Longevity and Lifetime Labor Supply: Evidence and Implications[¤]

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Abstract

Conventional wisdom suggests that increased life expectancy had a key role in causing a rise in investment in human capital. I incorporate the retirement decision into a version of Ben-Porath's (1967) model and find that a necessary condition for this causal relationship to hold is that increased life expectancy will also increase lifetime labor supply. I then show that this condition does not hold for American men born between 1840 and 1970 and for the American population born between 1890 and 1970. The data suggest similar patterns in Western Europe. I end by discussing the implications of my findings for the debate on the fundamental causes of long-run growth.

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1 Introduction

The life expectancy at age 5 of American men born in the mid 19$^{\text{th}}$ century was 52.5 years and their average years of schooling were less than 9. Their peers, born a hundred years later, gained more than 16 years of life and invested 6 more years in schooling (see Figure 1). Conventional wisdom suggests that these gains in life expectancy positively affected schooling by increasing the horizon over which investments in schooling have been paid off. Hereafter, I refer to this mechanism as the Ben-Porath mechanism, following the seminal work of Ben-Porath (1967).[1]

Prominent scholars have emphasized that in the context of economic growth, exogenous reductions in mortality rates were crucial in initiating the process of human capital accumulation, which itself was instrumental in the transition from "stagnation" to "growth". For example, Galor and Weil (1999) write,

> [...] A second effect of falling mortality is that it raises the rate of return on investments in a child's human capital and thus can induce households to make quality-quantity trade-offs. This inducement to increased investment in child quality would be complementary to the increase in the rate of return to human capital discussed in Section 1. [...] The effect of lower mortality in raising the expected rate of return to human capital investments will nonetheless be present, leading to more schooling and eventually to a higher rate of technological progress. This will in turn raise income and further lower mortality. (p.153)

This mechanism has been explored theoretically by others as well (see Meltzer (1992), de la Croix and Licandro (1999), Kalemli-Ozcan, Ryder, and Weil (2000), Boucekkine, de la Croix, and Licandro (2002, 2003), Soares (2005), Cervellati and

[1] The essence of the Ben-Porath model is that individuals choose their human capital according to the future rewards that this human capital will receive. The mechanism described above and labeled "the Ben-Porath mechanism" is one of but several predictions of the Ben-Porath model and the aim of the current paper is the empirical evaluation of only this prediction. Another prominent prediction of the Ben-Porath model suggests that an increase in the rental rate on human capital will increase future rewards to human capital and hence increase investment in schooling. This prediction is discussed in the concluding remarks.

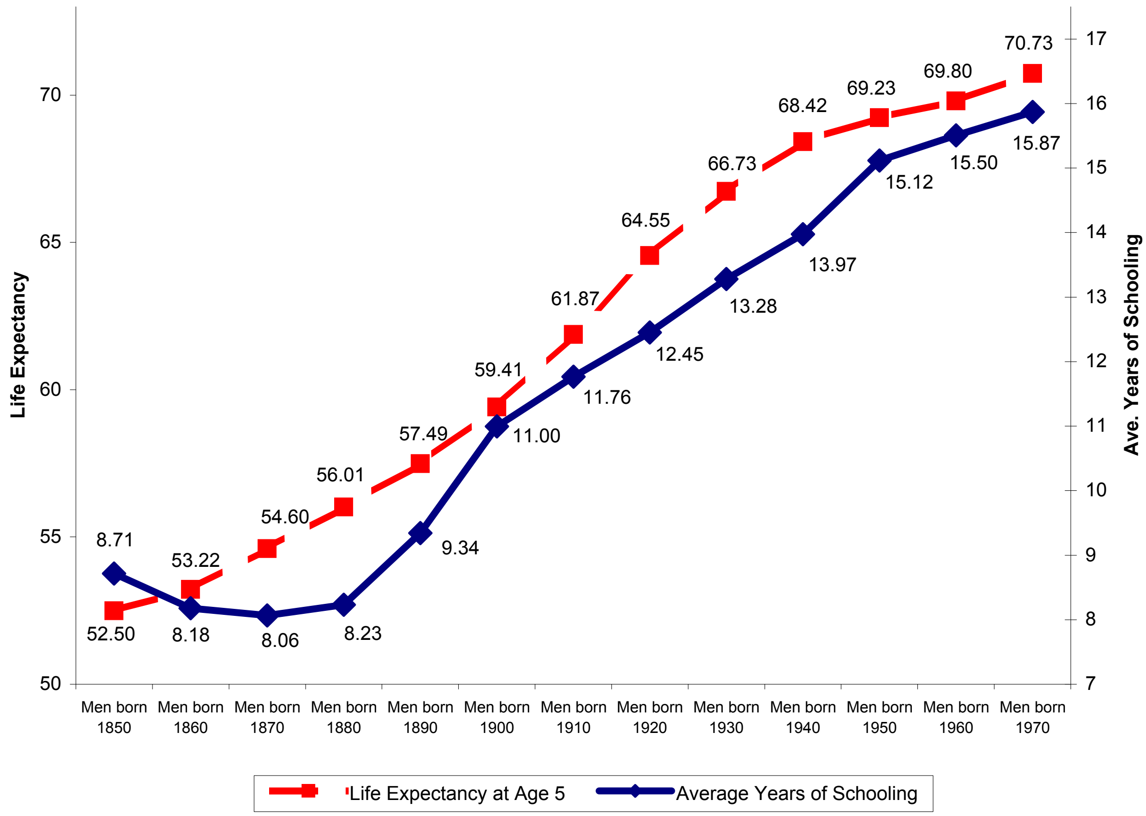

Figure 1: Life Expectancy at Age 5 and Average Years of Schooling by Year of Birth. Sources: Average Years of Schooling are own estimates using IPUMS data and Margo's (1986) methodology. For Data Sources on Life Expectancy see Section 4.1.

Sunde (2005), Boldrin, Jones, and Khan (2005), among others).[2] But while each work emphasizes different aspects, all of these works have two things in common: a common objective, namely, to explain the transition from stagnation to growth and a shared crucial reliance on the Ben-Porath mechanism.

Jena, Mulligan, Philipson, and Sun (2008) take the Ben-Porath mechanism one step further and quantify the monetary gains accrued over a lifetime due to this mechanism. Focusing on the gains in life expectancy in the U.S. from 1900 to 2000, their estimates range between $3,711 and $26,505 per capita, in 1996 dollars.

[2]Hazan and Zoabi (2006) criticize this literature, arguing that in a setting where parents choose fertility and the education of their children, a rise in the life expectancy of the children, increases not only the returns to quality but also the returns to quantity, mitigating the incentive to invest more in the children's education.

The Ben-Porath mechanism, however, is not just a legacy of the past. In the context of comparative development, several scholars, using different tools, have tried to evaluate the causal effect of life expectancy on investment in human capital. Acemoglu and Johnson (2006) and Lorentzen, McMillan, and Wacziarg (2008) find no effect of life expectancy on school enrolment using cross country regressions, whereas Bils and Klenow (2000) and Manuelli and Seshadri (2005) find positive effects, although of a different order of magnitude, using calibrated general equilibrium models.[3] The causal effect of life expectancy on investment in human capital is studied in the development literature as well. Jayachandran and Lleras-Muney (2009) find significant effect of a decline in maternal mortality risk on female literacy rates and school enrolment in Sri Lanka, and Fortson (2007) finds a large negative effect of regional HIV prevalence on individual human capital investment in sub-Saharan Africa.

Finally, the Ben-Porath mechanism is also mentioned outside the academic realm. In the public debate on the benefits of improving health in developing countries, a popular view suggests that while improving the health and longevity of the poor is an end in itself, it is also a means to achieving economic development. This view is best reflected in the report of the World Health Organization's Commission on Macroeconomics and Health (2001) that states,

> The gains in growth of per capita income as a result of improved health are impressive, but tell only a part of the story. Even if per capita economic growth were unaffected by health, there would still be important gains in economic well-being from increased longevity. [...] Longer-lived households will tend to invest a higher fraction of their incomes in education and financial saving, because their longer time horizon allows them more years to reap the benefits of such investments (p. 25).

Despite its popularity, the evidence on the Ben-Porath mechanism is brief and mixed, and encompasses the experience of only recent decades. My purpose is to investigate empirically the relevance of this mechanism to the transition from stagnation to growth of today's developed countries.

[3]See also Caselli (2005) and Ashraf, Lester, and Weil (2008). Both works present calibrated values for the elasticity of human capital with respect to the adult mortality rate. The former uses cross country data and the latter use micro estimates.

I do so by noting that there is a fundamental asymmetry between providing support for a hypothesis and refuting it. While meeting a necessary condition is only a prerequisite for providing supportive evidence for a hypothesis, failure to meet a necessary condition is sufficient to refute one. I examine therefore a crucial implication of the Ben-Porath mechanism. Specifically, I argue that although the Ben-Porath mechanism is phrased as the effect of the prolongation of (working) life, it in fact suggests that as individuals live longer, they invest more in human capital, if and only if, their lifetime labor supply increases. Importantly, incorporation of the retirement choice into a version of Ben-Porath's (1967) model does not change the above statement.[4] Section 2 of the paper formulates this argument. Clearly, this statement is true as long as schooling is desired only in order to increase labor market productivity. In Section 9 I discuss several other motives that may positively affect the investment in human capital in response to an increase in longevity.

The discussion above suggests that the necessary condition for the Ben-Porath mechanism can be tested directly, by looking at the correlation between longevity and lifetime labor supply. I therefore suggest estimating the empirical counterpart of the lifetime labor supply, i.e., the expected total working hours over a lifetime (henceforth: ETWH) of consecutive cohorts of American men, born between 1840 and 1970 and of all American individuals born between 1890 and 1970. A positive correlation between ETWH and longevity should serve as supportive evidence for the Ben-Porath mechanism. Conversely, a negative correlation between these two variables would suggest that the Ben-Porath mechanism cannot account for any of the immense increase in education that has accompanied the growth process over the last 150 years.

The ETWH is determined by three factors: the age specific mortality rates, which determine the probability of being alive at each age, and the labor supply decisions along both the extensive and intensive margins at each age. Clearly, holding labor supply decisions constant, the Ben-Porath mechanism suggests a positive effect of longevity on lifetime labor supply and thereby on investment in educa-

[4] An earlier version of this paper, (Hazan 2006), showed that incorporation of a leisure choice does not change the statement made above.

tion.[5] However, the data suggest that the reduction in labor supply along both the extensive and intensive margins outweighs the gains in longevity, leading to a decline in lifetime labor supply. Thus, if one attempts to decompose the observed change in schooling over the relevant period to its different sources, the total effect of the Ben-Porath mechanism enters with a non-positive sign, and it therefore cannot provide an explanation for the observed rise in education.

My approach has two major advantages. Firstly, it relies on sound theoretical prediction and therefore the empirical test is not specific to econometric specifications or structural assumptions. Secondly, it uses the experience of today's developed countries over more than 150 years and can therefore shed light on the long-run economic consequences of the prolongation of life in the developing world.

The rest of the paper is organized as follows. In Section 2 I present a simplified version of the Ben-Porath model to explicitly derive the effect of an increase in life expectancy on education and lifetime labor supply. In Section 3 I present my methodology for the estimation of the ETWH and in Section 4 I describe the data. In Section 5 I present my results for men and in Section 6 I present results for all individuals by combining the labor supply of both men and women. In Section 7 I explore the robustness of the results and in Section 8 I provide suggestive evidence that my results are not confined to the U.S. but are a robust feature of the growth process in nineteenth and twentieth centuries. In Section 9 I discuss the broader implications of my findings and present some concluding remarks.

