Does Longevity Cause Growth?*

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Abstract

This article challenges conventional wisdom by arguing that greater longevity cannot explain the significant accumulation of human capital during the transition from stagnation to growth. This is because greater longevity raises children's future income proportionally at all levels of education, leaving the relative return between quality and quantity unaffected. This result is consistent with historical evidence that longevity began to increase long before education did. Our theory also casts doubts on recent findings about a positive effect of health on education. This is because health raises the marginal return on quality and quantity, resulting in an ambiguous effect on the accumulation of human capital. We conclude that longevity and health have had a minor effect, if any, on the transition from stagnation to growth via investment in 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 Yormam Ben-Porath (1967), according to which prolonging the period in which individuals may receive returns on their investment spurs investment in human capital.[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 the causality runs from longevity to growth through education. This literature, however, disregards fertility choice.[2]

The historical evidence, however, shows that output growth and population growth have been positively correlated throughout most of human history and that the reversal of this relationship in Western Europe in the last quarter of the nineteenth century marked the beginning of the modern growth era. This correlation is so profound that it has been the focus of the oldest growth theory, conceived by Malthus (1798). About fifteen years ago, nearly two hundred years after Malthus and thirty years after the renewal of interest in economic growth, population growth resurfaced as a central building block in growth theory. Earlier models such as Barro and Becker (1989), Becker, Murphy and Tamura (1990), and Galor and Weil (2000) incorporated fertility choice into these models, focusing on the negative correlation between population growth and income in the modern era. As growth theory continued to develop, new theories have emerged that explain the long-term development process from early human society to the modern era (Galor and Weil (2000), Jones (2001), Galor and Moav (2002), and Lucas (2002)). Population growth is central in all of them.[3]

A more realistic framework for exploration of the effect of longevity on in-

[1] For instance see Kalemli-Ozcan, Ryder and Weil (2000), Boucekkine, de la Croix and Licandro (2002), Boucekkine, de la Croix and Licandro (2003), Cervellati and Sunde (2005), and Soares (2005), among others.

[2] In Soares (2005), fertility is endogenous and parents invest in their children's human capital and in their own. In reference to one's own investment in human capital, Soares employs the Ben-Porath mechanism and assumes that the impact of an increase in children's longevity on their human capital is positive.

[3] See Galor (2004) for a survey of these theories.

vestment in education would assume that education choices are made by parents in combination with fertility choice. Several studies have conjectured that the Ben-Porath mechanism remains relevant within this framework (Galor and Weil (1999), (Kalemli-Ozcan et al. (2000)). Their argument is based on the intuitive proposition that greater longevity of children will raise the rate of return on investments in children's human capital and, for this reason, may induce households to make quality-quantity tradeoffs.

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. Although this outcome may seem counterintuitive, it is in fact straightforward. If parental preferences are homothetic with respect to the quality and quantity of their children, an increase in children's longevity will increase each child's income proportionally irrespective of her level of education. Thus, it does not change the relative return between quality (education) and quantity (fertility) and, hence, cannot cause any increase in the level of education chosen by the parents.[4] We call this result the "neutrality result." Thus, unless we accept the argument that individuals increase their investment in formal education upon reaching adulthood in anticipation of a longer productive life, our result casts doubt on the relevance of the Ben-Porath mechanism in explaining the observed increase in formal-education investment in its historical context.[5]

The historical evidence lends credence to our neutrality result. As we show in detail in Part 2, life expectancy of adults has been increasing monotonically at least since early eighteenth century whereas education was relatively low and stagnant until the middle of the nineteenth century, when it started its secular increase. This raises the question why the causality has held since the middle of the nineteenth century but not before.

