Longevity and Lifetime Labor Input:
Data and Implications[*]

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Abstract

Recent growth theories have utilized the Ben-Porath (1967) mechanism according to which prolonging the period in which individuals may receive returns on their investment spurs investment in human capital and cause growth. An important, though sometime implicit implication of these models is that total labor input over the lifetime increases as longevity does. We propose a thought experiment to empirically evaluate the relevancy of this mechanism to the transition from "stagnation" to "growth" of the nowadays developed economies. Specifically, we estimate the expected total working hours over the lifetime of nine consecutive cohorts of American men born between 1840 and 1920. Our results show that despite a gain of almost 9 years in the expectations of life at age 20, the expected total working hours over the lifetime have declined from more than 117,000 hours to less than 90,000 between the oldest and the youngest cohorts. We conclude that the Ben-Porath mechanism have had a lesser effect than previously thought on the accumulation of human capital during the growth process.

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1 Introduction

During the last fifteen years a plethora of research has been investigating the intriguing transition from "stagnation" to "growth". For thousands of years of human existence, the living standards of most of the population has been relatively constant at very low levels, when judged from the perspective of the contemporary developed economies. This long lasting state of stagnation has been suddenly interrupted and a new era of rapid growth in the living standards has emerged, starting from the second half of the nineteenth century. Among economic historians, there seems to be a consensus on the key role played by human capital in that process. There is, however, less of a consensus on the quantitative importance of the various mechanisms that have been suggested for the causes of the massive increase in the investment in human capital.[1]

One mechanism that has gained much popularity in the growth literature during the last decade suggests that prolonging the period in which individuals may receive returns on their investment spurs investment in human capital.[2] Hereafter we shell refer to this mechanism as the "Ben-Porath mechanism," following the seminal work of Ben-Porath (1967). However, despite its popularity, little is known on the causal effect of longevity on education, either in the historical context, or in contemporary world. The purpose of this study is to evaluate empirically the relevancy of this mechanism to the transition from stagnation to growth.[3]

Standard econometric techniques require a convincing econometric identification, namely, some sort of exogenous variation in the explanatory variable. The difficulty of finding such a variation may be one of the reasons for the poor state of knowledge on that relationship.[4] In this research we do not suggest any econometric identification. Instead,

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[1] See Galor (2005) for a comprehensive survey of the historical evolution of income per capita, longevity, and human capital and the theories that have explored these dynamics.

[2] See Ehrlich and Lui (1991), Kalemli-Ozcan, Ryder, and Weil (2000), Boucekkine, de la Croix, and Licandro (2002, 2003), Lagerlof (2003), Cervellati and Sunde (2005), and Soares (2005), among others. Manuelli and Seshadri (2005) argue that differences in demographic structure (fertility and life expectancy) has a relatively large effect on differences in human capital and hence on output per worker in a cross section of countries. This empirical result, however, is built on the same theoretical reasoning common to the theories mentioned in this footnote.

[3] Hazan and Zoabi (2006) have criticized this mechanism on theoretical grounds, arguing that in a model in which parents choose education in combination with the fertility decision, an increase in longevity of the children increases both the marginal utility from quality as well as from quantity, leaving the relative returns unaffected. See also Moav (2005).

[4] Two recent papers present evidence on the casual effect of longevity on growth and education. Acemoglu and Johnson (2005) build an instrument for life expectancy using the pre-intervention distribution of mortality from various diseases around the world and the dates of global health interventions that began in the 1940s. Lorentzen, McMillan, and Wacziarg (2005) pursue a structural econometric approach to explore

we propose a thought experiment to get around the identification problem. We argue that although the Ben-Porath (1967) mechanism is phrased as the effect of the prolongation of (working) life, it implies that as individuals live longer, the total labor input over their lifetime has to increase.[5,6] This hypothesis can be tested directly without getting into econometric issues of identification. We suggest therefore to estimate the expected total working hours over the lifetime (Henceforth: ETWH) of consecutive cohorts and conduct the the following thought experiment. If ETWH of consecutive cohorts of men have increased over time, the empirical relevancy of the Ben-Porath (1967) mechanism would remain unsolved. However, if ETWH of consecutive cohorts have declined, the Ben-Porath (1967) mechanism would be much less relevant than previously thought for the transition from stagnation to growth.

Three factors determine the ETWH of each cohort of individuals. The first factor that affects the ETWH is the mortality rate at each age. Ceteris paribus, lower mortality rates at each age (i.e., higher longevity) implies higher ETWH. Figure 1 shows the expectations of life at age 20 of consecutive cohorts of American men born between 1840 and 1940, taken from both period life table and cohort life table. As can be seen from the figure, the expectations of life at age 20 has been increasing substantially. The data from period life table suggest that the individuals born in 1940 were expected to live about 9 years more than their counterparts, born 100 years earlier. The data from the cohort life table suggest a larger gain over this time period. Similarly, figure 2 presents the expectations of life at age 5 of successive cohorts of American men born between 1840 and 1940 and shows similar pattern.[7] The second factor that affects ETWH is labor force participation rates, or retirement rates. Ceteris paribus, an increase in the retirement rate implies a lower ETWH. Figure 3 shows labor force participation of men of the different cohorts by age. As can be seen, while participation is rather constant until age 55, the younger

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the effect of adult mortality on economic development. Both papers do not find an effect of life expectancy on investment in human capital.