2 A Prototype of the Ben-Porath Model

In this section I present a simplistic version of the Ben-Porath model. The purpose of this section is to explicitly emphasize the implications of this type of model for the effect of an increase in longevity on lifetime labor supply and

[5] This is the partial, casual effect of life expectancy on education which the literature aims to estimate. See e.g., Acemoglu and Johnson (2006), Lorentzen, McMillan, and Wacziarg (2008) and Jayachandran and Lleras-Muney (2009).

thereby on investment in schooling.[6]

Denote consumption at age t by $c(t)$ and let the utility from consumption, $u(c)$, be twice continuously differentiable, strictly increasing and strictly concave. Assume that labor supply is indivisible so the individual may either be fully employed or retired. Disutility of work, $f(t)$, is independent of consumption and increases in age, $f'(t) > 0$.[7] The individual works until retirement, R, and lives until T, $R \cdot T$. This structure implies that the individual's lifetime utility, V is given by:

$$V = \int_0^T e^{-\rho t} u(c(t))dt \text{ ¡ } \int_0^R e^{-\rho t} f(t)dt,$$

where ρ is the subjective discount rate.

The individual's productivity during the working period is assumed to be equal to his human capital h. The latter is determined by the individual's choice of the length of the schooling period, s, and the human capital production function, $h(s) = e^{\theta(s)}$. Finally, schooling occurs prior to entering the labor market and the sole cost of schooling is foregone earnings. The budget constraint of the individual is then given by:

$$\int_s^R e^{-rt} e^{\theta(s)} dt = \int_0^T e^{-rt} c(t)dt, \tag{1}$$

where r is the interest rate.

Define the Lagrangian associated with maximizing lifetime utility V, subject to the budget constraint, (1), and let λ be the Lagrange multiplier associated with this problem. The first order conditions with respect to $c(t)$, R and s are, respectively:

$$e^{-\rho t} u'(c(t)) = \lambda e^{-rt},$$

[6] The Ben-Porath model allows for continuing investment in human capital during the phase of working life. My simplistic variant of the model does not allow for that. Modeling the schooling decision as in Ben-Porath (1967) will complicate the model, making the derivation of lifetime labor supply analytically intractable. I conjecture, nevertheless, that the results derived in this section would hold under the more realistic structure of the original Ben-Porath model.

[7] This is a conventional way to model the retirement motive. See, for example, Sheshinski (2008) and Bloom, Canning, and Moore (2007).

$$e^{-rs+\theta(s)} \geq \int_s^R e^{-rt+\theta(s)}\theta'(s)dt, \tag{2}$$

and,

$$e^{-\rho R}f(R) \leq \lambda e^{-rR}e^{\theta(s)}. \tag{3}$$

To illustrate the relationship between lifetime labor supply and investment in human capital in the most transparent way, I make two simplifying assumptions. Firstly, I assume that $r = \rho$. This assumption ensures that consumption is constant throughout the individual's life. This property is warranted because the Ben-Porath mechanism is silent with respect to life-cycle considerations of consumption. Secondly, I concentrate on an interior solution for the schooling and retirement choices. This implies that both (2) and (3) hold with strict equality.[8]

Using the budget constraint, the optimal consumption becomes:

$$c = c(s, R) = \frac{e^{\theta(s)}(e^{-rs} - e^{-rR})}{1 - e^{-rT}} \tag{4}$$

and (2) and (3) can be re-written respectively as:

$$\frac{1}{\theta'(s)} = \frac{1 - e^{-r(R-s)}}{r} \tag{5}$$

and,

$$f(R) = u'(c(s, R))e^{\theta(s)}. \tag{6}$$

Note that the left hand side of (5) is the cost to increase schooling to the point where productivity rises by one unit, while the right hand side of (5) is the discounted value of an increase in income by one unit per period over the productive life, $R - s$. Similarly, the left hand side of (6) is the disutility from work at age R, while the right hand side of (6) is the marginal cost of retiring, measured in terms of the loss of utility from foregone consumption.

Inspection of (4), (5) and (6) reveals the effect of longevity on the optimal level of schooling, s and lifetime labor supply, $R - s$. This effect is summarized in the

[8]Sufficient conditions for an interior solution for R are $f(0) = 0$ and $f(T) = \infty$.

following two propositions. The proofs are relegated to the appendix.

Proposition 1 *If $\theta(¢)$ is twice continuously differentiable, strictly increasing and strictly concave, an increase in longevity induces an increase in schooling and in lifetime labor supply.*

Proposition 2 *If $\theta(¢)$ is linear, an increase in longevity induces an increase in schooling and has no effect on lifetime labor supply.*

It follows that if there are no diminishing returns to schooling, changes in longevity positively affect schooling but leave the optimal lifetime labor supply unaffected. Hall and Jones (1999) and Bils and Klenow (2000) argue that in a cross section of countries there are sharp diminishing returns to human capital.[9] In contrast, the typical finding in studies based on micro data within countries is that of linear returns to education. Some argue, however, that the latter studies are more prone to ability bias, which may drive the estimates toward linearity (Card 1995, e.g.). Assuming that the returns to education are (weakly) concave, the effect of an increase in longevity on lifetime labor supply that increases human capital investment, is non-negative.

I conclude from Propositions 1 and 2 that for any reasonable human capital production function, a rise in longevity that induces an increase in the investment in human capital must also induce a rise in lifetime labor supply. It should be mentioned that in an earlier version of this paper, (Hazan 2006), the intensive margin of the labor supply decision was modeled and the results with respect to the effect of longevity on schooling and lifetime labor supply were similar to those summarized in Propositions 1 and 2. I now proceed with my empirical exercise of estimating the ETWH of consecutive cohorts of Americans to see whether their expected lifetime labor supply has indeed increased in parallel to the increase in their longevity and schooling, as the Ben-Porath mechanism predicts.

[9] Most models which analyze long-run growth assume that human capital is strictly increasing and strictly concave with respect to time invested (see Galor and Weil (2000), Kalemli-Ozcan, Ryder, and Weil (2000), Hazan and Berdugo (2002) and Moav (2005), among others). The assumption that $\theta(¢)$ is strictly increasing and strictly concave implies that the rate of return is diminishing, a less restrictive assumption.

3 Methodology

In this section, I explain my methodology for estimating the ETWH of each cohort. Let TWH_c denote the lifetime working hours of a representative member of cohort c. Then $ETWH_c$ is an average of working hours at each age t, $l_c(t)$, weighted by the probability of remaining in the labor market at each age, the *survivor function*, denoted by $S_c(t)$. The ETWH depends, of course, on the age at which expectations are calculated. Formally, the ETWH of an individual aged t_0 who belongs to cohort c is:

$$E(TWH_c | t \geqslant t_0) = \sum_{t=t_0}^{\infty} l_c(t) S_c(t | t \geqslant t_0).$$

Below I explain how I estimate the survivor function, $S_c(t | t \geqslant t_0)$ and then discuss how I deal with the manner in which individuals form their expectations with respect to the relevant variables that determine the ETWH.

3.1 The Survivor Function

To estimate the survivor function, $S_c(t | t \geqslant t_0)$, I estimate the *hazard function*, i.e., the rate of leaving the labor market in the age interval $[t, t + 1)$, and then calculate the survivor function directly. Two factors affect this hazard function: (i) mortality rates–at each age individuals may die and leave the labor market, and (ii) retirement rates–conditional on being alive, at each age individuals choose whether to continue working or to permanently leave the labor market and retire. Specifically, an individual of cohort c who survives to age t_0 and is still alive at age t, leaves the labor market if he dies in the age interval $[t, t + 1)$, an event that occurs with probability $q_c(t)$. If he remains alive, an event that occurs with probability $1 - q_c(t)$, he may choose to retire with probability $R_c(t)$. Applying the law of large numbers, it follows that the *hazard function* for the representative member of cohort c is given by:

$$\lambda_c(t) = q_c(t) + (1 - q_c(t)) \cdot R_c(t), \tag{7}$$

where $q_c(t)$ and $R_c(t)$ are now interpreted as the *mortality rate* and the *retirement rate* of the representative member of cohort c at age t, respectively. Hence, to estimate the hazard function using (7), I need data on mortality and retirement rates for each cohort c at each age t, $t \geqslant t_0$. Finally, the survivor function, $S_c(t|t \geqslant t_0)$ is given by:

$$S_c(t|t \geqslant t_0) = \prod_{i=t_0}^{t} (1 - \lambda_c(i)) \,. \tag{8}$$

3.2 The Formation of Expectations

It is important to understand how individuals form expectations regarding mortality rates, retirement rates and the hours they intend to work over the course of their lives, because most of the investment in human capital predates entry to the labor market. Specifically, I am interested in the way each cohort anticipates its mortality rate at each age, $q_c(t)$, its retirement rate at each age, $R_c(t)$, and the hours it intends to work at each age, $l_c(t)$. At one extreme, one can assume that each cohort perfectly foresees its course of life and hence use the *actual* mortality rates, retirement rates and hours worked of cohort members at each age. I refer to these estimates as *cohort* estimates. At the other extreme, one can assume that each cohort has static expectations and hence use mortality rates, retirement rates and hours worked by age from the cross section at the age at which expectations are formed. I refer to these estimates as *period* estimates. I estimate the ETWH using these two extreme assumptions, assuming that individuals' beliefs about the future are a weighted average of these two extremes.

4 Data

As suggested in Section 3, to estimate the ETWH I need data on three variables: the *expected* mortality and retirement rates and the *expected* working hours. As mentioned in Section 3.2, I need different data for the cohort estimates and the period estimates. In particular, since the cohort estimates require the utilization of *actual* cohort data, I can produce these estimates for cohorts born between 1840 and 1930. In contrast, the period estimates require cross-sectional data and hence I have these estimates for cohorts born between 1850 and 1970.[10] In what follows, each subsection begins by discussing data sources and a general description of each variable. A description of the data for the cohort estimates then follows.[11]

4.1 Mortality Rates

Generally, there are two types of life tables: period life tables and cohort life tables. A period life table is generated from cross-sectional data. It reports, among other things, the probability of dying within an age interval in the concurrently living population. A cohort life table, on the other hand, follows a specific *cohort* and reports, among other things, the probability of dying within an age interval in that specific cohort. If mortality rates at each age were constant over time, the period life table and the cohort life table would coincide. However, if mortality rates were falling over time, the period life table would underestimate gains in life expectancy of each cohort. In my estimation, I employ data from cohort life tables for the cohort estimates and period life tables for the period estimates.

My main source is Bell, Wade, and Goss (1992), who provide both period and cohort life tables from 1900 to 2080.[12] For earlier periods, I use period life tables from Haines (1998). Note that one can construct cohort life tables from the period life table by culling mortality rates for different ages from different years.

Looking across the cohorts I observe that mortality rates have been declining at all ages for men born in 1840 onward. Since I aim to discover whether individuals were expected to increase or decrease their ETWH and decide on their education in relation to that, I am interested in mortality rates at the "relevant ages". Since investment in formal education does not start prior to age 5, and entrance to the

[10]More accurately, men born between 1836-45 are referred to as "men born 1840", men born between 1846-55 are referred to as "men born 1850", etc.

[11]For brevity, I niether discuss nor present the data for the period estimates in detail and only present the period estimates of the ETWH. A discussion of these data can be found in Hazan (2006).

[12]Data for the years 1990-2080 reflect projected mortality.

labor market starts, on average, at age 20, I focus on mortality rates, conditional on surviving to ages 5 and 20.

The available data on mortality can be presented in several ways. One way is to use mortality rates at each age to construct survival curves. These curves show the percentage of individuals who are still alive at each age. A second way is to estimate the life expectancy. Graphically, this is the area under a survival curve. Below I present summary data of these two approaches.

