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Impact of mortality reductions on years of schooling and expected lifetime labor supply

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ABSTRACT

Hazan (2009) performs empirical analysis based on the conjecture that a necessary condition for mortality decline to cause longer years of schooling is that it also increases expected lifetime labor supply, and reaches controversial conclusions. We aim to examine the theoretical validity of Hazan's (2009) conjecture, and more generally, to understand the relation between these two conditions in a standard life-cycle model. We find that the relation between the effects on optimal years of schooling and expected lifetime labor supply differs systematically with respect to mortality reductions at different stages of the life cycle. Based on these systematic differences, we find that longer lifetime labor supply is *not sufficient* for increased years of schooling for all mortality reductions occurring during the schooling phase, and *not necessary* for increased years of schooling for some mortality reductions during the working phase.

1. Introduction

Hazan (2009) examines whether the increase in average years of schooling in USA from mid-19th century to mid-20th century was caused by mortality decline or not. Using a life-cycle model with perfectly rectangular survival function (with zero probability of death during lifetime, and then dying with certainty when reaching the maximum age), he suggests that a necessary condition for higher life expectancy to cause longer years of schooling is that it also increases lifetime labor supply. His empirical analysis based on the data of USA (as well as several European countries) suggests that expected lifetime work hours actually decreased with a rise in life expectancy, and he concludes that the observed increase in years of schooling cannot be explained by mortality reductions. As mentioned in Cervellati and Sunde (2010, 2013) , Hazan's (2009) conclusion, which challenges a conventional prediction of the human capital theory, has important policy implications regarding the benefit of health improvement and mortality decline.

Not surprisingly, Hazan's (2009) controversial conclusions generate heated responses.[1] In particular, Cervellati and Sunde (2010, 2013) argue that the rectangular survival function specification is not empirically relevant, since longevity increases from mid-19th century to mid-20th century were caused by mortality reductions at various ages (especially those in youth and working ages). Cervellati and Sunde (2010) then show that in a life-cycle model with a general survival function, a mortality decline induces more schooling if and only if it increases the benefits of increased schooling relative to the costs, and that their condition is reduced to the condition on lifetime labor supply emphasized in Hazan (2009) when the survival function is rectangular.[2] Moreover, Cervellati and Sunde (2010, 2013) perform empirical analysis and show that while there is a pronounced decline in expected lifetime labor supply across the cohorts of men born at different decades from 1840 to 1930 (as in Hazan, 2009), there is no evidence of a decline in the benefits relative to the opportunity costs of schooling. Their empirical results challenge Hazan's (2009) conclusions that the increase in schooling cannot be caused by mortality decline.

To complement the empirical analysis of Cervellati and Sunde (2013), this paper focuses on the theoretical question: Is "mortality decline raising expected lifetime labor supply" (to be labeled as MDrELLS) a necessary or sufficient condition for "mortality decline raising years of schooling" (to be labeled as MDrYS) in the standard

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[1] Some researchers (such as Hansen and Lønstrup, 2012; Sánchez-Romero et al., 2016) respond by constructing theoretical models to rationalize the simultaneous increase in years of schooling and decrease in retirement age or expected lifetime labor supply when life expectancy improves. Other researchers (such as Cervellati and Sunde, 2010, 2013) question whether Hazan (2009) has used the appropriate condition or not when reaching his conclusion.

[2] Cervellati and Sunde (2010) point out that in a continuous-time model, their condition (4) will be reduced to condition (5) of Hazan (2009) when the survival function is rectangular. Note that Cervellati and Sunde (2013) use a discrete-time framework, but they use a continuous-time one in an earlier working paper (Cervellati and Sunde, 2010). Since this paper uses a continuous-time model, we also refer to their earlier version for easier comparison.

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life-cycle framework used in the literature.[3] A careful investigation of this issue is important for two reasons. First, Hazan's (2009) conclusions depend crucially on the theoretical conjecture that MDrELLS is *a necessary condition* for MDrYS, and his conclusions would be questionable if the theoretical foundation is not sound.[4] Second, while Hazan (2009) makes the above-mentioned conjecture, MDrELLS is interpreted, explicitly or implicitly, as *a sufficient condition* for MDrYS by a number of researchers. For example, Kalemli-Ozcan et al. (2000, p. 18) state that "(h)igher life expectancy raises the optimal quantity of schooling because investments in education will earn a return over a longer period of time". Similarly, Bils and Klenow (2000, p. 1164) mention that "a higher life expectancy results in more schooling, since it affords a longer working period over which to reap the wage benefits of schooling". Given these diverse interpretations,[5] we aim to clarify the relationship between these two conditions and provide intuitive explanation. In this paper we conduct comparative static analysis of the optimality condition on the schooling duration choice. In particular, we examine the derivative of optimal years of schooling with respect to mortality decline at an arbitrary age, and obtain results that, to the best of our knowledge, have not been emphasized in the literature.

Our novel results arise from the discovery of the systematic differences in the effects of mortality reductions at different stages of the life cycle,[6] but not from any unconventional features of the model. To highlight this point, we use a life-cycle model as similar as possible to those in the literature, especially in Hazan (2009) and Cervellati and Sunde (2010). After obtaining the first-order condition characterizing the optimal years of schooling, we study the effect of mortality decline on optimal years of schooling and the associated expected lifetime labor supply. We obtain two main results. First, the effects on optimal years of schooling are systematically different in the three distinct phases of the life cycle: no effect in schooling and retirement phases, and a positive effect during the working phase. (We will provide the economic intuition in Section 3, after presenting Proposition 1.) Second, we study the effect of mortality decline on expected lifetime labor supply, and find that it consists of two effects: a survival effect due to possible changes in survival probabilities at various ages, and a behavioral effect due to a change in optimal years of schooling. We then combine these two sets of results to show that MDrELLS is neither necessary nor sufficient for MDrYS in the life-cycle model with a general non-rectangular survival function. Our results raise doubts about Hazan's (2009) conclusion that the increase in years of schooling in the last century cannot be caused by mortality decline, because the theoretical foundation of his conclusion is invalid for a general survival function.

