of health and longevity in that process.

References

Acemoglu, Daron and Simon Johnson, "Disease and Development: The Effect of Life Expectancy on Economic Growth," 2005. unpublished manuscript, MIT.

Alderman, Harold, Jere R. Behrman, Victor Lavy, and Rekha Menon, "Child Health and School Enrollment-A Longitudinal Analysis," *Journal of Human Resources*, 2001, *36*, 185–205.

Basu, Kaushik, "Child Labor: Cause, Consequence, and Cure ,with Remarks on International Labor Standards," *Journal of Economic Literature*, September 1999, *37* (3), 1083–1119.

Becker, Gary S., *A Treatise on the Family*, Cambridge, MA: Harvard University Press, 1991.

_____ **, Kavin M. Murphy, and Robert Tamura**, "Human Capital, Fertility, and Economic Growth," *Journal of Political Economy*, October 1990, *98* (5), S12–S37.

Behrman, Jere R. and Mark D Rosenzweig, "Returns to Birthweight," *The Review of Economics and Statistics*, May 2004, *86* (2), 586–601.

Ben-Porath, Yoram, "The Production of Human Capital and the Life Cycle of Earnings," *Journal of Political Economy*, August 1967, *75*, 352–365.

Bleakley, Hoyt, "Disease and Development: Evidence from the American South," *Journal of the European Economic Association*, April-May 2003, *1*, 376–386.

_____ **and Fabian Lange**, "Chronic Disease Burden and the Interaction of Education, Fertility and Growth," 2005. unpublished manuscript.

Boucekkine, Raouf, David de la Croix, and Omar Licandro, "Vintage Human Capital, Demographic Trends, and Endogenous Growth," *Journal of Economic Theory*, 2002, *104*, 340–375.

_____ **,** _____ **, and** _____ , "Early Mortality Decline at the Dawn of Modern Growth," *Scandinavian Journal of Economics*, 2003, *105*, 401–418.

Cervellati, Matteo and Uwe Sunde, "Human Capital Formation, Life Expectancy and Process of Economic Development," *American Economic Review*, December 2005, *95* (5), 1653–1672.

Costa, Dora and Richard H. Steckel, "Long-Term Trends in Health, Welfare, and Economic Growth in the United States," in Richard H. Steckel and R Floud, eds., *Health and Welfare during Industrialization*, Chicago, IL: University of Chicago Press, 1997, pp. 47–89.

de la Croix, David and Omar Licandro, "Life Expectancy and Endogenous Growth," *Economics Letters*, 1999, *65*, 255–263.

Doepke, Matthias, "Accounting for Fertility Decline During the Transition to Growth," *Journal of Economic Growth*, September 2004, *9* (3), 347–383.

———, "Child Mortality and Fertility Decline: Does the Barro-Becker Model Fit the Facts?," *Journal of Population Economics*, June 2005, *18* (2).

——— **and Fabrizio Zilibotti**, "The Macroeconomics of Child Labor Regulation," *American Economic Review*, December 2005, *95* (5), 1492–1524.

Ehrlich, Isaac and Francis T Lui, "Intergenerational Trade, Longevity and Economic Growth," *Journal of Political Economy*, October 1991, *99* (5), 1029–1059.

Flora, Peter, F. Kraus, and W Pfenning, *State, Economy and Society in Western Europe 1815-1975*, Chicago, IL: St. James Press, 1983.

Fogel, Robert W., "Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy," *American Economic Review*, 1994, *84* (3), 369–395.

Galor, Oded, "From Stagnation to Growth: Unified Growth Theory," in Philip Aghion and Steven N. Durlauf, eds., *Handbook of Economic Growth*, Elsevier, 2005. forthcoming.

——— **and David N. Weil**, "From Malthusian Stagnation to Modern Growth," *American Economic Review*, May 1999, *89* (2), 150–154.

——— **and** ———, "Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond," *American Economic Review*, September 2000, *90* (4), 806–828.

——— **and Omer Moav**, "Natural Selection and the Origin of Economic Growth," *Quarterly Journal of Economics*, November 2002, *117* (4), 1113–1191.

Greenwood, Jeremy and Ananth Seshadri, "The U.S. Demographic Transition," *American Economic Review*, May 2002, *92* (2), 153–159.

Hansen, G. and E. Prescott, "Malthus to Solow," *American Economic Review*, September 2002, *92*, 1205–1217.

Hazan, Moshe, "Longevity and Lifetime Labor Input: Data and Implications," 2006. Unpublished manuscript, Hebrew University.

——— **and Binyamin Berdugo**, "Child Labor, Fertility, and Economic Growth," *Economic Journal*, 2002, *112* (482), 810–828.