4.1.1 Mortality Rates - Cohort Estimates for Men Born Between 1840 and 1930

Figure 2 plots the survival curves for men born in 1840, 1880 and 1930 who survived to age 20.[13] As can be seen from the figure, survival to each age has been increasing, with the largest gains concentrated in the ages 50 to 75. These gains are translated into sizable gains in life expectancy at age 20. While a 20 year-old man who belongs to the cohort born in 1840 was expected to live for another 43.2 years, his counterpart in the cohort born in 1880 was expected to live for another 45.65 years and their counterpart born in 1930 was expected to live for another 53.01 years. Overall, conditional on surviving to age 20, individuals born in 1930 were expected to live almost 10 years more than their counterparts born in 1840. Finally, there were also reductions in mortality rates at younger ages. The probability of surviving to age 20, conditional on being alive at age 5 has increased from 0.92 for individuals born in 1840 to 0.98 for individuals born in 1930, with most of the increase concentrated in the younger cohorts.[14]

4.2 Labor Force Participation and Retirement Rates

To estimate retirement rates, I first estimate labor force participation rates and then compute the retirement rates between age t and age $t+1$, $R_c(t)$, as the rate

[13] Including all ten cohorts on the same graph hides more than it reveals. I choose the cohort born in 1840 because it is the oldest, the cohort born in 1930 because it is the youngest and the cohort born in 1880 because it is in the middle.

[14] Figures showing the life expectancy at age 20 and the probability of surviving from age 5 to 20 can be found in Hazan (2006).

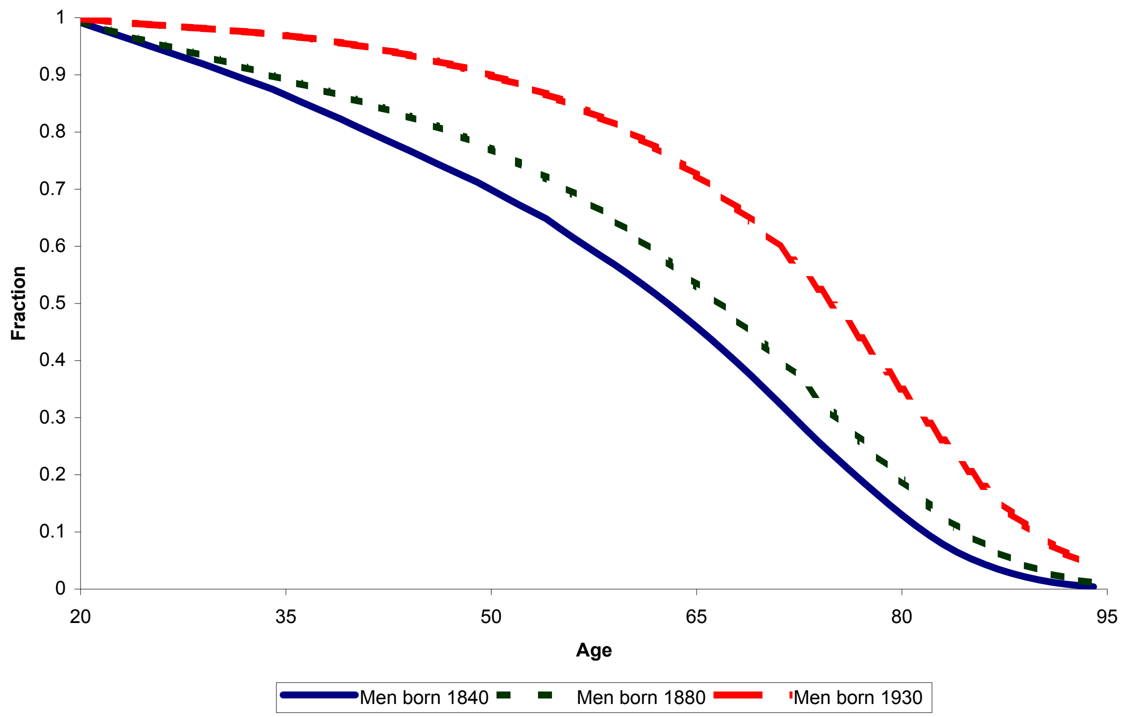

Figure 2: The Probability of Remaining Alive, Conditional on Reaching Age 20 for Men Born in 1840, 1880 and 1930: Cohort Estimates. See text for sources.

of change in labor force participation between age t and $t+1$.[15] To estimate labor force participation rates, I use the Integrated Public Use Microdata Series (IPUMS) which are available from 1850 to 2000 (except for 1890) (Ruggles, Sobek, Alexander, Fitch, Goeken, Kelly Hall, King, and Ronnander 2004). Prior to 1940, an individual was considered as part of the labor force if he or she reported having a gainful occupation. This is also known as the concept of "gainful employment". From 1940 onward, however, the definition changed and an individual is considered part of the labor force if within a specific reference week, he or she has a job from which he or she is temporarily absent, working, or seeking work. Some scholars have argued that the former definition is more comprehensive

[15] Although non-participation at a given age does not necessarily imply permanent retirement, this is what I assume here. This is not a bad assumption since I assume that retirement does not start prior to age 45. For men age 45 and above, the rate of exit and re-entry to the labor force is supposedly rather low. Furthermore, if the decision to leave the labor force and then return is uncorrelated across individuals of the same age and cohort, things would average out because I estimate variables at the cohort level. For expositional purposes, in this section I present the data on labor force participation rates.

than the latter. Moen (1988) suggests a method of estimating a consistent time series of labor force participation rates across all available IPUMS samples, based on the concept of gainful employment. In my estimation I employ the method suggested by Moen.[16]

4.2.1 Labor Force Participation and Retirement Rates - Cohort Estimates for Men Born Between 1840 and 1930

For each cohort I estimate the labor force participation rate based on the concept of gainful employment at each age starting from age 45.[17] Similar to Figure 2, Figure 3 presents labor force participation rates for men born in 1840, 1880 and 1930. As can be seen, from age 55 and over, the younger the cohort is, the faster the decline in its participation. Notice that while participation at age 45 is about 96-97 percent for all three cohorts, by age 60 it declines to 89 percent for men born in 1840, 80 percent for men born in 1880 and 76 percent for the men in 1930. By age 70, the estimates are 61 percent, 48 percent and 29 percent, respectively.[18] Thus, while the fraction of those who survive to each age has increased, the fraction of those who have already retired has increased as well. In Section 5.1, I combine the survival and retirement rates to obtain the fraction of those who remain in the labor market at each age, $S_c(t|t \geqslant t_0)$.

[16] See also Costa (1998a), Chapter 2.

[17] I assume that participation rates are constant for all cohorts between age 20 and 45. The data support this claim firmly. In addition, from age 75 and over, there are too few observations in each cell. Hence I estimate participation in 5-year intervals (75-9, 80-4, 85-9 and 90-4) and use a linear trend to predict participation at each age. Finally, members of the cohort born in 1920 were 84 years old in 2000 and members of the cohort born in 1930 were 74 years old in 2000. Hence for the cohort born in 1920 I use the participation rates of the cohort born in 1910 at ages 85-94 and for the cohort born in 1930 I use the participation rates of the cohort born in 1920 at age 75-84 and the participation rates of the cohort born in 1910 at ages 85-94.

[18] The long-run decline in labor force participation at age 55 and above is discussed by Costa (1998a) and Moen (1988). Lee (2001) discusses the length of the retirement period of cohorts of American men born between 1850 and 1990.

Figure 3: Labor Force Participation for Men born in 1840, 1880 and 1930: Cohort Estimates. See text for sources.

4.3 Hours Worked

Questions about hours worked last week or usual hours worked per week were not asked by the U.S. Bureau of the Census prior to 1940. Hence, it is not possible to estimate a consistent time series of hours worked by age and sex from micro data over my period of interest, 1860-present. Whaples (1990), which is probably the most comprehensive study on the length of the American work week prior to 1900, puts together the available aggregated time-series data from as early as 1830 to the present day. Clearly, such series suffer from biases due to the aggregation itself (e.g., changes over time in the workers' age composition, the fraction of part-time workers, the fraction of women in the labor force and so forth), due to sampling of different industries (e.g., manufacturing vs. all private sectors vs. all sectors of the economy) and a host of other reasons.

Whaples (1990) reports two time series for the pre 1900 period: the Weeks and the Aldrich series. The former suggests that the average work week was 62 hours in 1860, 61.1 hours in 1870 and 60.7 hours in 1880, while the latter suggests that the average work week was 66 hours in 1860, 63 hours in 1870, 61.8 hours in 1880 and 60 hours in 1890.

During the last quarter of the nineteenth century, state Bureaus of Labor Statistics published several surveys of the economic circumstances of non-farm wage-earners. I rely on nine such surveys published between 1888 and 1899, all of which contain information on individuals' daily hours of work, their wages, age and sex, as well as other personal characteristics.[19] Specifically, I combine the surveys from California in 1892, Kansas in 1895, 1896, 1897, and 1899, Maine in 1890, Michigan stone workers in 1888, Michigan railway workers in 1893 and Wisconsin in 1895. Altogether I have data on 13,515 male workers.[20] I use this combined dataset to generate an estimate of hours worked by males for 1890. Average hours worked by males yields an estimate of 10.2 hours per day, or 61.2 per week.[21] The micro data set allows me to study the distribution of hours worked across the male population in more detail. The data suggest that average weekly hours did not vary much by age: although hours are somewhat higher at ages 20-29 and 30-39, 61.7 and 61.8 respectively, they were only reduced to 60.2, 60.5, 60.3 and 60.2 for the age groups 40-9, 50-9, 60-9 and 70-9, respectively. Across the wage distribution, however, there is more variation. The work week of individuals whose wages are in the 10$^{\text{th}}$ percentile consisted of 62.15 hours while that of individuals whose wages are in the 90$^{\text{th}}$ percentile consisted of only 56.53 hours.

Starting in 1900, in contrast, consistent time-series on hours worked both by men,

[19] The data are available through the Historical Labor Statistics Project, Institute of Business and Economic Research, University of California, Berkeley, CA 94720. See Carter, Ransom, Sutch, and Zhao (n.d.).

[20] Costa (1998b) argues that when these data sets are pulled together, they represent quite well the occupational distribution of the 1900 census and the 1910 industrial distribution. Hence I assume that they represent the U.S. population at that time.

[21] Hours reported in these data sets are per day. As discussed in Costa (1998b), the 1897 Kansas data set included a question on whether hours worked were reduced or increased on Saturday. Nine percent reported that hours were reduced, 14 percent reported that hours were increased and 76 percent that they remained the same. Sundstorm (2006) also argues that the typical number of working days per week in the late nineteenth century was 6. Hence, I assume a 6-day work week.

women and all individuals are available from Ramey and Francis (2009), which are based on Kendrick (1961).[22] For my main results of ETWH for men, I use the time series of hours for males age 14+. These data, however, present hours worked by *person* and not per worker. Hence, to transform this data into hours per worker, I estimate employment rates for males age 14+ from Census data and divide the hours per person by the fraction of men employed in each year. The resulting time-series suggests that weekly hours per male worker fluctuated at around 50 hours between 1900 and 1925. It then sharply declined for about a decade during the Great Depression, rebounded to almost 57 hours a week during war time in the years 1943 and 1944, and then started its long run decline from about 45 hours a week in 1946 to about 36 hours by 1970. Since then it has fluctuated at around this value.[23]

4.3.1 A Baseline Time Series for Hours

The discussion above highlights several obstacles in generating a consistent time series of hours worked at each age t for each cohort c. Firstly, in some series the sample consists of men and women while in others it consists only men. Secondly, some series consist of only part of the economy while others report on all sectors of the economy. Thirdly, over time, there is a change in the pattern of hours worked over a lifetime: in the 1890s and in 1940, hours by age did not vary much, but starting in 1950, hours by age varied substantially.[24] These issues posit a problem in generating consistent time series of hours worked by age for each cohort.

In an attempt to overcome these obstacles, I make the following assumptions. Firstly, for the period 1860-1880, I take the Weeks estimates which are lower than the Aldrich estimates for all years: 62 hours in 1860, 61.1 hours in 1870 and 60.7 hours in 1880. For 1890, I take my estimate from the micro data sets published

[22] The data are available at
http://econ.ucsd.edu/~vramey/research.html/Century_Public_Data.xls

[23] See also Jones (1963) which documents average weekly hours in manufacturing for the years 1900-1957.

[24] Hazan (2006) presents the cross-sectional relationship between age and hours for various years.