Ehrlich and Lui (1991) and Lagerlof (2003) attempt to explore the effect of longevity on growth via investment in education in models where fertility is en-

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

[5]We claim that the Ben-Porath's argument is highly questionable due to the low levels of education attained in the nineteenth century. For example, average years of schooling in England and Wales were 2.3 and 5.2 for the cohorts born in 1801-1805 and 1852-1856, respectively (Matthews, Feinstein and Odling-Smee 1982). It is highly unrealistic to think that the prolongation of productive life induces individuals who were so poorly schooled as children to invest in their human capital as adults.

dogenous. Both of these models, however, disregarded the effect of children's longevity on the investment in their education, focusing instead on the effect of parents' longevity on resource allocation for children. According to Ehrlich and Lui (1991), the share of resources allocated to quality depends on the level of parents' human capital, whereas according to Lagerlof (2003) it depends on technological progress.[6]

The discussion thus far casts doubts on the argument that longevity has a positive effect on the acquisition of human capital during the transition from stagnation to growth. Since longevity may be thought of as the outcome of health, we examine below whether improvements in health may account for the accumulation of human capital during this transition process.[7] Although longevity and health are conceptually related, 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.

Many attempts have been made to assess the direct effect of health on growth, as well as the indirect effect of health via the accumulation of human capital. Fogel (1994) and Shastry and Weil (2003) quantified the direct effect of health on long-term per-capita growth and cross-country income differences. Fogel (1994), estimating the increase in energy available to the British population between 1790 and 1980, argues that the increase in caloric intake boosted labor-force participation and the intensity of work per hour and traces roughly one-third of per-capita income growth in England during that period to this increase in labor input.[8] 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. Alderman, Behrman, Lavy and Menon

[6]As we show in section 2, gains in adults' longevity were modest during the second half of the nineteenth century. Consequently, the effect of longevity on education could not have accounted for much of the substantial increase in education during that time.

[7]Many empirical studies use life expectancy and health interchangeably (Shastry and Weil 2003, e.g.)

[8]Fogel bases his argument on the first law of thermodynamics, which states that energy output cannot exceed energy input.

(2001), Bleakley (2003), Miguel and Kremer (2003), Behrman and Rosenzweig (2001), and Behrman and Lavy (1997) estimate the impact of health on education. Alderman et al. (2001) find that children's health positively affects school enrolment. Bleakley (2003) finds that the eradication of hookworm disease in the American South circa 1910 led to an increase in school attendance and literacy rates and to substantial gains in income. Miguel and Kremer (2003) find that the eradication of intestinal helminthes among school-aged children in Kenya has boosted school attendance although not school achievements. Finally, Behrman and Rosenzweig (2001) find that, controlling for genetic and family-background endowments, birth weight has a significant positive effect on school attainments. In contrast, Behrman and Lavy (1997) find no significant effect of a child's health on her success in school.

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 naive conclusion would be that the complementarity assumption is sufficient to assure that improvements in health would increase the investment in education (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. The implied premise that the production function of human capital must satisfy to generate this result is difficult to justify. Specifically, the degree of complementarity between health and education has to be high enough to elicit this result. For a household that chooses quality and quantity jointly, the evidence of Fogel (1994) is consistent with a sufficiently high degree of substitutability between health and education.[9] We conjecture that health improvements have had little if any indirect effect on growth via investment in education. Notably, this result does not contradict with the aforementioned findings of Alderman et

[9]Improvements in health have been detected in the Western population since the early nineteenth century and have been intensifying since the middle of that century (Mokyr and Stein 1997). Child labor, which was already a common practice before the nineteenth century, became more prevalent during that century and peaked in England and Wales between 1861 and 1871 (Cunningham 1996). Thus, our interpretation of this evidence is that better health increased children's labor productivity, causing child labor to increase (Hazan and Berdugo 2002).

al. (2001), Bleakley (2003), Miguel and Kremer (2003), and Behrman and Rosenzweig (2001), since all these studies abstract from fertility choice. Behrman and Lavy (1997) use family fixed effects that control, among other things, for fertility. Interestingly, their findings are consistent with our theory.

Our theory has important policy implications for international aid to poor countries. It suggests that although health interventions may be justified by their direct contribution to quality of life and per-capita income, when tallying up the costs and benefits of these interventions one should bear in mind that longevity and health have no effect on the relative return on education.[10]

The rest of the paper is organized as follows. Part 2 sets forth the historical evidence regarding the joint evolution of education and longevity. Part 3 formalizes our arguments and Part 4 presents concluding remarks.