[5]In section 2 we discuss the theoretical circumstances under which total number of hours worked over the lifetime are *nondecreasing* or *strictly increasing* in the length of life and their empirical relevance.

[6]For example, in the calibrated model of Boucekkine, de la Croix, and Licandro (2002), the transition from the slowly growing economy to fast growing economy is accompanied by an increase in life expectancy from 39 years to 73 years, the length of schooling from 13 to 27 years and hence the length of the working period increases from 26 years to 46 years.

[7]In subsection 4.1 we discuss data sources and in subsection 4.1.1 discuss in detail the trends in mortality rates across the cohorts at hand.

the cohort is, the lower its labor force participation at older ages.[8,9] Finally, the third factor that affects the ETWH is the length of the work week. Ceteris paribus, a shorter workweek implies a lower ETWH. Figure 4 plots the average weekly hours over the time period 1860-2004. As can be seen from the figure, the average hours worked per week have been declining dramatically by nearly 50 percent since the mid nineteenth century to the beginning of the twenty first century from about 60 hours a week to about 40.[10]

Before we present our estimates of the ETWH of consecutive cohorts of US males, it is important to discuss how individuals form expectations regrading mortality rates, labor force participation and hours they intend to work over the course of their lives. On the one extreme, we can assume that each cohort perfectly foresees its course of life and hence use the *actual* mortality rates, labor force participation rates and hours the members of this cohort worked at each age. Henceforth, we refer to these estimates as *cohort* estimates. On the other extreme, we can assume that each cohort has static expectations and hence use mortality rates, labor force participation rates and hours worked from the cross-section at the age at which the expectations are formed. Henceforth, we refer to these estimates as *period* estimates. We estimate the ETWH using these two extreme assumptions. Note that since the cohort estimates require the utilization of actual cohort data we have these estimates for cohorts born between 1840 and 1920.[11] In contrast, the period estimates require cross-sectional data we have these estimates for cohorts born between 1840 and 1970. We refer to individuals born in 1840 as members of cohort 1, individuals born in 1850 as members of cohort 2, ..., and individuals born in 1970 as members of cohort 14.[12]

Our findings suggest that the increase in retirement rates and the decline in hours worked per week outweigh the gains in longevity. Our cohort estimates suggest that over the period 1840–1920, total labor input of consecutive cohorts has been declining, big time. Assuming that individuals calculate the expected total hours worked over the lifetime

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[8]These data are the *actual* labor force participation of each cohort estimated from the various samples of the IPUMS. The figure plots only three cohorts, 1, 5 and 9. Putting all cohorts in the figure hides more than it reveals. Our statement above, however, is based on the full picture. We discuss in detail how we arrive to these estimates in subsection 4.2.1.

[9]See Costa (1998a) and Lee (2001) for a discussion on the trend in retirement and Kopecky (2005) and Kalemli-Ozcan and Weil (2005) for theories that account for this trend.

[10]See Vandenbroucke (2005) for a theory of the decline in weekly hours during the first half of the 20th century. In subsection 4.3 we discuss data sources and in subsection 4.3.1 we discuss in detail how we arrive to this series.

[11]Younger cohorts are still in the labor market and hence we cannot estimate their expected lifetime labor input.

[12]More accurately, men born between 1836-45 comprise cohort 1 and are referred to men born 1840, men born between 1846-55 comprise cohort 2 and are referred to men born 1850, etc.

at age 20, our results suggest that while individuals born in 1840 were expected to work more than 117,000 hours over their life, their counterparts born in 1920 were expected to work less than 90,000 hours.[13] However, since investment in education begins at age 5 one can rightfully argue that the age at which expectations should be taken is 5. If mortality rates for the age interval 5–20 have declined much over time, our result would weaken. Thus we also estimate the expected hours worked over the lifetime, assuming that expectations are calculated at age 5. Although the difference in the ETWH between the cohorts has somewhat narrowed, it is still substantial: while individuals born in 1840 were expecting at age 5 to work nearly 108,000 hours over their lifetime, individuals born in 1920 were expecting at age 5 to work for a little more than 86,000 hours.[14]

Comparing the educational achievements across these cohorts is not an easy task. We do however, provide some evidence that there has been a major progress in educational achievements across the nine cohorts born between 1840 and 1920. Figure 5 shows the fraction of high school graduate among individuals 17 years old. This time series is available from 1870, the year which roughly corresponds to cohort 2. The year 1937 roughly corresponds to cohort 9. As can be seen, across our nine cohorts, the fraction of high school graduate has increased monotonically from mere 2 percent to nearly 45 percent.[15]

In sum, our estimates suggest that despite the major gains in life expectancies and educational achievements, ETWH have declined by almost 25 percent between members of cohort 1 and cohort 9. Thus we conclude that the Ben-Porath (1967) mechanism has probably contributed considerably less than previously thought for the transition from stagnation to growth.[16]

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[13]Compared to the cohort estimates, the period estimates are higher for each cohort, but the trend across cohorts is almost identical to both types of estimates. We discuss the period estimates in details in section 5.4.