Figure 4: Weekly Hours Worked by Men, 1860-Present. See text for sources.

by the state Bureaus of Labor Statistics, 61.2 hours a week.[25] For the years 1900 to present I use the time series of Ramey and Francis (2009) for males age 14+, adjusted to account for the employment rate as discussed above in Section 4.3. Secondly, I have to overcome the changes in the pattern of hours worked over the life-cycle of the different cohorts. Given the data limitations, in the baseline estimates I do not allow for any age variation in hours in a given year. Under this assumption, the only difference in annual hours worked across cohorts arises from the year of entry and year of retirement from the labor market.[26] Figure 4 displays the time-series for weekly hours worked by males used for the main estimates of ETWH presented in Section 5.

[25]Since I have very few observations for the period 1860-1900 I use a quadratic fitting curve to assign values for years in which data are missing.

[26]Figures 9, 11, 12 and 13 present estimates of ETWH both for men and all individuals using data taken solely from Ramey and Francis (2009), which allow me to utilize age-year variation in hours worked. These estimates, however, are only available for a subset of cohorts.

For each cohort in my cohort estimates I use a subset of this series. For example, men born in 1880 joined the labor market in 1900 (by assumption, all cohorts enter the labor market at age 20). Since I need data on hours worked until $S_{\text{born 1880}}(t|t \geqslant t_0) = 0$, and this is true for the cohort born in 1880 at age 94, $l_{\text{born 1880}}(t)$ is hours worked from 1900 to 1993.[27] For my period estimates I only need the average hours worked at the age at which expectations are calculated, which, by assumption, is age 5. Hence for the cohort born in 1850, I use average hours in 1855-1864, for the cohort born in 1860, I use average hours in 1865-1874, etc. Finally, since this series is expressed in terms of weekly hours worked and my mortality rates and retirement rates are annual, I convert the hours series to

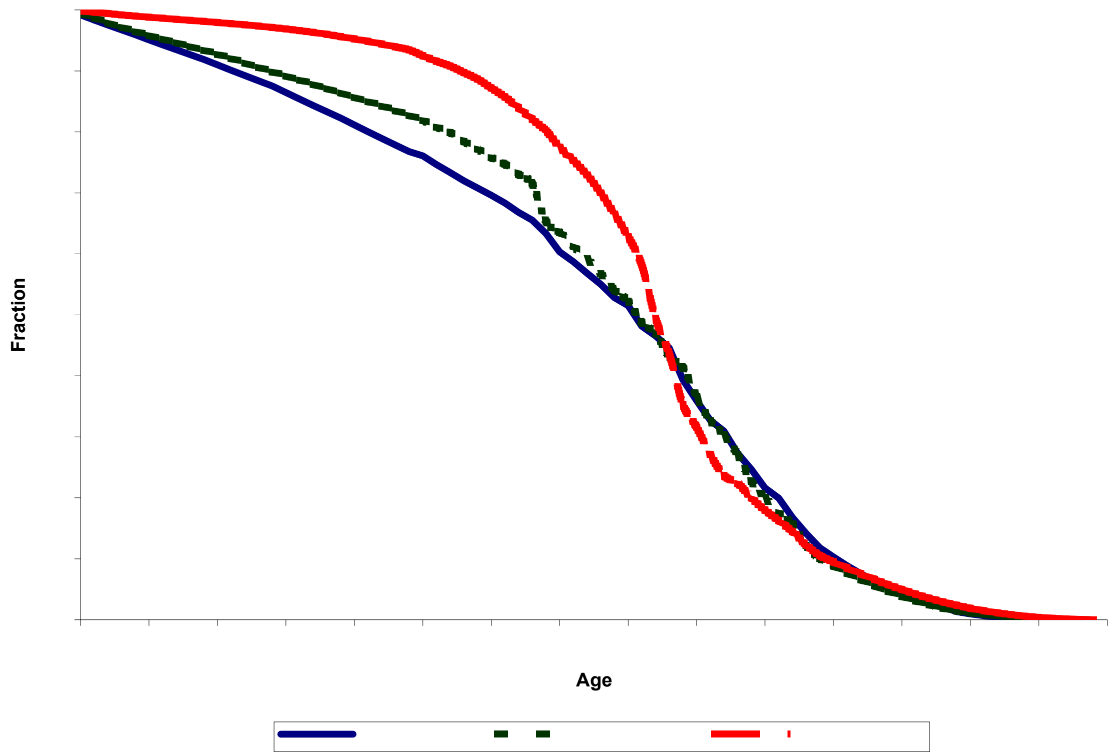

Figure 5: The Probability of Remaining in the Labor Market, Conditional on Entry into the Labor Force at Age 20: Cohort Estimates for Men. See text for sources.

market with the series of hours worked per year to arrive at my main results, the ETWH.

5.1 The Probability of Remaining in the Labor Market - Cohort Estimates for Men Born 1840–1930

In this section I present my cohort estimates of $S_c(tjt \geqslant t_0)$, the fraction of individuals who remain in the labor market at age t, conditional on being alive at age t_0, for members of cohort c. Specifically, I let $t_0 = 20$ and assume that individuals of each cohort enter the labor market at age 20. I then estimate the fraction of those who remain in the labor market at all ages over 20, by estimating the hazard function, (7), and computing $S_c(tjt \geqslant 20)$ using (8). Figure 5 shows the fraction of individuals who remain in the labor market conditional on being alive

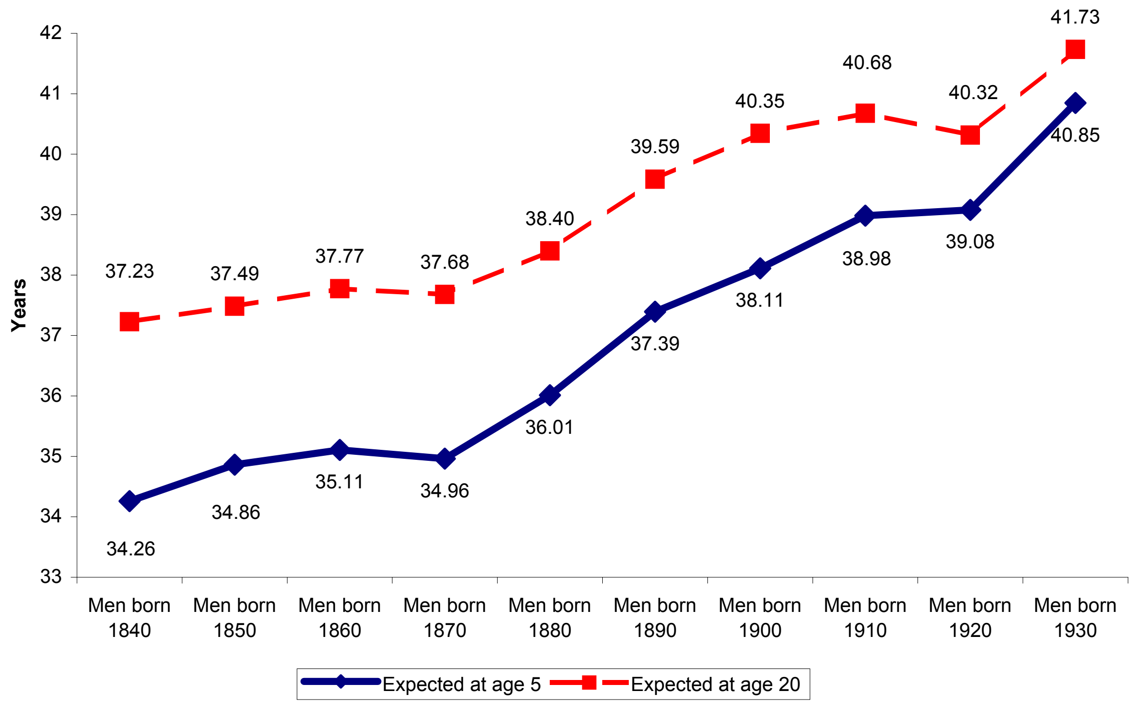

Figure 6: Expected Number of Years in the Labor Market at Age 5 and Age 20, Conditional on Entry into the Labor Force at Age 20: Cohort Estimates for Men. See text for sources.

at age 20 and on entering the labor market at that age. Given my assumption that participation rates remain constant from age 20 to age 45, it is evident from (7) that the fraction of individuals who participate in the labor market over the age interval 20-45 is affected solely by death rates. Since it was shown in Section 4.1.1 that mortality rates have been declining monotonically over time, it is not surprising that the fraction of those who participate in the labor market is higher for younger cohorts than for older ones, up to age 45. However, from age 55, the two variables that affect the fraction of those who participate in the labor market work in opposite directions. As a result, while this fraction is higher at younger ages for the younger cohorts, the curves for men born in 1840, 1880 and 1930 intersect at about the age of 63.[31]

It is worth noting that the area under each such survival curve is the expected number of years each cohort is expected to be working in the labor market. Fig-

[31]In fact this is the pattern across all the cohorts.

ure 6 plots the number of years that each cohort was expected to work, for individuals who survive to age 20, assuming that entry age is fixed at 20.[32] As can be seen from this figure, the representative member of the cohort born in 1840 sured by the ETWH of consecutive cohorts has been declining monotonically. The oldest cohort, born in 1840, was expected to work 115,378 hours in its lifetime. In contrast, the youngest cohort, born in 1930, was expected to work only 81,411 hours. This amounts to a decline of more than 29 percent between men born in 1840 and 1930, an average decline of more than 2.5 percent between two adjacent cohorts.

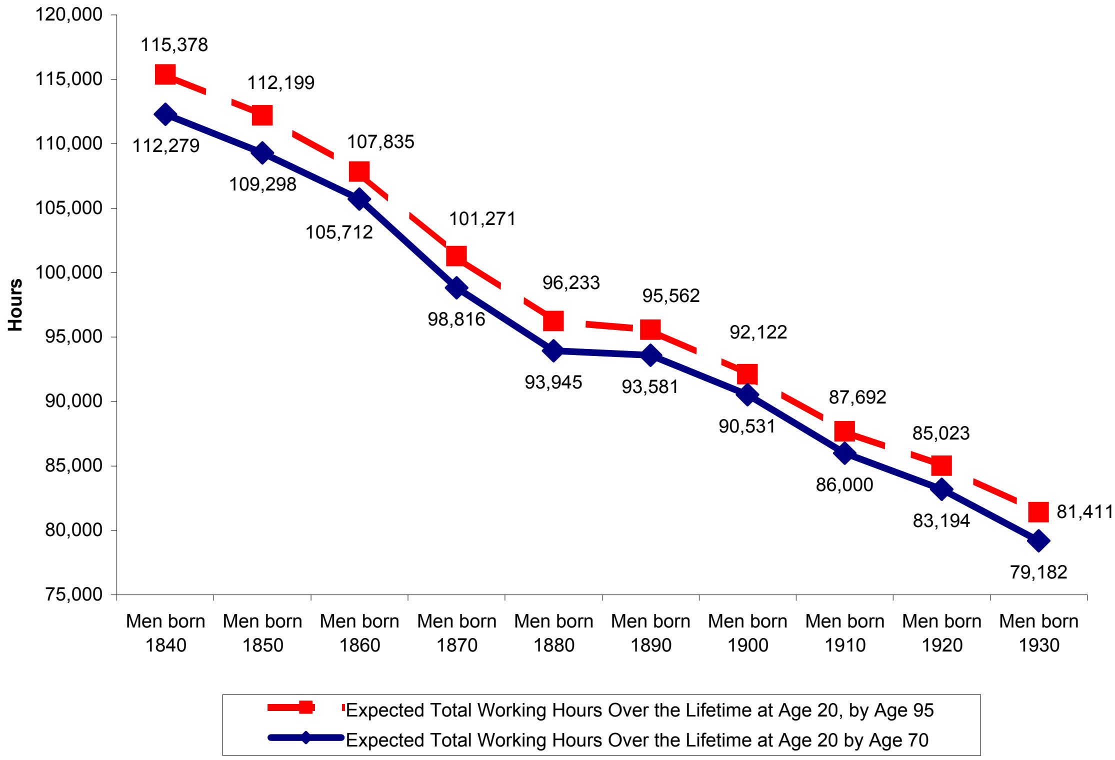

Figure 7: Expected Total Working Hours over the Lifetime of Consecutive Cohorts of Men Born Between 1840 and 1930. Individuals Are Assumed to Enter the Labor Market at Age 20: Cohort Estimates are Calculated at Age 20. See text for sources and estimation procedure.