This paper is organized as follows. Section 2 introduces the model and derives the first-order condition characterizing the schooling duration choice. Section 3 examines the impact of mortality decline on optimal years of schooling. Section 4 studies the impact on expected lifetime labor supply, and examines the relationship between MDrELLS and MDrYS. Section 5 provides the concluding remarks.

2. The model

We consider a continuous-time life-cycle model in which an individual chooses the consumption path (up to T, the maximum age) and years of schooling (S) in the presence of lifetime uncertainty. The lifetime uncertainty is represented by a general survival function

$$l(x) = e^{-\int_0^x \mu(q)dq}, \tag{1}$$

where $l(x)$ is the probability of surviving up to at least age x, $l(0) = 1$, $l(T) = 0$, and $\mu(q) \geq 0$ (with $\lim_{q\to T}\mu(q) = \infty$) is the instantaneous mortality rate at age q.

We assume that schooling and labor supply activities are indivisible, and that the progression from schooling to working is irreversible.[7] These assumptions follow many researchers studying the effects of demographic changes on life-cycle decisions, such as Kalemli-Ozcan et al. (2000), Hazan (2009) and Heijdra and Romp (2009). We also make the simplifying assumption that retirement age (R) is exogenously fixed, as in Kalemli-Ozcan et al. (2000), Heijdra and Romp (2009) and Cervellati and Sunde (2013). In this environment, an individual chooses a consumption path and years of schooling (between age 0 to age R) to maximize expected lifetime utility

$$\int_0^T e^{-\rho x} l(x)\left[\frac{c(x)^{1-\frac{1}{\sigma}}-1}{1-\frac{1}{\sigma}}\right]dx, \tag{2}$$

subject to

$$a'(x) = \begin{cases} [r+\mu(x)]\,a(x) + h(S) - c(x) & \text{if } S < x \leq R \\ [r+\mu(x)]\,a(x) - c(x) & \text{if } x \leq S \text{ or } x > R, \end{cases} \tag{3}$$

and boundary conditions $a(0) = 0$, $a(T) \geq 0$, where ρ is the discount rate, σ is the coefficient of intertemporal elasticity of substitution, r is the constant real interest rate, $c(x)$ is consumption at age x, $a(x)$ is financial wealth at age x, $a'(x)$ is the derivative of $a(x)$ with respect to x, and $h(S)$ is the individual's labor income at age x, if he receives S years of schooling.[8] We assume that $\rho \geq 0$, $r > 0$, and $0 < \sigma < 1$.

This life-cycle model with (1) to (3) also contains the following features. First, we assume that individuals have no bequest motive, and that the annuity market is perfect (as in Yaari, 1965; Blanchard, 1985). It is well known that in such an environment, individuals will find it optimal to purchase annuity contracts only. As captured in (3), an individual aged x will surrender financial wealth $a(x)$

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[3] After analyzing the benefits and costs of an individual's schooling choice when facing a general survival function, Cervellati and Sunde (2013, p. 2059) mention that their results imply "an increase in lifetime labor supply is neither a necessary nor a sufficient condition to observe an increase in optimal schooling". However, it is unclear how this implication arises, because they do not explicitly consider the effects of mortality changes on expected lifetime labor supply. Our paper tackles this question directly.

[4] Hazan (2009) emphasizes that while satisfying a necessary condition (MDrELLS in this context) only provides supporting evidence for a hypothesis (MDrYS), the rejection of a necessary condition is enough to refute the hypothesis.

[5] We give one more example to illustrate the diverse interpretations about the relationship of these two conditions. While Hazan (2009) mentions several times that MDrELLS is a necessary condition for MDrYS, he also indicates that it is *a necessary and sufficient condition* in one instance, when he states that "as individuals live longer, they invest more in human capital if and only if their lifetime labor supply increases" (Hazan, 2009 p. 1832).

[6] Our interest in this question is partly stimulated by d'Albis et al. (2012) who show that mortality changes at young versus old ages may have different effects on optimal retirement age. Empirically, mortality decline concentrates mainly on children and young adults in the early stages of the demographic transition, but mainly on older people at the later stages. This pattern is well documented by demographers and health economists. For example, Wilmoth and Horiuchi (1999, pp. 484–5) mention that during the later stage of demographic transition, an "aging of mortality decline" has occurred, characterized by "successively larger reductions in mortality rates at older ages, and by smaller reductions at younger ages". Eggleston and Fuchs (2012) discuss various behavioral and policy issues related to longevity improvement of high-income countries in recent decades, in which mortality decline occurs mainly late in life. They label it the "new demographic transition".

[7] The assumption that the progression from schooling to work is irreversible, used here and by many researchers, is partly motivated by the theoretical results in Ben-Porath (1967).

[8] Note that human capital is accumulated only through formal schooling in this model, following Bils and Klenow (2000), Kalemli-Ozcan et al. (2000), Hazan (2009) and Cervellati and Sunde (2010). On the other hand, human capital is also accumulated through on-the-job training in Manuelli et al. (2012).