[14]Notice that regardless of the age at which expectations are calculated, all cohorts are *assumed* to enter the labor market at age 20. Hence our results do not stem from the fact that older cohorts enter the labor market at younger ages.

[15]One can argue that hours per school day may have been reduced as well, challenging our argument that schooling has been increasing. Although we do not have direct evidence on that, Goldin (1999) provides data on the average length of school term and the average number of days attended per pupil enrolled. Both series show monotonic increase 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.

[16]It should be clear that we do not argue that falling mortality rates or increasing in life expectancies do not cause growth. Our paper shed light on one particular channel through which longevity may affect human capital accumulation and hence growth. In the model of Jones (2001), for example, a decline in mortality rates has a positive effect on population and hence on the amount of new ideas that are translated to growth.

The rest of the paper is organized as follows. In section 2 we present a prototype of the Ben-Porath model to derive explicitly the effect of an increase in the expectation of life on education and hours worked over the lifetime. In section 3 we present our methodology of estimating the ETWH of consecutive cohorts and in section 4 we describe our data. In section 5 we present our results and discuss their implications and in section 6 we present some concluding remarks.

2 A Prototype of the Ben-Porath Model

In this section we present a prototype of the models that have utilized the Ben-Porath mechanism in growth models. The purpose of this section is to explicitly emphasize the implication of this type of model to the effect of an increase in longevity on investment in human capital and on the total labor input over the lifetime. To make things simple, we shell present here only the individual decision. Assume that preferences are defined over consumption of one final good. Assume also that each individual supplies his human capital, h, in the labor market and receives a wage w per one unit of human capital. We normalize w to one. Finally, assume that the investment in human capital takes place prior to entering the labor market and that the sole cost of education is foregone earnings. The optimization faced by the individual is:

$$\max_{c,s} \int_0^T e^{-\rho t} u(c(t)) dt \tag{1}$$

s.t.

$$\int_0^T e^{-rt} c(t) dt = \int_s^T e^{-rt} h(s,t) dt \tag{2}$$

$$h = h(s,t) \tag{3}$$

where $u(\cdot)$ is strictly increasing and strictly concave, $c(t)$ is consumption at date t, T is the expectation of life at the age at which consumption and education decisions are taken, r is the interest rate, ρ is the subjective discount rate and $h(s,t)$ is the human capital production function, which takes education, s, and age, t, as its inputs.

The first order condition with respect to the schooling decision is give by:

$$-e^{-rs} h(s,s) + \int_s^T e^{-rt} h_s(s,t) dt = 0 \tag{4}$$

Consider the following human capital production function,

$$h(s,t) = e^{\alpha + \theta(s) + \beta(t-s)} \qquad (5)$$

This formulation allows for a non linear effect of schooling on earnings through the function $\theta(s)$, a linear effect of experience in a rate of β as well as TFP effect on human capital and earnings through α.[17]

Using (5) in (4), the first order condition w.r.t the schooling decision becomes:

$$-e^{\alpha + \theta(s) - rs} + \int_s^T e^{-rt}[\theta'(s) - \beta]e^{\alpha + \theta(s) + \beta(t-s)}dt = 0 \qquad (6)$$

This condition gives rise to the following lemma:

Lemma 1 *If $h(s,t)$ is give by (5), the effect of the expectation of life T on the optimal schooling decision, s^*, is:*

$$\frac{ds^*}{dT} = \frac{\theta'(s) - r}{\theta'(s) - r - \theta''(s)} \qquad (7)$$

Proof: Follows immediately from (6) and the implicit function theorem. □

A common assumption in the growth literature is that the production function is strictly increasing but with diminishing returns with respect to time invested.[18] Following this literature we have the following result:

Lemma 2 *If $\theta(s)$ is twice continuously differentiable, strictly increasing and strictly concave, the total labor input over the lifetime, $T - s^*$, is strictly increasing in the expectation of life T.*

Proof: Follows immediately from (7) and the strict concavity of $\theta(s)$. □

Perhaps the most common human capital production function used in (applied) economics is the Mincerian human capital production function. If we assume that $\theta(s)$ is linear, (5) is reduced to the Mincerian human capital production function without the quadratic term in experience. We then have the following result:

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[17]As can be verified, total factor productivity (α)has *no* effect on the optimal level of schooling. See Manuelli and Seshadri (2005).

[18]See Bils and Klenow (2000), Galor and Weil (2000), Kalemli-Ozcan, Ryder, and Weil (2000), Galor and Moav (2002), among others.

Lemma 3 *If $\theta(s)$ is linear in s, the total labor input over the lifetime, $T - s^*$, is unaffected by the expectation of life T.*

Proof: Follows immediately from (7) and the linearity of $\theta(s)$. □

It follows that if there are no diminishing returns to schooling (in production human capital), any increase in the length of the working period is allocated to education leaving the optimal lifetime labor input 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. In contrast, the typical finding in studies based on micro data within countries is linear returns to education. Some argue, however, that the latter studies are more prone to ability bias that may drive the estimates toward linearity (Card 1994). Assuming that human capital is not strictly convex in schooling time, the effect of increase in longevity on total labor input over the lifetime is non-negative.