The probability of surviving to age 20 from age 5, however, has increased from 0.92 for the cohort born in 1840 to 0.98 for the cohort born in 1930. Since investment in education begins at age 5, one might rightfully argue that the age at which expectations should be calculated is age 5.[34] This is what I do in Fig-

[34]Recall that while expectations are calculated at age 5, it is assumed that the age of entery the labor market is 20.

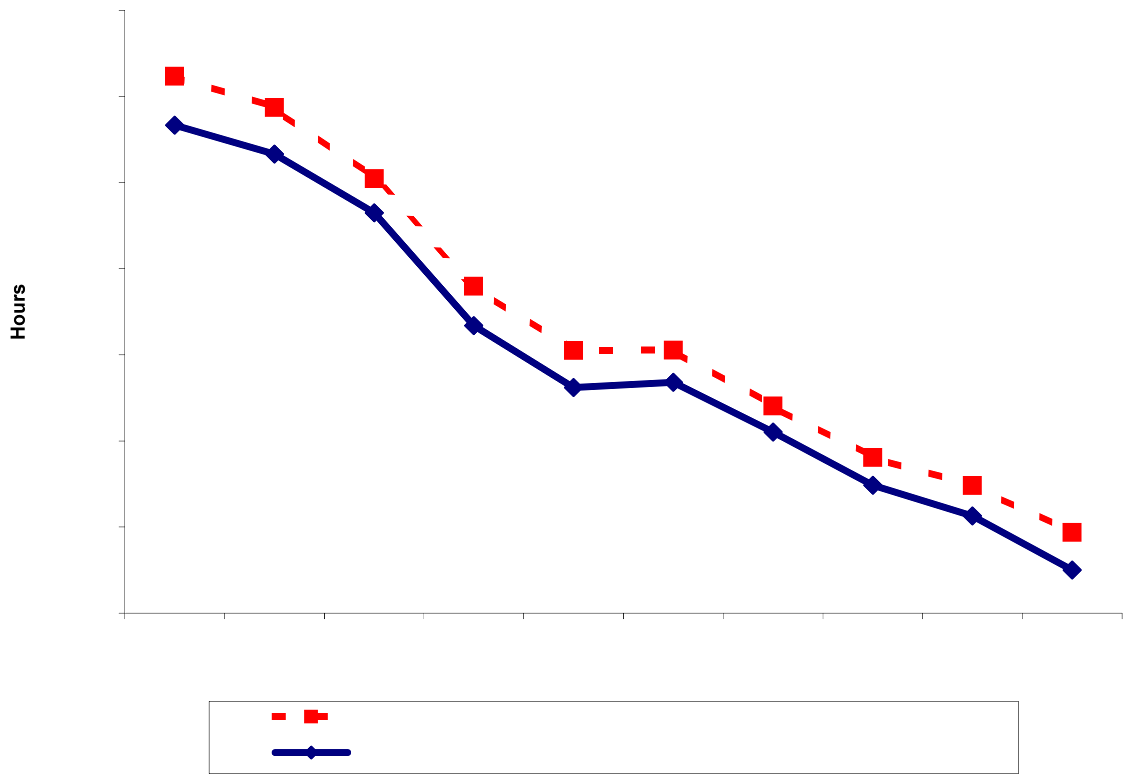

Figure 8: Expected Total Working Hours over the Lifetime of Consecutive Cohorts of Men Born Between 1840 and 1930. Individuals Are Assumed to Enter the Labor Market at Age 20: Cohort Estimates are Calculated at Age 5. See text for sources and estimation procedure.

ure 8. As can be seen, although the difference in the ETWH between the cohorts has narrowed, it is still substantial: while members of the earliest cohort were expected at age 5 to work for 106,176 hours over their lifetime, their counterparts born ninety years later, were expected at that age to work for 79,684 hours. This amounts to a decline of nearly 25 percent between men born in 1840 and 1930, an average decline of more than 2 percent between two adjacent cohorts. Finally, note that in both figures, the decline in ETWH is monotonic across the cohorts.

The main advantage of the estimates presented in Figures 7 and 8 is that they encompass ten cohorts of men born over a period of ninety years. They suffer, however, from two disadvantages, due to the time-series of annual hours-worked used in the estimation. Firstly, the hours series used for these estimates combines different sources for the pre 1900 and post 1900 period. Secondly, it does not allow for age-year variation in hours worked. To alleviate concerns that the declining trend in ETWH is generated due to potential biases in the time-series of hours worked used, I employ data on hours worked by men from 1900 to 2005, computed by Ramey and Francis (2009). These data enable me to overcome the two shortcomings just mentioned, at the expense of obtaining cohort estimates of the ETWH of men born between 1890 and 1930.[35] Given that Ramey and Francis report hours per person by age groups with the youngest age group containing men aged 10 till 13, I assume that expectations are formed at age 10, and remove my earlier assumption that men of all cohorts enter the labor market at age 20.

Figure 9 presents the cohort estimates of ETWH for men born 1890-1930, using Ramey and Francis' data.[36] A few points are worth mentioning. Firstly, similar to the estimates presented in Figures 7 and 8, ETWH is monotonically decreasing across cohorts. Secondly, although the estimates based on Ramey and Francis' data are somewhat larger than those presented in Figures 7 and 8, the difference across cohorts is almost constant. Finally, the decline across cohorts does not spring from different behavior at very old ages: the difference between the ETWH by age 95 and by age 70 is almost constant.

5.3 ETWH: Period Estimates

One reason to present the period estimates is that assuming that individuals perfectly foresee their entire lifetime may be a strong assumption. Hence, I also present the period estimates for ETWH for men born between 1850 and 1970. Figure 10 presents the period estimates for ETWH until age 79, assuming that expectations are taken at age 5.[37] While the period estimates series does not mono-

[35]The Ramey and Francis' data comprise hours per person and not per worker. I therefore adjust my methodology such that I define the survivor function as the probability of being alive and weight it by hours worked per person, a series which already takes into account the participation decision, conditional on being alive.

[36]Men born 1920 were of age 85 in 2005 and men born 1930 were of age 75 in 2005. I assume that men born 1920 work the same number of hours at ages 86-95 as men born 1910. Similarly, I assume that men born 1930 work the same number of hours at ages 75-84 as men born 1920 and the same number of hours at ages 86-95 as men born 1910.

[37]The truncation at age 79 is because the period life tables in Haines (1998) do not report the death rate for individuals age 80 and over. This is not a major problem, however. Since $S(¢)$ is

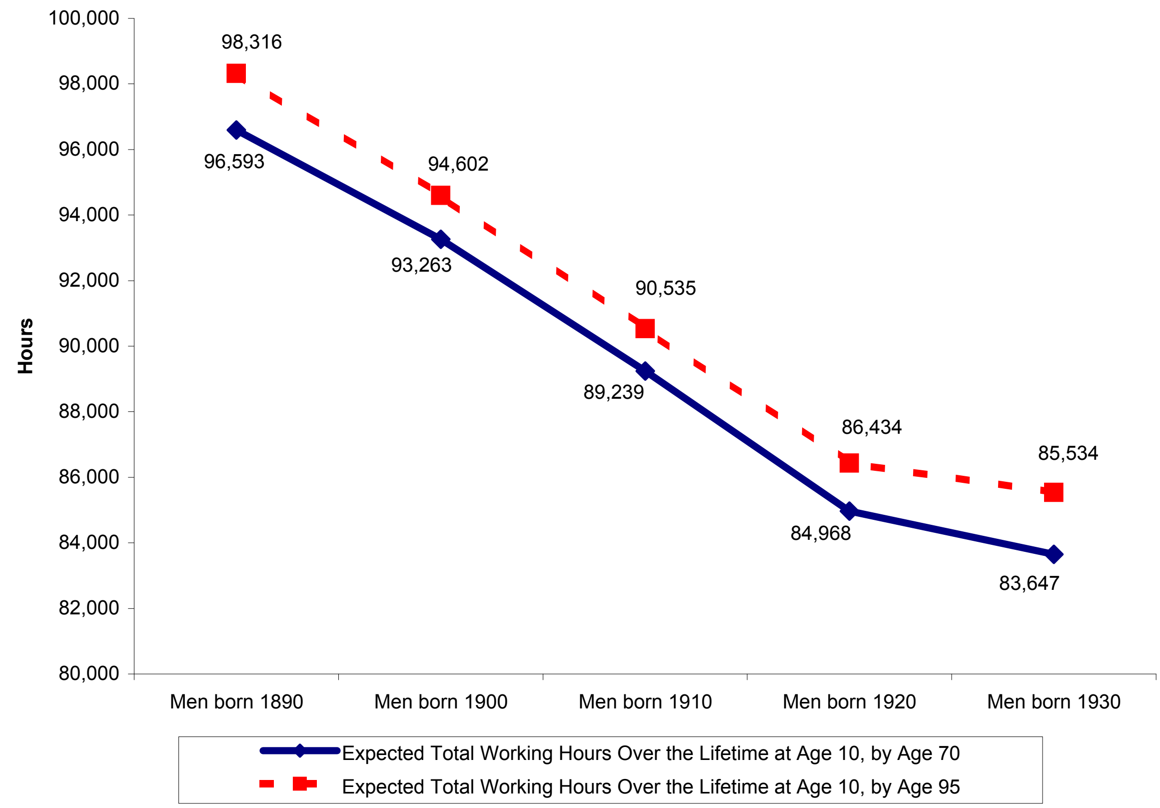

Figure 9: Expected Total Working Hours over the Lifetime of Consecutive Cohorts of Men Born in 1890-1930. Cohort Estimates Calculated at Age 10. Hours series based on Ramey and Francis (2008). See text for sources and estimation procedure.

tonically decline between each adjacent cohorts, e.g., men born 1850 expected to work a thousand hours less than men born 1860, the general trend is clear: ETWH declined by more than 35 percent between men born in 1850 and men born in 1970.

The baseline time series of hours used in these estimates is the one used in the cohort estimates presented in Figures 7 and 8. Note that the nature of the period estimates exposes them to a larger biases than the cohort estimates, for a given bias in the hours-series. Hence, to alleviate the concern that the declining trend

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non-increasing, and since in the data the older the cohort is, the larger the value of $S_c(79)$, when I use $S_c(t), t \cdot 79$, to estimate the ETWH, I under-estimate the differences across cohorts. Estimates of the ETWH by age 70 are not presented, for clarity, because their values are very similar to those presented here.