2 The Historical Evidence

2.1 The Evolution of Longevity

Conventional wisdom suggests that life expectancy has been rising throughout human history, although at a negligible pace during most of this period.[11] Life expectancy at birth in England fluctuated around an average of 35 years during the pre-industrial revolution (1541-1760). During the first phase of the Industrial Revolution, life expectancy increased at a modest rate, edging upward to 40 years in 1850 before accelerating to nearly 50 years at the end of the nineteenth century, more than 66 by the middle of the twentieth century, and 77 by 2002 (Dublin, Lotka and Speigelman 1947, Wrigley and Schofield 1981, World-Bank 2004).

Our theory, however, focuses on longevity of adults. Life expectancy conditioned on survival to adulthood has been making less dramatic progress. Life expectancy for females at age 30 in England, for example, rose from slightly

[10]Becker, Philipson and Soares (2005) find that life expectancy converged among countries over the period 1965-1995 and argue that if one takes into consideration not only income per capita but also life expectancy as a measure of welfare, the data suggest convergence rather than divergence among countries over that period.

[11]Galor and Moav (2004) survey evidence that life expectancy declined around the time of the agricultural revolution (c. 7000 BCE). They develop an evolutionary growth model, arguing that the gains in longevity in recent centuries trace to a process of natural selection.

more than 60 in 1700-1750 to about 64 in the 1840s and less than 66 by 1900[12] (Dublin, Lotka and Speigelman 1949, Wrigley and Schofield 1981). Similarly, life expectancy at age 20 in Sweden climbed from about 60 in 1785 to roughly 66 by 1890 (Keyfitz and Flieger 1968). Furthermore, gains in life expectancy conditioned on survival to adulthood predated the gains in life expectancy at birth. Data from Geneva and Venice on cohorts born in 1625-1825 and 1630-1740, respectively, suggest that death rates dropped monotonically and that most of the decrease occurred in the 40-65 age range[13] (Boucekkine et al. 2003). In the US, adults' death rates have been trending down since the seventeenth century. In particular, the probability that a cohort that reached the age of 20 would survive to age 50 increased monotonically from 0.585 in 1650-1700 to 0.74 in 1850 and to 0.95 in 1960[14] (Fischer 1978).

2.2 The Evolution of Education

Although the secular rise in life expectancy has been accompanied by a significant increase in human-capital formation since the second half of the nineteenth century, education in England was not widespread until that time. In particular, literacy rates soared from a rather constant level of about 65 percent in 1760-1830 to nearly 100 percent at the end of the nineteenth century (Stone 1969, Clark 2003) and the proportion of children aged 5-14 in school rose from 0.11 in 1855 to 0.74 in 1900 (Flora, Kraus and Pfenning 1983). Average years of schooling climbed from only 2.3 for the cohort born in 1801-1805 to 5.2 for the cohort born in 1852-1856 and 9.1 for the cohort born in 1897-1906 (Matthews et al. 1982). Finally, the average years of schooling of the male labor force in England, relatively stagnant until 1830s, nearly tripled by 1900 (Matthews et al. 1982).[15]

This evidence suggests that although a positive correlation between life expectancy and education has been prevalent since the middle of the nineteenth

[12] The gains for males were more modest.

[13] They do not report, however, quantitative gains in longevity.

[14] Figures 1, 2 and 3 present the data on longevity for England, Sweden, and the US, respectively.

[15] Similar patterns appear throughout Europe and the United States. For a survey of the evolution of education in Europe and the US and the rise of the public education, see Galor and Moav (2003).

century, the onset of the secular increase in education lagged behind that of longevity by one hundred if not two hundred years.[16]

3 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 labor force participation.[17]

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.

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.[18]

[16]Figure 4 presents the data on longevity and education in England.

[17]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. Doepke (2004) shows quantitatively that the incorporation of sequential fertility choice eliminates the impact of the decline in child mortality on fertility. Thus, we abstract from child mortality and treat n_t as the number of surviving children.