We conclude from lemma 2 and lemma 3 that given the commonly used human capital production functions, a model that utilizes the Ben-Porath mechanism implies that the total labor input over the lifetime is increasing, or at least nondecreasing. We shell now continue with our thought experiment by estimating the ETWH of consecutive cohorts of American males to see whether their expected total labor input over the lifetime has indeed increase, or at least has not declined, as the suggested models in the literature predict.

3 Methodology

In this section we explain our methodology of estimating ETWH of each cohort. Let TWH_c denote total working hours over the lifetime by the representative member of cohort c. Then $ETWH_c$ is a weighted 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:

$$E(TWH_c | t \geqslant t_0) = \sum_{t=t_0}^{\infty} l_c(t) S_c(t | t \geqslant t_0) \tag{8}$$

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

3.1 The Survivor Function

To estimate the survivor function, $S_c(t|t \geqslant t_0)$, we need to estimate the *hazard function*, the rate of leaving the labor market in the age interval, $[t, t+1)$ and then calculate the survivor function directly.[19] Two factors affect this hazard function: (i) mortality rates–at each age individuals may die and leave the labor market. (ii) retirement rates–at each age individuals choose whether to continue working or to permanently leave the labor market and become retired. Denote by $q_c(t)$ the mortality rate at age t of individuals of cohort c and by $LPF_c(t)$ the labor force participation rate at age t of individuals of cohort c. Note however that we observe the LFP only for individuals who got to age t. Let $x_c(t)$ be the size of cohort c at age t, then the number of workers at age t is given by:

$$x_c(t) \cdot LFP_c(t),$$

and the number of workers of cohort c at age $t+1$ is given by:

$$x_c(t+1) \cdot LFP_c(t+1) = (1 - q_c(t)) \cdot x_c(t) \cdot LFP_c(t+1).$$

Hence the number of individuals of cohort c who leave the labor market between age t and $t+1$ is:

$$x_c(t) \cdot LFP_c(t) - x_c(t+1) \cdot LFP_c(t+1)$$

and the fraction of individuals who leave the labor market between age t and $t+1$, *the hazard rate*, denoted by $\lambda_c(t)$, is:

$$\lambda_c(t) = \frac{x_c(t) \cdot LFP_c(t) - x_c(t+1) \cdot LFP_c(t+1)}{x_c(t) \cdot LFP_c(t)}$$

which can be written as:

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[19]See for example, Wooldridge (2002) chapter 20, pp. 686–688.

$$\lambda_c(t) = 1 - (1 - q_c(t)) \cdot \frac{LFP_c(t+1)}{LFP_c(t)} \tag{9}$$

Hence, to estimate the hazard function using (9), we need for each cohort c, data on labor force participation and mortality rate at each age t. In section 4 we explain in detail our data sources and how we estimate these variables for each cohort.

3.2   The Formation of Expectations

As discussed in the introduction, the most important issue in estimating the ETWH is related to the way individuals form expectations regrading their future. Specifically, we are interested in the way each cohort anticipates its mortality rates at each age, $q_c(t)$, its labor force participation at each age, $LFP_c(t)$, and the hours it intends to work at each age, $l_c(t)$. On the one extreme, we can assume that each cohort perfectly foresees its course of life and hence use the *actual* mortality rates, labor force participation rates and hours the members of this cohort worked at each age. As mentioned in the introduction, these estimates are labelled *cohort* estimates. On the other extreme, we can assume that each cohort has static expectations and hence use mortality rates, labor force participation rates and hours worked by age from the cross-section at the age at which the expectations are formed. As mentioned in the introduction, these estimates are labelled *period* estimates. We estimate the ETWH using these two extreme assumptions.

4   Data

In this section we describe our data along with their sources for each variable. As suggested in section 3, in order to estimate the ETWH we need data on three variables: the *expected* mortality rates, the *expected* labor force participation rates and the *expected* working hours. As mentioned in section 3.2, we need different data for the cohort estimates and the period estimates. In particular, since the cohort estimates require the utilization of *actual* cohort data we have these estimates for cohorts born between 1840 and 1920, which we refer to as cohort 1, cohort 2, ..., cohort 9. In contrast, the period estimates require cross-sectional data and hence we have these estimates for cohorts born between 1840 and 1970, which we refer to as cohort 1, cohort 2, ..., cohort 14.[20] In what follows,

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[20]More accurately, men born between 1836-45 comprise cohort 1 and are referred to men born 1840, men born between 1846-55 comprise cohort 2 and are referred to men born 1850, etc.

each subsection begins by discussing data sources and a general description of the variable. It is then followed by the description of the data for the cohort estimates and the period estimates.

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 section data. It reports, among other things, the probability of dying within an age interval of the currently lived 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 of this 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 at each age were falling over time, the period life table would underestimate gains in life expectancy of each cohort. In our estimation we employ both cohort life tables and period life tables. As discussed in section 3, we employ the former for the cohort estimates and the latter for the period estimates.