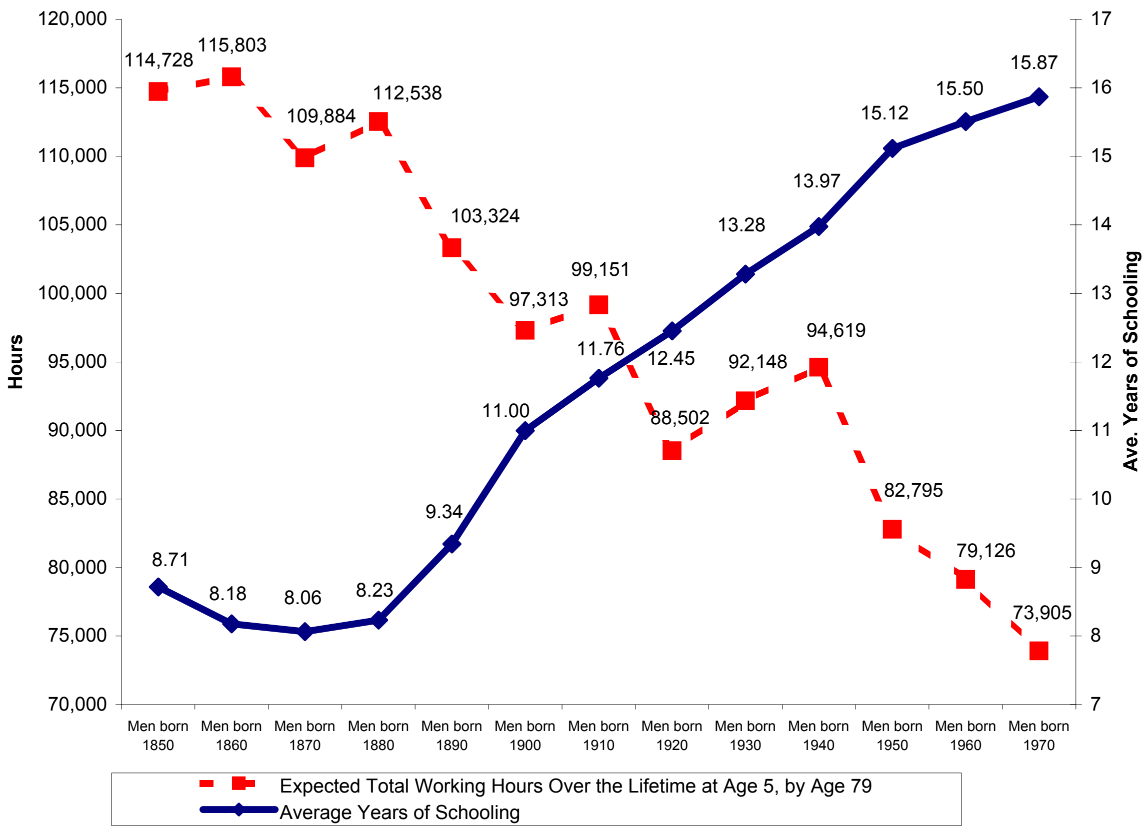

Figure 10: (i) Expected Total Working Hours of Consecutive Cohorts of Men Born in 1850-1970. Individuals Are Assumed to Enter the Labor Market at Age 20: Period Estimates are Calculated at Age 5. (ii) Average Years of Schooling of Consecutive Cohorts Born in 1850-1970. See text for sources.

in ETWH is driven by biases in the time series of hours worked, I use the Ramey and Francis data to derive period estimates, which, similar to the corresponding estimates presented in Figure 9, have the two advantages mentioned in Section 5.2. These estimates are presented in Figure 11. As can be seen from the figure, the period estimates of the ETWH are downward trending, with a decrease of nearly 30,000 hours between men born 1890 and men born 1970.[38]

[38]The ”dip” in the ETWH for men born 1920 results from the far fewer hours worked during the years 1931-1935. Recall that ”men born 1920” in effect were born between 1916-1925 so they were 10 years-old between 1926-1935. The hours-series used for this cohort is the average across these ten years.

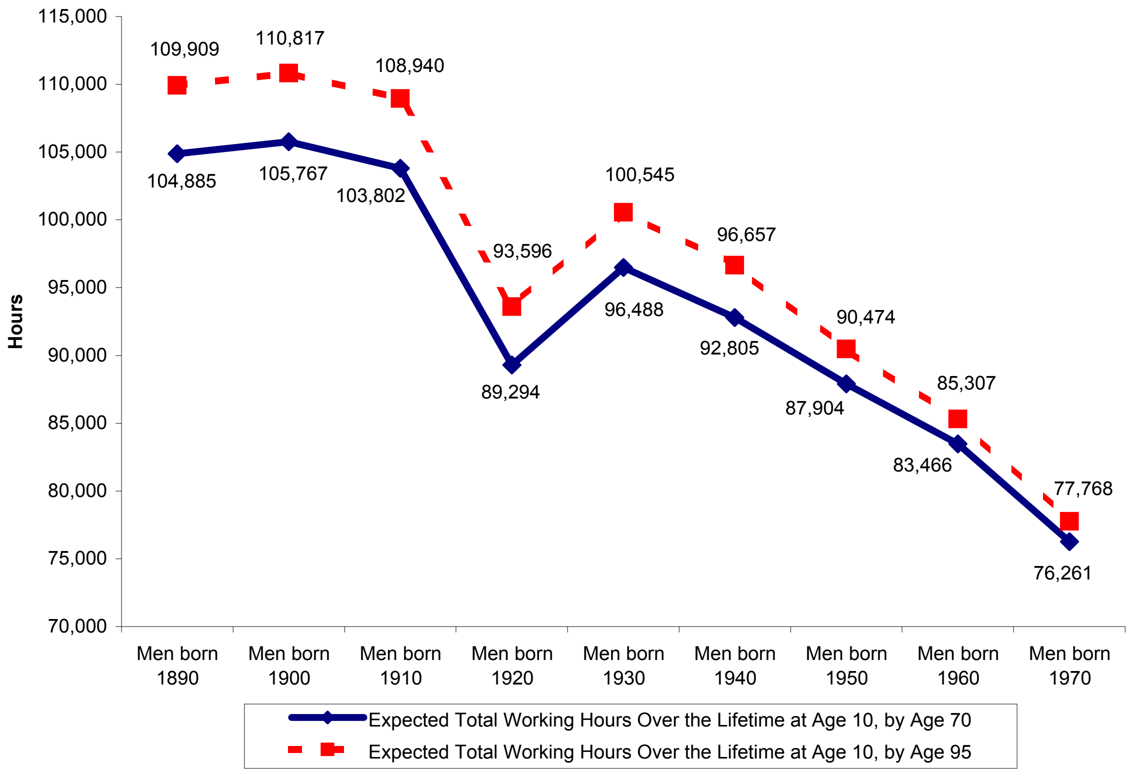

Figure 11: Expected Total Working Hours over the Lifetime of Consecutive Cohorts of Men Born in 1890-1970. Individuals Are Assumed to Enter the Labor Market at Age 20: Period Estimates are Calculated at Age 10. Hours series based on Ramey and Francis (2009). See text for sources and estimation procedure.

6 Results for All Individuals

Thus far, the estimates presented of ETWH were only for men. One may worry, however, that the focus on men may be biasing the results against the Ben-Porath mechanism. To see why, suppose one tested the theory on women instead. One would find that as longevity increased, both education and lifetime labor supply increased, thereby supporting the Ben-Porath mechanism. Thus, in this section I present estimates of ETWH for all individuals by combining mortality data and labor market decisions for both men and women.[39]

Due to data availability on hours worked by all individuals, however, I can only

[39] I thank two referees for raising this point and for suggesting that I make use of the Ramey and Francis data to address this issue.

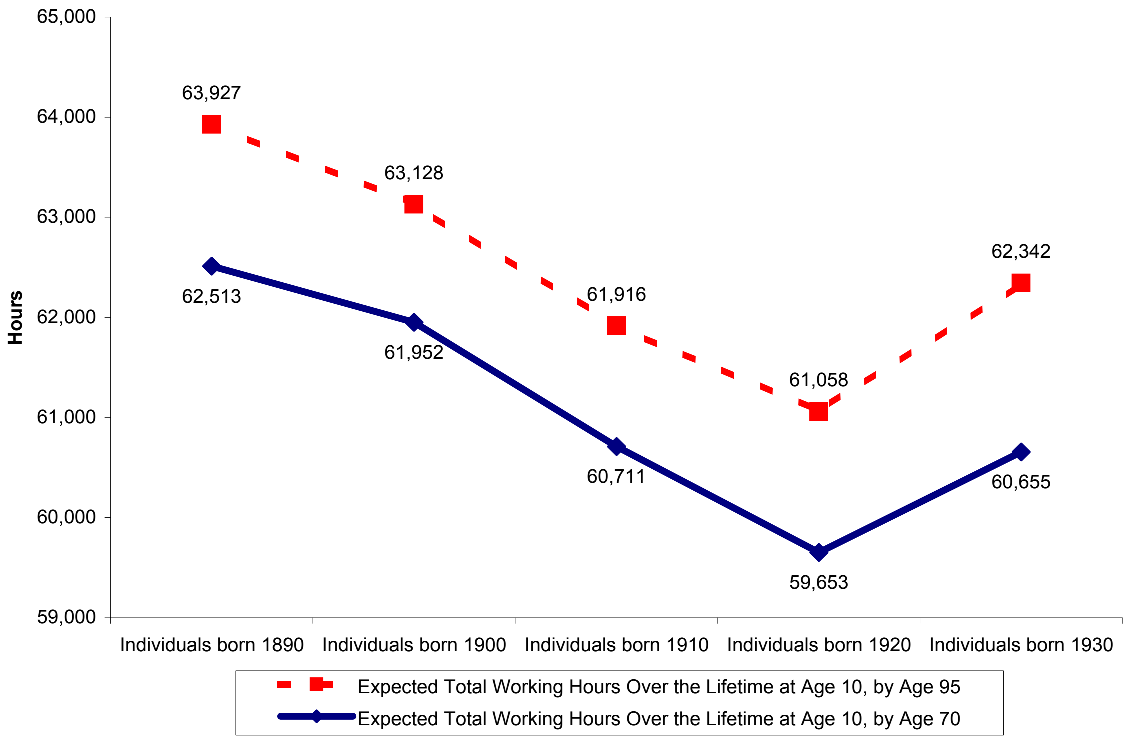

Figure 12: Expected Total Working Hours over the Lifetime of Consecutive Cohorts of All Individuals Born in 1890-1930. Cohort Estimates are Calculated at Age 10. See text for sources and estimation procedure.

present cohort estimates of ETWH for individuals born between 1890 and 1930 and period estimates for individuals born between 1890 and 1970. These are presented in Figures 12 and 13, respectively.[40]

Two main features are worth mentioning. Firstly, the ETWH of all individuals still shows a declining trend across cohorts, although not monotonically across each two adjacent cohorts. The reason for the declining trend is that although average hours of work across men and women were virtually unchanged for those aged 22 to 54, hours fell substantially for the younger and older age groups (Ramey and Francis 2009). It turns out that this fall outweighs the gains in life-

[40]The Ramey and Francis data comprise hours per person and not per worker. I therefore adjust my methodology such that I defined the survivor function as the probability of being alive, and weight it by hours worked per person, a series which already takes into account the of participation decision, conditional on being alive. Mortality data for all individuals have been used.