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

The adult in period t faces the following budget constraint:

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

3.1 Longevity and Exogenous Fertility

To illustrate the mechanism proposed in Ben-Porath's pioneering work (1967), which has been recently employed in the growth literature, this section treats fertility as exogenous. Therefore, we set $n_t = 1$. Maximizing 1 with respect to 2 yields the following first-order condition:[19]

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

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 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 an individual decides on her level of education she chooses the level that maximizes her lifetime consumption. When she chooses the level of her child's education, she has to forgo some of her consumption to give her child more education.

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

[19] To highlight our arguments, we focus on an interior solution for e throughout the paper.

$$-V''(\pi_{t+1}h(e_{t+1}))\frac{(\pi_{t+1}h(e_{t+1}))}{V'((\pi_{t+1}h(e_{t+1}))} < 1.^{20} \tag{4}$$

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.*

3.2 Longevity and Endogenous Fertility

By treating fertility as endogenous, we obtain the following first-order conditions:

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

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 5 is the marginal cost of children, measured in the utility loss from foregone consumption, and RHS of 5 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:

[20] 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.

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 crucially dependent on the assumption that fertility is exogenous.[21]

3.3 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 Part B 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 two may increase, decrease, or remain unchanged. Therefore, health improvements will have a positive effect on education investment if and only if:

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

[21] 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.

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.[22] While the degree of complementarity of education and health is an empirical issue that has not yet been explored, it seems a relatively restrictive assumption. Suppose, for example, that better nutrition translates (among other things) into better physiological health, as suggested by Fogel (1994). While the empirical literature surveyed in the Introduction finds that better nutrition improves students' achievements, the improvement in nutrition may well increase physical ability even more. Therefore, such improvements in health may change the comparative advantage in favor of performing manual labor. Although we cannot argue that health has no effect on education investment in the transition from stagnation to growth, examples of the type presented here cast doubts on the relevance of health in generating economic growth by means of education.

4 Concluding Remarks

Bucking the conventional wisdom, we have argued that greater longevity cannot explain the significant accumulation of human capital during the transition from stagnation to growth. This is because greater longevity raises children's future income proportionally at all levels of education, leaving the relative return between quality and quantity unaffected. Our theory also casts doubts on recent findings about a positive effect of health on education. This is because health raises the marginal return on quality and quantity, resulting in an ambiguous effect on the accumulation of human capital. Thus, we conclude that longevity

[22]The frequently used Cobb-Douglas production does not satisfied 9. 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.

and health have little if any effect on the transition from stagnation to growth via investment in education.

Our model suggests an additional result that casts even greater doubt on the relevance of the Ben-Porath mechanism for prescribing investment in education during the transition from stagnation to growth. We showed that even when fertility is exogenous, the mere fact that parents decide on the education of their children rather than individuals for themselves, does not guarantee that the Ben Porath mechanism holds. The rationale is that when an individual decides on her level of education she chooses the level that maximizes her lifetime consumption, i.e., education is a pure investment. When she chooses her child's level of education, however, she has to forgo some of her consumption to increase her child's education. Thus the distinct roles played by one's own education and one's children's education impose restrictions on parental preferences in order to generate the Ben-Porath mechanism.

Our theory is more consistent with the historical evidence than other studies that model the relationship among longevity, human-capital accumulation, and population. As shown in Part 2, life expectancy has been increasing monotonically at least since the beginning of the eighteenth century while investment in formal education was negligible until the mid-nineteenth century.

Furthermore, our "neutrality result" is robust. Pursuant to a vast literature, we assume that parents maximize their children's full income.[23] In fact, this result holds for a broader set of preferences. When longevity is disregarded, parental preferences are defined over the number of children (quantity) and each child's level of human capital (quality). When longevity is incorporated into the analysis, however, it stands to reason that parental utility is derived from the expected number of children as well as from each child's expected level of human capital, i.e., $W = U(c) + V(\pi n, \pi h(e))$. Consequently, the "neutrality result" holds as long as preferences are homothetic with respect to the quantity and quality of their children.[24]

[23]See Ehrlich and Lui (1991), Galor and Weil (2000), Galor and Moav (2002), Hazan and Berdugo (2002), Lagerlof (2003), and Moav (2005), among others.

[24]Furthermore, even if preferences are defined for the number of children as well as the lifetime earnings of each child, the "neutrality result" holds if $W = U(c) + V(n + ln(\pi h(e)))$, i.e., if the sub-utility from children is quasi-linear.