Our main source is Bell, Wade, and Goss (1992), who provide both period as well as cohort life tables from 1900 to 2080.[21] For earlier periods, however, we use Haines (1998) period life tables. Note that we can construct cohort life tables from the period life table by reading mortality rates for different ages from different years.[22]

Mortality rates have been declining at all ages for men born 1840 and onward. Since our investigation aims to recover whether individuals were expected to increase or decrease their ETWH and decide on their education in relation to that, we are interested in mortality rates in the "relevant ages". Since investment in formal education does not start prior to age five, and entrance to the labor market starts, on average, at age 20 we focus on mortality rates, conditional on surviving to age 5 and to age 20. 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 of summarizing mortality rates is to estimate the expectation of life, which is the area under a survival curve. A third way of summarizing mortality rate is to estimate the probability of surviving to some specific age, conditional on surviving to a younger age. We present data of these three types.

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[21]Data for the years 1990–2080 reflect projected mortality.

[22]For example, for a cohort born in 1840–49, the mortality rates for the age interval 20-9 are taken from period life table of 1860, for the age interval 30-9 from the period life table of 1870 etc.

4.1.1 Mortality Rates – Cohort Estimates for Cohorts 1–9

Figure 6 plots the survival curves for members of cohorts 1, 5 and 9 who survive to age 20.[23] As can be seen, from the figure, the survival to each age has been increasing. It can also be seen that the largest gains are concentrated in the ages 50 to 75. These gains are translated into sizable gains in the expectations of life at age 20. Figure 1 plots the expectations of life at age 20 for all cohorts. As can be seen from the figure, the expectations of life has been increasing monotonically and quite significantly. While a 20 years old who belong to cohort 1 was expected to live for another 43.2 years his counterpart who belong to cohort 5 was expected to live for another 45.65 years and their counterpart who belongs to cohort 9 was expected to live another 51.36 years. Overall, conditional on surviving to age 20, individuals born in 1920 were expected to live about 8 years more than their counterpart born in 1840. Finally, there were also reductions in mortality rates at younger ages. Figure 7 plots the probability of surviving to age 20, conditional on being alive at age 5. This probability has increased from 0.92 for cohort 1 to 0.97 for cohort 9, with most of the increases concentrated in the younger cohorts.

4.1.2 Mortality Rates – Period Estimates for Cohorts 1–14

Figure 1 plots the expectations of life at age 20 for 11 out of our 14 cohorts for which we have period estimates of ETWH. As can be seen from the figure, the expectations of life has been increasing quite significantly, though they are lower than the cohort estimates and have somewhat lower slope, reflecting the declining trend in mortality over time. It can be seen from the figure that while a 20 years old who belong to cohort 1 was expected to live for another 40.3 years his counterpart who belong to cohort 11 was expected to live for another 49.65 years and their counterpart who belongs to cohort 14 was expected to live for another 52.95 years (not shown in the figure). Overall, conditional on surviving to age 20, individuals born in 1970 were expected to live about 12 years more than their counterpart born in 1840.

4.2 Labor Force Participation Rates

To estimate labor force participation rates, we use the Integrated Public Use Microdata Series (IPUMS) which are available from 1850 to 2000 (except for 1890). Prior to 1940,

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[23]Putting all 9 cohorts on the same graph hides more than it reveals. We choose cohort1 because it is the oldest cohort 9 because it is the youngest and cohort 5 which is in the middle.

an individual was considered as part of the labor force if he or she reported to have a gainful occupation. This is also known as the concept of "gainful employment". From 1940 onward, however, the definition has changed and an individual is considered as 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 than the latter. Moen (1988) suggests a method of estimating a consistent time series of labor force participation rates across all the available IPUMS samples, based on the concept of gainful employment.[24] We employ the method suggested by Moen in our estimation, for the cohort as well as the period estimates.

4.2.1 Labor Force Participation Rates – Cohort Estimates for Cohorts 1–9

For each cohort we estimate the labor force participation rate based on the concept of gainful employment at each age starting from age 45.[25] Similar to figure 6, figure 3 presents labor force participation rates for cohorts 1, 5 and 9. As can be seen, from age 55 and above, participation has been declining faster, the younger the cohort is. 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 cohort 1, to 80 percent for cohort 5 and to 78 percent for cohort 9. By age 70, the estimates are 61 percent, 48 percent and 31 percent respectively. Thus, while the probability of surviving to each age has gone up, the probability of participating in the labor market has gone down. In subsection 5.1 we combine the data on the probability of surviving to each age with the data on the probability of participating in the labor market at each age to estimate the probability of remaining in the labor market at each age using (9).

4.2.2 Labor Force Participation Rates – Period Estimates for Cohorts 1–14

Similar to our estimation in subsection 4.2.1, we estimate the labor force participation rate based on the concept of gainful employment for cohorts 1 through 14 at each age

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[24]See also Costa (1998a), chapter 2.