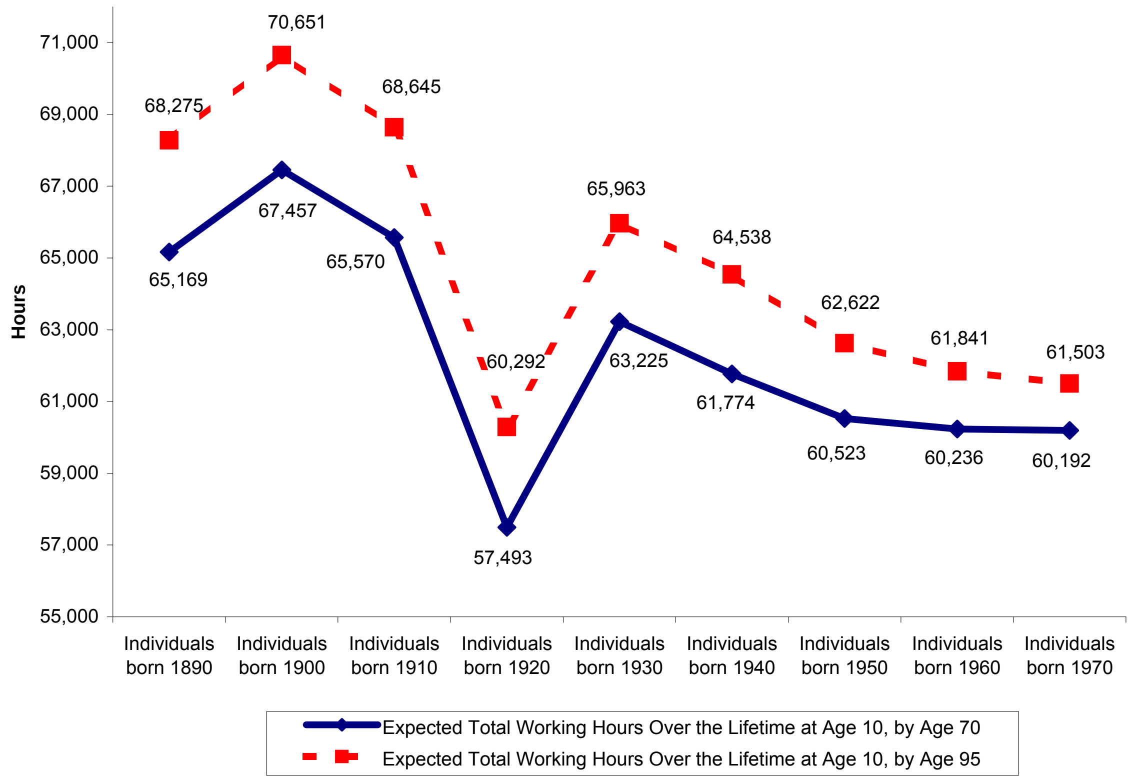

Figure 13: Expected Total Working Hours over the Lifetime of Consecutive Cohorts of All Individuals Born in 1890-1970. Period Estimates are Calculated at Age 10. See text for sources and estimation procedure.

expectancy across the cohorts at study. Secondly, in light of the long-run trend of increasing labor supply of women, the decline in ETWH across cohorts is of a much smaller magnitude, compared to the estimates for men.

7 Robustness of the Results

In this section I explore the robustness of my estimates for the ETWH for men. Some scholars argue that in nineteenth century America, most employment, particularly that in agriculture, was seasonal (Atack and Bateman 1992, Engerman and Goldin 1994). Since seasonality in employment declined over time, my assumption that workers of all cohorts work 52 weeks a year biases upward the difference across cohorts in the ETWH. To explore this possibility I conduct a

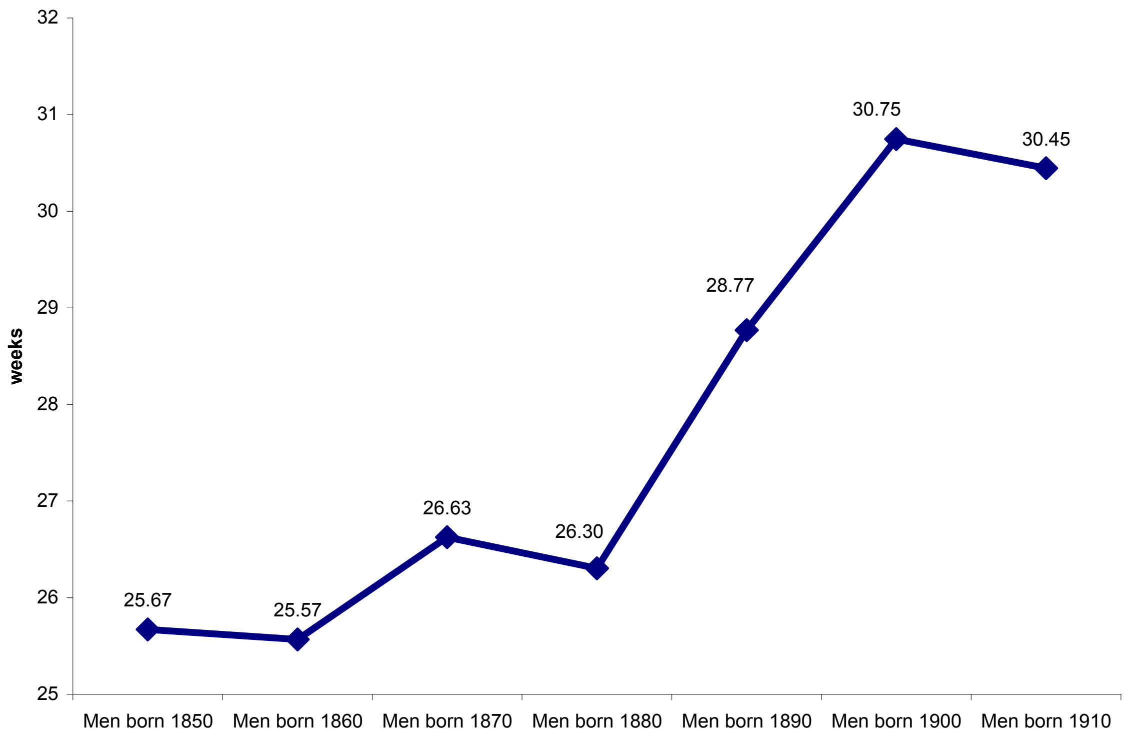

Figure 14: Counterfactual Experiment: Expected Number of Weeks of Employment that would equalize ETWH to that of the Cohort Born in 1970. See text for the derivation of these estimates.

counterfactual experiment. I try to answer the hypothetical question: how many weeks of employment a year does the representative member of the cohorts born between 1850 and 1910 expect to work, such that his ETWH would be equal to that of the representative member of the cohort born in 1970. I then compare the answer to the estimates implied by Engerman and Goldin (1994).

In order for the representative member of the cohort born in 1850 to have his ETWH equal that of the representative member of the cohort born in 1970, he should have expected to work 1,596 hours a year. In 1860, the year at which the representative member of the cohort born in 1850 was 10 years old, the weekly average hours of work was 62.17. Hence, to work 1,596 annual hours the representative member of this cohort should have expected to be employed for about 26 weeks a year. The answer for this hypothetical question for all cohorts born between 1850 and 1910 is presented in Figure 14. As can be seen, for all these cohorts, employment of less than 31 weeks a year was enough to expect a lifetime labor supply that is equal to that of the cohort born in 1970. Note that these numbers imply an expected length of unemployment of almost 5 months a year, which is well above the findings of Engerman and Goldin (1994) and Atack, Bateman, and Margo (2002). Specifically, Engerman and Goldin find that in 1900 the length of unemployment, conditional on being unemployed, was between 3 to 4 months. Yet, the probability of being unemployed in 1900 was less than 50 percent. Taking these two findings together, it follows that the expected months of unemployment did not exceed 2. Similarly, Atack, Bateman, and Margo (2002) find that the full time equivalent months of employment was nearly 11 months a year both in 1870 and 1880.

8 The European Experience

Was the American experience unique? Does the lifetime labor supply of European men display a different time trend? In this section I briefly discuss the data on the determinants of lifetime labor supply in some European countries and compare them to U.S. data.[41] Although the data in this section are somewhat suggestive, my purpose is to show that my results are not unique to the U.S. experience, but rather a robust feature of the process of development of today's developed economies. To this end, I present time series of (i) life expectancies for males at age 5 (Figure 15), (ii) labor force participation of men aged 65 and over (Figure 16) and (iii) annual hours of work of full-time production workers (Figure 17). Figures 15–17 demonstrate remarkable similarities across these countries in the determinants of ETWH, both in terms of the trends and magnitudes. I therefore conjecture that the decline in ETWH across cohorts is not unique to the American experience but a robust feature of the process of development in today's developed economies.

[41] The selection of countries reflects availability of data from the various sources used. References to the various sources are given in the figures.

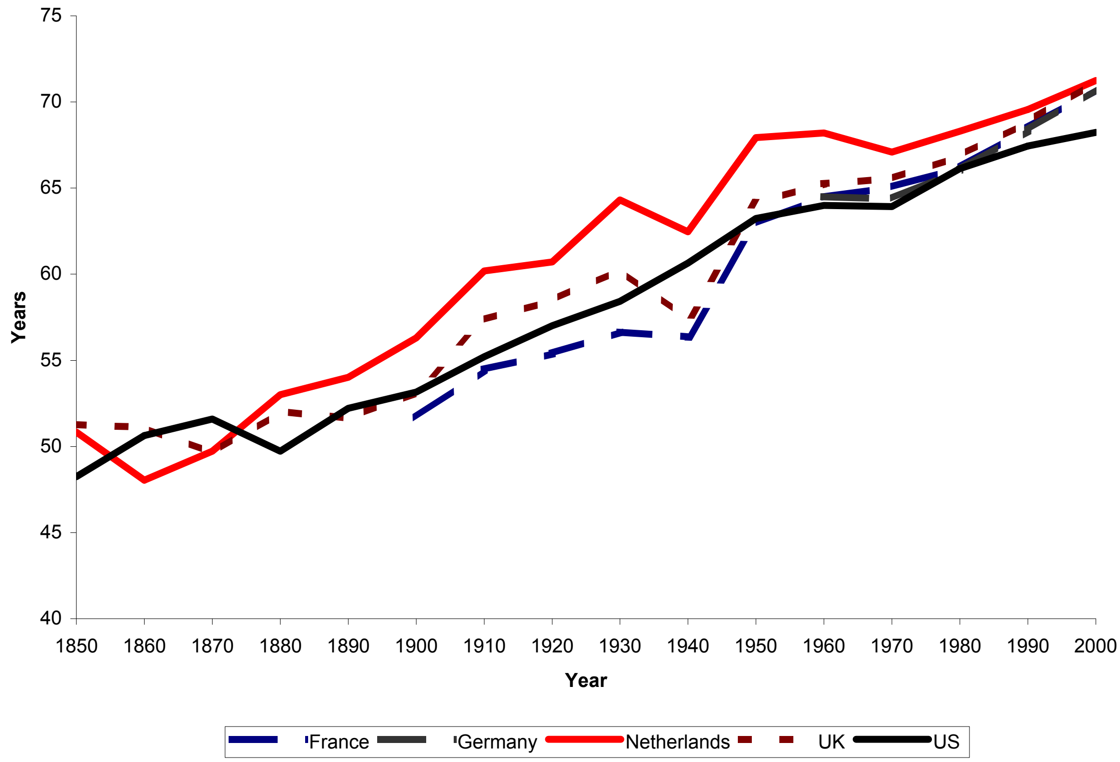

Figure 15: Life Expectancies at Age 5 for Males in Selected Countries, Period Life Tables. Sources: Data for France, Germany, Netherlands and UK are from the Human Mortality Database. Data sources for the U.S. are described in Section 4.1.