Our theory suggests a new guideline for investigation of the empirical relationship between health and education. We have shown the relevance of fertility choice for examination of the effect of health on education. In particular, our theory suggests that abstracting from fertility choice hides the true impact of health improvements on the investment in education.[25]

Finally, our theory has important policy implications for international aid to poor countries. It suggests that although health interventions may be justified by their direct contribution to quality of life and per-capita income, when tallying up the costs and benefits of these interventions one should bear in mind that longevity and health have no effect on the relative return on education.

[25]Behrman and Lavy (1997) control for fertility by including family fixed effects. Interestingly, their finding is consistent with our theory.

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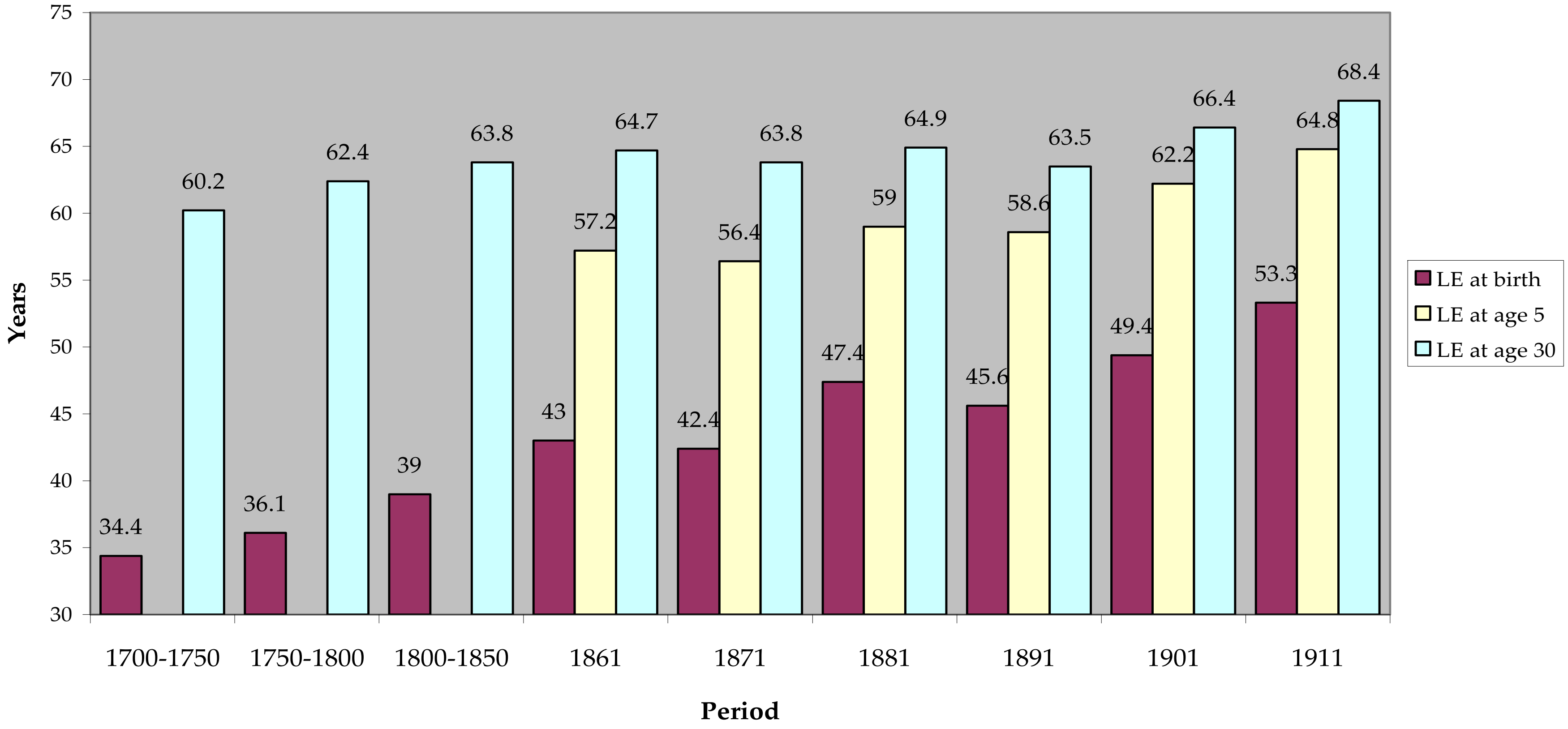
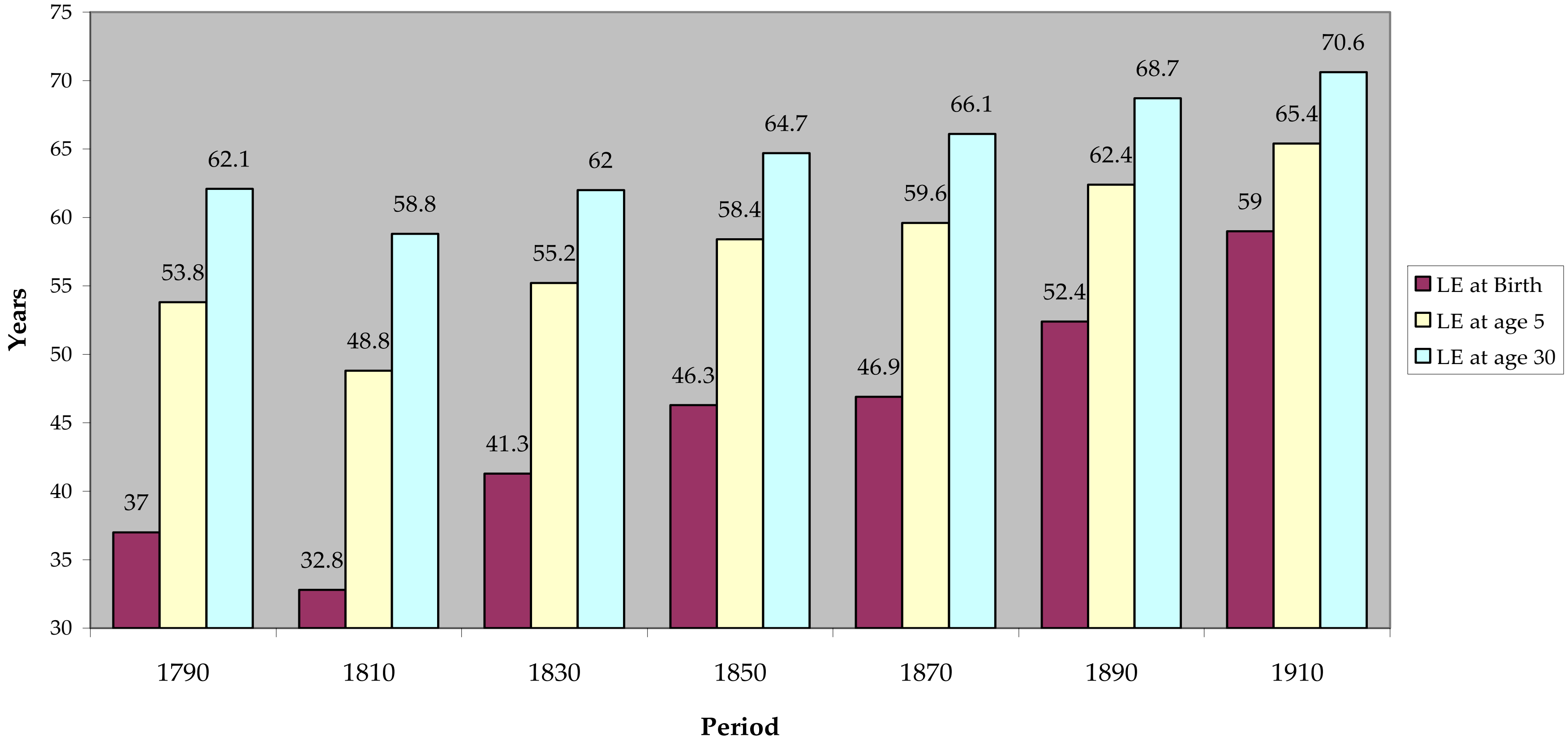
Figure 1
Life Expectancy in England (Females)