Jones, Charles, "Was an Industrial Revolution Inevitable? Economic Growth over the Very Long Run," *Advances in Macroeconomics*, 2001, *1*, 1–43.

Kalemli-Ozcan, Sebnem, "Does the Mortality Decline Promote Economic Growth?," *Journal of Economic Growth*, 2002, *7*, 411–439.

———**, Harl E. Ryder, and David N. Weil**, "Mortality Decline, Human Capital Investment, and Economic Growth," *Journal of Development Economics*, 2000, *62*, 1–23.

Lorentzen, Peter, John McMillan, and Romain Wacziarg, "Death and Development," 2005. CEPR Discussion Paper 5246.

Lucas, Robert E., *Lectures on Economic Growth*, Cambridge, MA: Harvard University Press, 2002.

Matthews, Robert Charles Oliver, Charles Hilliard Feinstein, and Jhon C. Odling-Smee, *British Economic Growth 1856-1973*, Stanford, CA: Stanford University Press, 1982.

Miguel, Edward and Michael Kremer, "Worms: Identifying Impacts on Education and Health in the Presence of Treatment Externalities," *Econometrica*, January 2004, *72* (1), 159–217.

Moav, Omer, "Cheap Children and the Persistence of Poverty," *Economic Journal*, 2005, *115* (500), 88–110.

Shastry, Gauri K. and David N. Weil, "How Much of Cross-Country Income Variation is Explained by Health?," *Journal of the European Economic Association*, April/May 2003, *1* (2-3), 387–396.

Soares, Rodrigo R., "Mortality Reductions, Educational Attainment, and Fertility Choice," *American Economic Review*, June 2005, *95* (3), 580–601.

Stokey, Nancy L., "A quantitative model of the British Industrial Revolution, 17801850," *CarnegieRochester Conference Series on Public Policy*, 2001, *55*, 55–109.

US Bureau of the Census, *Historical Statistics of the United States, Colonial Times to 1970*, Bicentennial Edition, 1975.

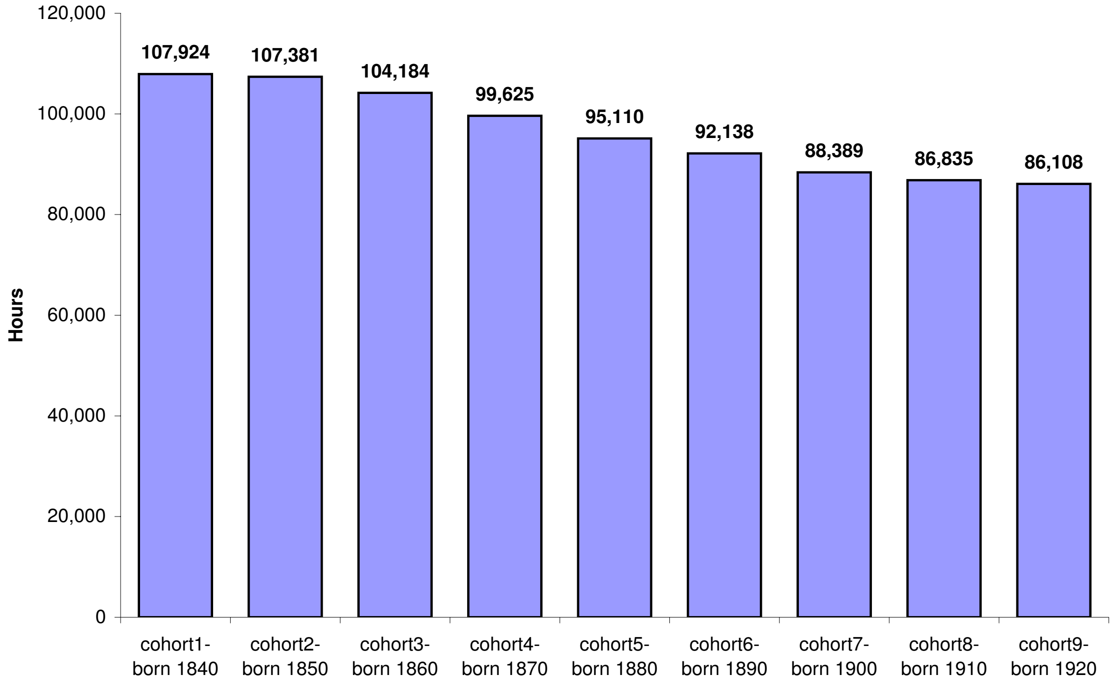

Figure 1: The Expected Working Hours over the Lifetime of Consecutive Cohorts born 1840–1920. Individuals are Assumed to Enter the Labor Market at Age 20 and form their Expectations at Age 5. This figure is taken from Hazan (2006). See Hazan (2006) for data sources and estimation procedure.