9 Concluding Remarks

In this paper, I demonstrate that the commonly utilized mechanism according to which prolonging the period in which individuals may receive returns on their human capital, spurs investment in human capital and causes growth, has an important implicit implication. Namely, that as life prolongs, lifetime labor supply must increase as well. Hence, I argue that this mechanism has to satisfy this necessary condition. Utilizing data on consecutive cohorts of American men, born between 1840 and 1970, I show that this mechanism fails to satisfy its necessary condition. Specifically, the estimates of lifetime labor supply, and average years of schooling, which are shown together in Figure 10, reject this necessary condi-

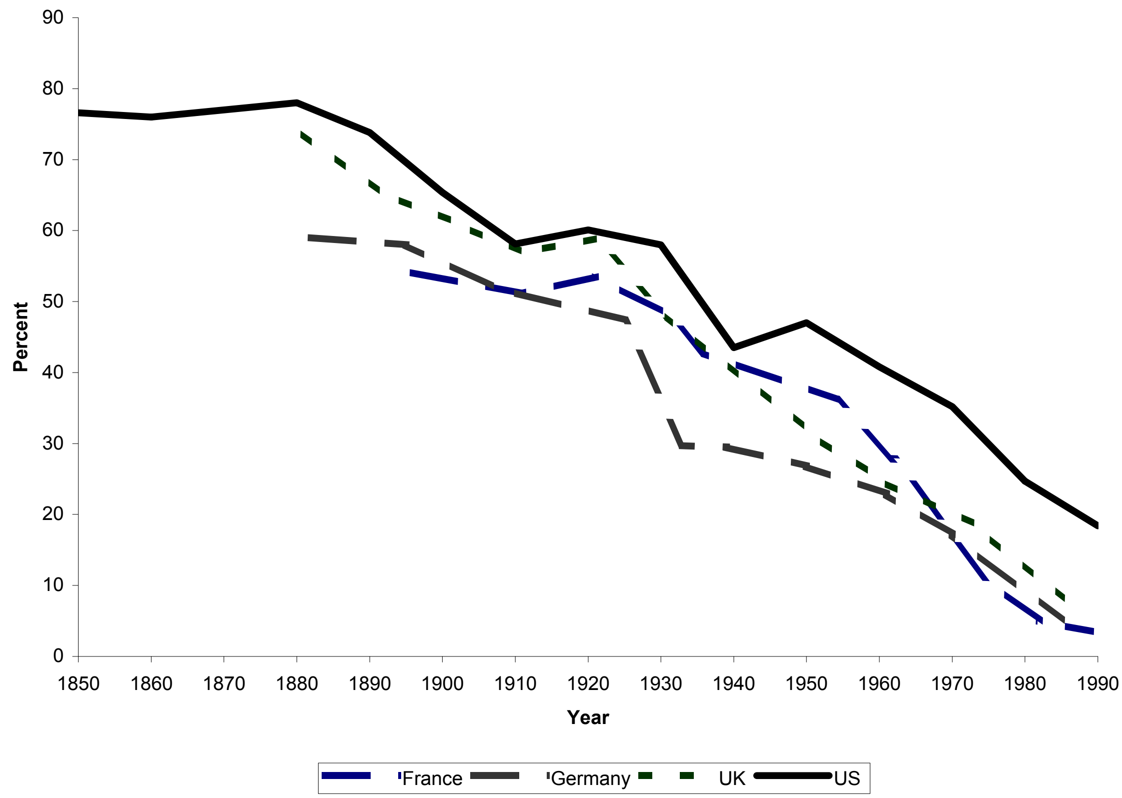

Figure 16: Labor Force Participation of Men Aged 65 and over in Selected Countries. Source: Costa (1998a), Table 2A.2.

tion unequivocally.[42] I also provide suggestive evidence that the determinants of lifetime labor supply are remarkably similar between the U.S. and other developed countries, such as England, France, Germany, and the Netherlands. Thus, I conjecture that my main result that ETWH has declined is a robust feature of the process of development in today's developed economies. I therefore con-

[42]The correlation between the period estimates of ETWH and schooling is -0.93 with a p value of 0, and between the cohort estimates of ETWH and schooling is -0.85, with a p value of 0.0081. One may argue that hours per school day may have been reduced as well, challenging the argument that schooling has been increasing. Ramey and Francis (2009) argue that the average weekly hours spent in school by individuals in the age group 14-17 has increased from 1.4 in 1900 to 20.2 in 1970 and has been fluctuating around this value since then (see their Table 3). Goldin (1999) provides data on the average length of the school term and the average number of days attended per pupil enrolled. Both series show monotonic increases from the school year 1869-70 (which is the earliest data point of this series). For example, the average number of days attended per pupil enrolled has increased from about 80 days in the school year 1869-70, to nearly 100 in the school year 1899-1900, and to 150 day in the school year 1939-40.

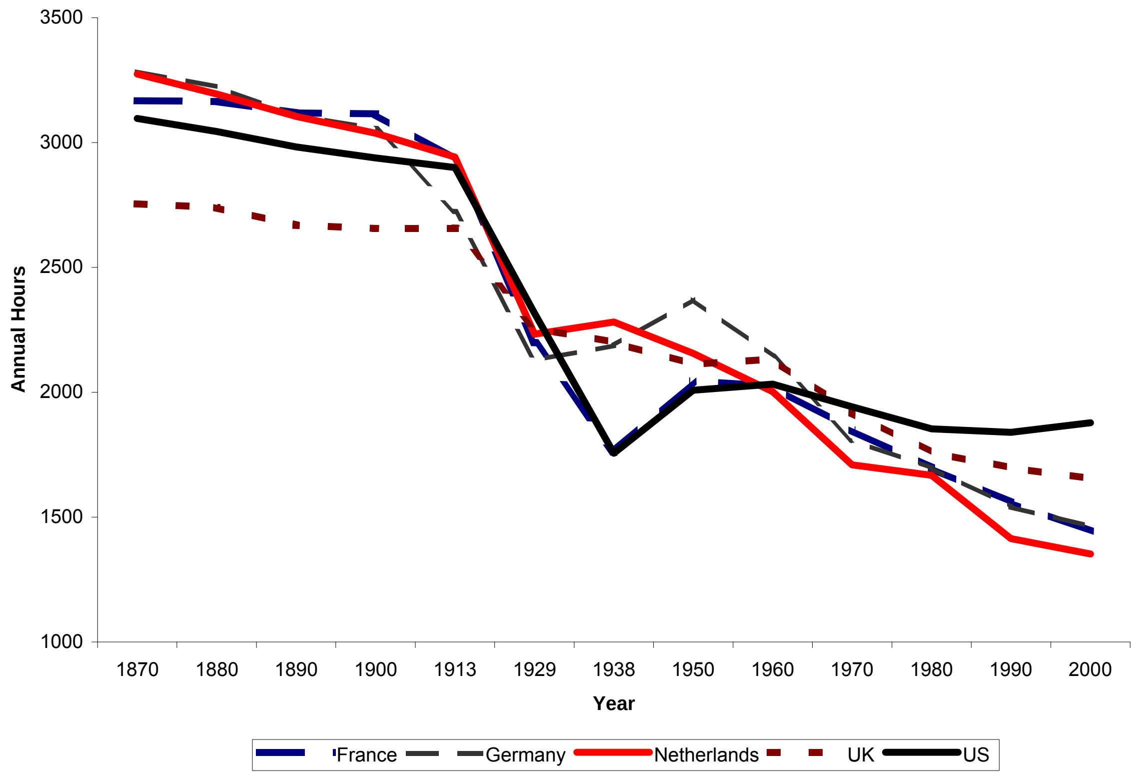

Figure 17: Annual Hours Worked by Full-Time Production Workers in Selected Countries. Source: Huberman and Minns (2007)

clude that the Ben-Porath mechanism had a non-positive effect on investment in education, and therefore, cannot account for any of the immense increase in educational attainment observed over the last 150 years.

My results lend credence to mechanisms that emphasize an increase in the *net* return to private investment in human capital. One possible candidate is technological progress which increases the economic return to human capital.[43] Another candidate is public education which increases the net private returns to human capital by reducing the cost of acquiring education (Galor and Moav 2006).

My results have implications at a broader level as well. In the recent debate on the *fundamental* causes of long run growth, several scholars have advocated the "Geography" hypothesis. According to this hypothesis, exogenous differences in

[43]See Galor and Weil (2000) for a growth model driven by the interplay between human capital and technological progress, and Acemoglu (2007) for a theoretical analysis of the interplay between factors' supply and the nature of technological change.

the environment are the fundamental cause of long run growth. One important difference is the "disease burden" in the tropics, which, compared to temperate zones, results in high morbidity and mortality rates, and in turn, impedes development (Bloom and Sachs 1998, Sachs 2003). My results, however, suggest that an important element of the geography hypothesis is not supported by the data, namely that mortality decline did not play a role in the growth process of the U.S. and Western Europe via the human capital channel. Furthermore, mortality rates in mid 19$^{\text{th}}$ century America were much higher than those existing in Sub-Saharan Africa today.[44] Hence, if lessons of the past guide our perceptions of the future, my results cast doubt on the optimistic view advocated by World Health Organization's Commission on Macroeconomics and Health (2001), as quoted in the introduction.

Some caveats are in place. Firstly, my analysis was conducted for a representative member of each cohort. However, it could be that ETWH have increased for more educated individuals, while declining for less educated workers and that the latter dominated. While this is possible, data limitations preclude me from estimating ETWH in different segments of the skill distribution. In particular, weekly hours worked by wage or education cannot be estimated consistently prior to 1940, and mortality rates by wage or education are not available.

Secondly, one should not conclude from this paper that gains in life expectancy are useless, or that they do not affect growth. For one thing, they are desirable for their own sake, as long as individuals value life (over death). Murphy and Topel (2006) build a model to value longevity and health, based on individuals willingness to pay, and estimate substantial economic gains from both gains in life expectancies and improvements in health over the twentieth century in America.[45]

[44]Using data from the World Development Indicators for the year 2000, I average three measures of mortality across all 48 countries of Sub-Saharan Africa: life expectancy at birth, adult mortality rate and child mortality rate. The figures for Sub-Saharan Africa are 51.61 years, 407 per 1,000 and 147 per 1,000, respectively. The corresponding numbers for mid 19$^{\text{th}}$ century America are 37.23 years, 585 per 1,000 and 322 per 1,000, respectively.

[45]Related to gains in longevity are improvements in health. From a theoretical point of view, however, longevity and health are distinct. While longevity measures the length of (productive) life, health affects the productivity (in school or in the labor market) per unit of time. Interestingly, Bleakley (2007) analyzes the eradication of the nonfatal disease hookworm from the American

Finally, human capital might also make leisure more valuable (Vandenbroucke 2009), provide social status (Fershtman, Murphy, and Weiss 1996), and increase the attractiveness in the marriage market (Gould 2008). Thus, greater longevity can potentially increase the investment in human capital for these reasons, rather than for labor market productivity. Hence, one can build a model in which an increase in longevity reduces total lifetime labor supply and increases education and total welfare, reconciling my findings with the Ben-Porath (1967) model.

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south, and finds a positive effect of the eradication on schooling. Moreover, in a related work (Bleakley 2006), he finds an interesting natural experiment that forms a bridge between health and longevity. In Colombia, most of the malarial areas were afflicted with *vivax* malaria, a high-morbidity strain. However, significant portions of the country suffered from elevated rates of *falciparum*, a malaria parasite associated with high mortality. Bleakley finds that eradicating *vivax* malaria produced substantial gains in human capital and income, while on the other hand, his estimates indicated no such gains from eradicating *falciparum*.

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A Proofs for Propositions 1 & 2

Differentiating (5) and (6) with respect to longevity, T, yields, respectively:

$$-\left(\frac{1}{\theta'(s)}\right)^2 \theta''(s)\frac{ds}{dT} = e^{-r(R-s)}\left(\frac{dR}{dT} - \frac{ds}{dT}\right) \tag{9}$$

and,

$$f'(R)\frac{dR}{dT} = u'(\cdot)e^{\theta(s)}\theta'(s)\frac{ds}{dT} + e^{\theta(s)}u''(\cdot)\frac{dc}{dT} \tag{10}$$

where $\frac{dc}{dT}$ is given by:

$$\frac{dc}{dT} = e^{\theta(s)}\frac{\left[\theta'(s)(e^{-rs} - e^{-rR})\frac{ds}{dT} + r(e^{-rR}\frac{dR}{dT} - e^{-rs}\frac{ds}{dT})\right](1 - e^{-rT}) - re^{-rT}(e^{-rs} - e^{-rR})}{(1 - e^{-rT})^2} \tag{11}$$

Proof of Proposition 1: Solving for $\frac{ds}{dT}$ in equations (9), (10) and (11), using the first order conditions and taking into account the second order conditions yields $\frac{ds}{dT} > 0$. Given that, by the strict concavity of $\theta(\cdot)$, the left-hand side of (9) is positive. Clearly, the right-hand side of (9) is positive, if and only if $\frac{dR}{dT} > \frac{ds}{dT}$, which implies that $\frac{d(R-s)}{dT} > 0$. □

Proof of Proposition 2: Solving for $\frac{ds}{dT} > 0$ in equations (9), (10) and (11), using the first order conditions and taking into account the second order conditions yields $\frac{ds}{dT} > 0$. The linearity of $\theta(\cdot)$ implies that the left-hand side of (9) equals 0. Clearly, the right-hand side of (9) equals 0, if and only if $\frac{dR}{dT} = \frac{ds}{dT}$, which implies that $\frac{d(R-s)}{dT} = 0$. □