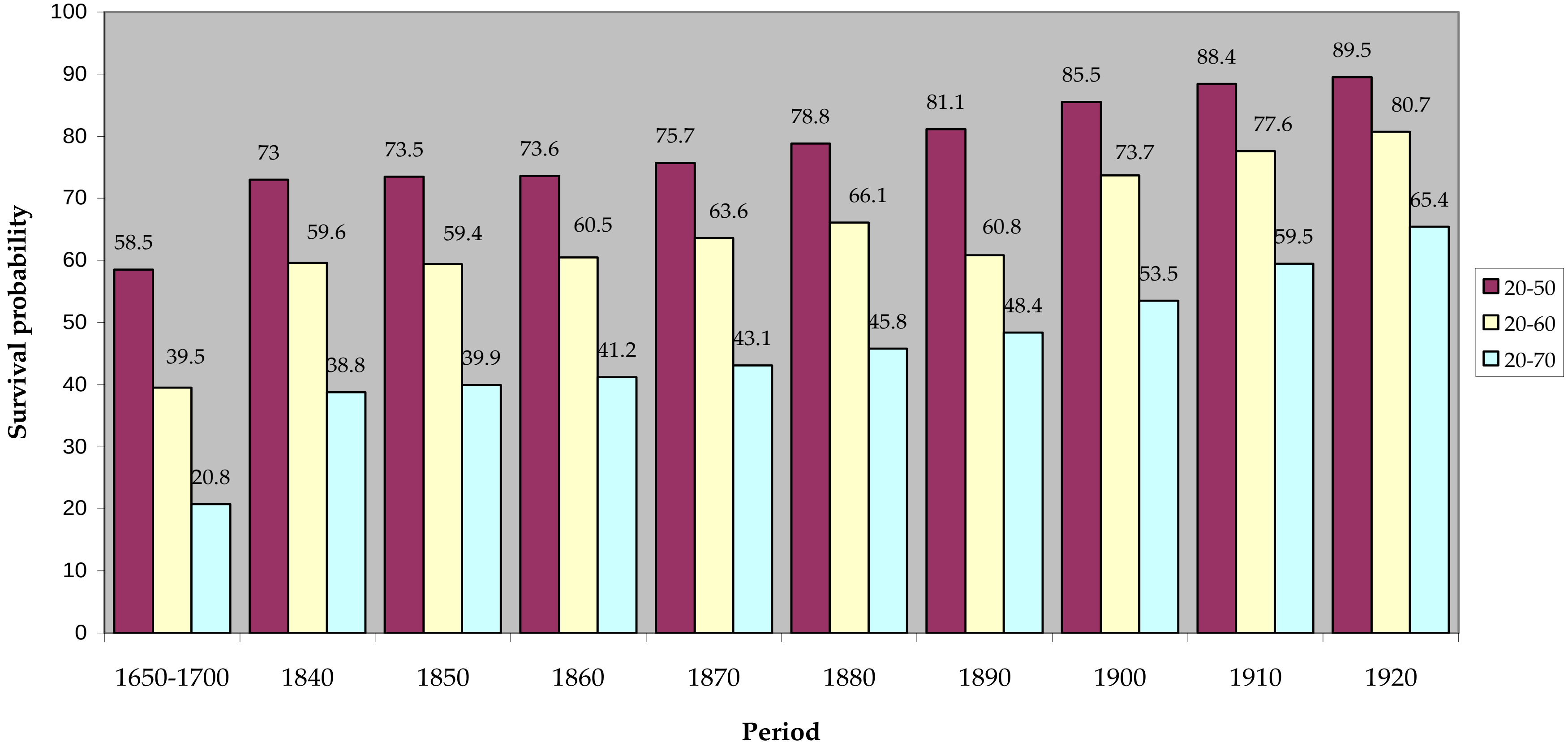
Source: Dublin, Lotka and Speigelman (1949); Keyfitz and Flieger (1968); and Wrigley and Schofield (1981).