[25]In our estimation we assume that participation rates are constant for all cohorts in the age interval 20 to 45. The data support this claim quite firmly. See also Lee (2001) who argues that individuals do not start to retire prior to age 50. In addition, from age 75 and above, the number of observations in each cell is too small. Hence we estimate participation in 5 years intervals (75-9, 80-4, 85-9 and 90-4) and used linear trend to predict participation at each age. Finally, members of cohort 9 were 84 years old in 2000. Hence for cohort 9 we used the participation rates at ages 85-94 of cohort 8.

starting from age 45. Figure 8 presents period estimates on labor force participation rates for cohorts 1, 5, 9 and 14. These are simply the labor force participation rates, based on the concept of gainful employment, estimated from the IPUMS of the years 1860, 1900, 1940 and 1990. As can be seen, the trend resemble that of the cohort estimates. One noticeable feature of this figure is that participation at each age is lower the younger the cohort is.[26] Thus, similar to our conclusion in subsection 4.2.1, while the probability of surviving to each age has gone up, the probability of participating in the labor market has gone down. In subsection 5.2 we combine the data on the probability of surviving to each age with the data on the probability of participating in the labor market at each age to estimate the probability of remaining in the labor market at each age using equation (9).

4.3   Hours Worked

Questions about hours worked last week or usual hours worked per week were not asked by the US 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 our period of interest, 1860–present.[27] Whaples (1990) is probably the most comprehensive study on the length of the American work week in historical perspectives. Whaples puts together the available aggregated time series data from as early as 1830 to present days. Clearly, such series may suffer from different sources of biases. For example, biases may arise 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) and a host of other reasons. Despite that Whaples writes,

> Despite these data limitations and caveats, there is general agreement that the Weeks and Aldrich series come close to reality in their broader implication that the length of the work week declined in virtually every decade from 1830 to 1900, and that the pace of this change was very erratic. Both shows the 1850s to be the decade of the greatest reductions, both show that the length of the work week fell by about nine hours between 1830 and 1900. (p. 26)

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[26]Notice, however, that our estimates of ETWH are *not* affected by the lower participation in age 45, since by assumption participation is constant between age 20 and age 45 and the hazard function, (9), is affected only by the rate of change in LFP, and not by the *level* of LFP.

[27]Recall that our oldest cohort was born in 1840 and hence we do not utilize data on hours worked before 1860.

Hence, due to the lack of other alternatives sources, we use the Weeks and Aldrich reports for the years 1860–1880 . Note that we utilize hours data only from 1860, just after the greatest declines in hours worked were taken place.

During the last quarter of the nineteenth century state Bureau of Labor Statistics published several surveys of the economic circumstances of non-farm wage earners. We 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.[28] Specifically, we combine the surveys from California 1892, Kansas 1895, 1896, 1897, and 1899, Maine in 1890, Michigan stone workers in 1888, Michigan railway workers in 1893 and Wisconsin in 1895. Altogether we have data on 13,515 male workers.[29] We use this combined data set to generate an estimate of hours worked by males for 1890.

In contrast to the nineteenth century, Whaples argues that starting from 1900, two reliable annual series are available. These are the manufacturing hours series of Ethel Jones for the years 1900–1957 and the Owen series for non-students males in all sectors of the economy for the years 1900-1986.

Finally, starting from 1940 to present, we rely mostly on IPUMS data and generate estimates on hours worked from micro data. Our estimates of hours worked from the various samples of the IPUMS also serve as a check on the Jones' and Owen's series for the years they overlap.

4.3.1 Weekly Hours Worked: 1860–Present

In this subsection we present the available data on hours worked in chronological order and then explain our choice of a baseline series. As mentioned above, two time series of hours are available for the period prior to 1890. These are the Weeks and the Aldrich series. The Weeks series suggests that the average week work comprised of 62 hours in 1860, 61.1 hours in 1870 and 60.7 hours in 1880. The Aldrich series is somewhat higher, suggesting that the average week work comprised of 66 hours in 1860, 63 hours in 1870, 61.8 hours in 1880 and 60 hours in 1890.

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[28]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 (????).

[29]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 we assume that they represent the US population at that time quite well.

Using the data set that combines the nine micro data sets published by state Bureau of Labor Statistics described above, average hours worked by males yields an estimate of 10.2 hours per day, or 61.2 per week.[30] The micro data set allows as in addition to study the distribution of hours worked across the male population in more details. 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 week work of individuals who's wage is in the 10th percentile consisted of 62.15 hours while that of individuals who's wage is the 90th percentile consisted of 56.53 hours.

The series of Ethel Jones for the manufacturing sector 1900-1957 and the series of John D. Owen for non-student males in all sectors of the economy 1900-1986 are presented in figure 9. As can be seen from the figure, the two series are highly correlated although the Owen's series is generally about three hours above that of Jones'.[31]

Starting with the 1940 Census, a question about hours worked last week or usual hours worked per week were asked.[32] Average weekly hours for all white males had been declining from 43.32 in 1940, to 41.83 in 1950, 39.28 in 1960 and 38.15 in 1970. They then rebounded to 38.52 in 1980, 39.56 in 1990 and 39.92 in 2000.[33]

Figure 10 shows the average hours worked by age groups reveals an interesting finding. While hours in 1940 did not vary much by age, from 1950 onward, hours by age tend to show an inverted U shape: they are slightly lower at younger ages, and much lower at older ages. Note how the steepness of the decline at older ages become more pronounced as we progress in time. Figure 11 plots weekly hours worked by white males in the 10th, median, and 90th percentile of the wage distribution.[34] As can be seen, while in 1940

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[30]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. 9 percent reported that hours were reduced, 14 percent reported that hours were increased and 76 percent that they remained the same. Hence, similar to Costa, we assume a work week of 6 days.