Figure 2
Life Expectancy in Sweden (Females)



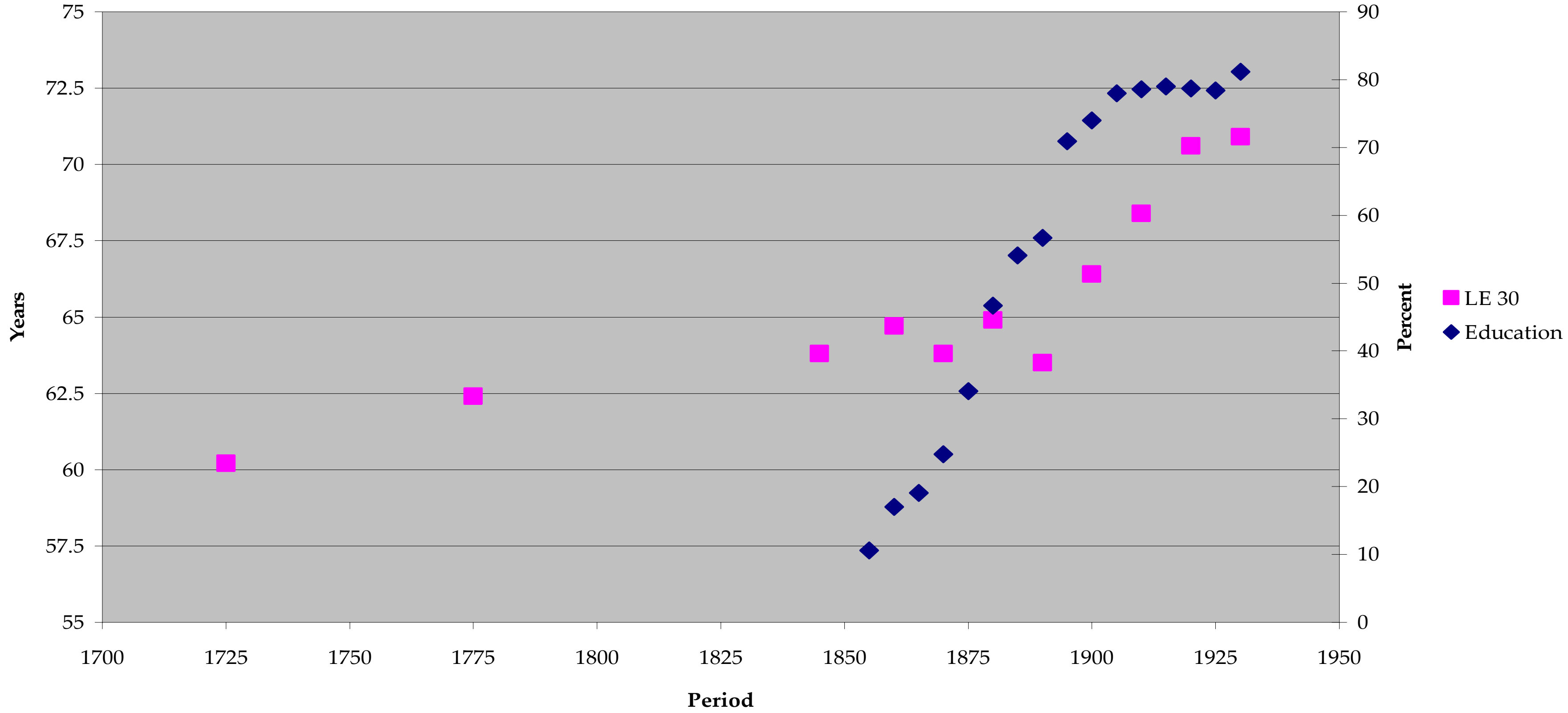
Source: Keyfitz and Flieger (1968)

Figure 3
Legth of Life in the US - Survival from Age 20 to Age 50, 60 and 70 (White Males)



Source: Fischer (1978)

Figure 4
Life Eepectancy at Age 30 and the Fraction of Children Age 5-14 in Public Primary Schools England



Source: Flora et al (1983); Dublin, Lotka and Speigelman (1949); Keyfitz and Flieger (1968); and Wrigley and Schofield (1981)