[31]The correlation between the two series is 0.978.

[32]The Censuses of 1940, 1950, 1980 and 1990 asked a question about hours worked last week, the 1960 and 1970 asked the same question but the data was coded in intervals. Hence for individuals in the 1960 and 1970 censuses we assign the mean value of each interval. The question on usual hours worked per week was asked in the 1980, 1990 and 2000 censuses.

[33]See McGrattan and Rogerson (2004) for a comprehensive analysis of hours worked by sex, age and marital status for the time period 1950–2000.

[34]In practice we estimated the average hours worked for a band of plus minus two percent around the reported percentile, i.e., average hours worked by men in the 10th percentile of the wage distribution is in fact the average hours worked by men in the 8th to the 12th percentile of the wage distribution. Similarly "median" refer to men between the 48th and the 52th percentile in the wage distribution and "90th" to men between the 88th and the 92th percentile

the poorer workers worked more, the reverse is true by 2000.[35] Note the sharp decline in hours worked by men in the 10th decile, especially between 1940 and 1970 and the increase in hours worked by men in the 90th decile. Weekly hours worked by men in the median of the wage distribution have been rather constant, at least since 1950.

4.3.2   A Baseline Time Series for Hours

The discussion above highlight several problems in generating a consistent time series of hours worked at each age t for each cohort c. First, in some series the population consist of men and women while other consist only of men. Second, some series consist only part of the economy while others consist all sectors of the economy. Thirdly, over time we see a change in the pattern of hours worked over the life-cycle: while in the 1890s and in 1940, hours by age did not vary much, starting in 1950, hours by age varied substantially. These three points posit a problem in generating consistent time series of hours worked by age for each cohort.

In an attempt to be as conservative as possible, we take the following assumptions. First, for the period 1860-1880, we 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 we take our estimate from the micro data sets published by state Bureau of Labor Statistics of 61.2 hours a week. For the years 1900–1986 we take the Owen's series and for 1990-2000 our estimates from the IPUMS data.[36] Second, we have to overcome the changes in the pattern of hours worked over the life-cycle of the different cohorts. The most conservative way to deal with it is to ignore life-cycle and assume that regardless of age, in a given year, all men work the same average hours.[37] Under this assumption, the only different in hours worked per year across cohorts arises only due to the year of entry and the year of leaving the labor market. Assuming that, we obtain our baseline time series for hours, which is presented in figure 4. The figure presents both the original data points (the dark points) and estimated data points for the missing years.

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[35]This is a well established fact, which has been discussed in Coleman and Pencavel (1993), Costa (1998b) as well as others.

[36]For the period 1860–1900 we have only 5 observations. Hence we use a quadratic fitting curve to assign values for these years. In the Owen series, nine data points are missing. Since the time intervals for these missing data are very short, we use linear fitting curve between two adjacent data points to assign values for the missing data.

[37]We argue that this is a conservative assumption because our scattered data suggest that while in the 1890s and the 1940 hours by age were rather constant they were decreasing with ages above 60 starting with the 1950.

For our cohort estimates we use a subset of this series. For example, cohort 5 was born in 1880 and join the labor market in 1900. Since we need data on hours worked until $S_5(t|t \geqslant t_0) = 0$, and this is true for cohort 5 at age 99, $l_5(t)$ is hours worked from 1900 to 1999.[38] For our period estimates we only need the average hours worked at the age at which expectations are calculated, age 20. Hence for cohort 1 we use average hours in 1860, for cohort 2 we use average hours in 1870, etc.[39] Finally, note that this series is expressed in terms of weekly hours worked. Since we aim to estimate the expected total hours worked over the lifetime, we need to convert this series to yearly series. Given that most men in the labor market work most of the year, we avoid further complications and assume that all cohorts work 52 weeks a year.[40] Hence our annual series, $l(t)$ is simply 52 times the series presented in figure 4.

5 Results and Implications

In this section we present our results and discuss their implications. We begin by estimating the probability of remaining in the labor market of successive cohorts of American males, conditional on being alive at age 5 and age 20. This also enables us to present estimates on the expected number of years each cohort were expected to work. We then combine these estimates with the series of hours worked per year to arrive at our main results, the ETWH.

5.1 The Probability of Remaining in the Labor Market – Cohort Estimates for Cohorts 1–9

In this section we present our cohort estimates of $S_c(t|t \geqslant t_0)$, the probability remaining in the labor market at age t, conditional on entering the labor market at age t_0 of members of cohort c. Specifically, we let $t_0 = 20$, i.e., we assume that individuals of each cohort enter the labor market at age 20, and estimate the probability of remaining in the

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[38]Note that for each cohort we need data for hours worked for all ages as long as $S_c(t|t \geqslant t_0) > 0$. While this age ranges from 93 to 99, depending on the cohort at hand, in practice, for all cohorts, at ages 80 or 85, $S_c(t|t \geqslant t_0)$ is sufficiently close to 0 and has only minor effect on the ETWH.

[39]In practice, since cohort 1 comprises individuals born between 1836-45, we average across 10 years to generate the yearly hours for the period estimates. Hence, for cohort 1 we used the average of hours worked for the period 1856-1865, and so forth.

[40]Although we take this as a simplifying assumption, there seem to be evidence that the fraction of non-farm workers who report to have taken vacations has increased substantially, at least since the beginning of the twentieth century (Lebergott 1976).

labor market at all ages older than 20. This estimation is done by estimating the hazard function,(9), and computing $S_c(t|t \geqslant 20)$ directly.

Figure 12 show the probability of participating in the labor market conditional on being alive at age 20 and on entering the labor market at that age. Given our assumption that participation rates remain constant from age 20 to age 45, it is evident from (9) that the probability of participating in the labor market over the age interval 20–45 is affected solely by death rates. Since we saw in section 4.1.1 that mortality rates have been declining monotonically over time, it is not surprising that the probability of participating in the labor market is higher for younger cohorts than for older cohorts up to age 45. However, since age 55 the two variables that affect the probability of participating in the labor market work in opposite directions. As a result, while this probability is higher at younger ages for the younger cohorts the curves for cohorts 1, 5 and 9 intersect at about the age of 63.[41] Notice that the area under each such survival curve gives the expected number of years each cohort is expect to be part of the labor market. Figure 13 plots the expected number of years that each cohort was expected to work, assuming that entry age is fixed at 20.[42] As can be seen from this figure, while a member of cohort 1 was expected to work for 34.4 years, his counterpart in cohort 9 was expected to work for 39.5 years.

5.2 The Probability of Remaining in the Labor Market – Period Estimates for Cohorts 1–14

In this section we present our period estimates of $S_c(t|t \geqslant t_0)$, the probability remaining in the labor market at age t, conditional on entering the labor market at age t_0 of members of cohort c. Specifically, we let $t_0 = 20$, i.e., we assume that individuals of each cohort enter the labor market at age 20, and estimate the probability of remaining in the labor market at all ages older than 20. This estimation is done by estimating (9) and computing $S_c(t|t \geqslant 20)$ directly. Figure 14 is similar to figure 13 with two differences. First, it utilized the period estimates. Second, it is based on the probability of surviving on the labor market only until age 80.[43] As can be seen, the expected number of years increases for

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

[42]Note that this is a very conservative assumption. While participation at age 20-4 is lower than at age 25-45 for the younger cohorts, probably due to college eduction, for the oldest cohorts, the average age of entrance to the labor market has probably been lower than 20. Hence it can be said quite confidently that we overestimate the difference in the expected number of years in the labor market between the oldest and the youngest cohorts. This, in turn, underestimate the difference in ETWH.

[43]This is because the period life tables in Haines (1998) do not elaborate the death rate for individuals older than 80 years. This is not a major problem, however, which can be addressed in several ways. Since $S(\cdot)$ is

all cohorts younger than cohort 11 and then it declines.[44]

5.3 The ETWH: Cohort Estimates for Cohorts 1–9

In this section we present our main results. Figure 16 presents the cohort estimates of the ETWH of successive cohorts born between 1840–1920, cohorts 1–9. The estimation was done under the assumption that expectations are calculated at age 20. As can be seen, the ETWH of consecutive cohorts have been declining monotonically. The oldest cohort, born in 1840 was expected to work more than 117,000 hours over their life. In contrast, the youngest cohort born in 1920 was expected to work less than 90,000 hours. This amounts to a decline of more than 24 percent between cohort1 and cohort9, an average decline of 3.4 percent from cohort to cohort. Figure 7, however, shows that the probability of surviving to age 20 from age 5 has increased from 0.92 for cohort1 to 0.97 for cohort9. Since the investment in education begins at age 5, one can rightfully argue that the age at which expectations should be calculated is age 5.[45] This is what we do in figure 17. As can be seen, although the difference in the ETWH between the cohorts has narrowed, it is still substantial: while individuals of cohort 1 at age 5 were expecting to work for nearly 108,000 hours over their lifetime, their counterparts of cohort 9 at age 5 were expected to work for a little bit more than 86,000 hours. This amounts to a decline of more than 20 percent between cohort 1 and cohort 9, an average decline of 2.8 percent from one cohort to the next. Finally, note that in both figures, the decline in ETWH has been monotonic across the cohorts.

5.4 The ETWH: Period Estimates for Cohorts 1–14

One reason to present the period estimates is that assuming that one perfectly foresees his lifetime may be a strong assumption. Hence, in this section we present the period estimates for the ETWH for cohorts 1–14.[46] Figure 18 presents the period estimates for the ETWH until age 80.[47] Note, however, that since the function $S(\cdot)$ is non-increasing,

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non-increasing, we show in figure 15 that $S_c(80)$ is decreasing across cohorts. Hence when we use $S_c(80)$ to estimate the expected number of years in the labor market we overestimate the difference across cohorts while when we use $S_c(t)$ in the estimation of ETHW we underestimate the differences across cohorts.

[44]This statistics also decline for cohort 3. The reason is that death rates in 1880, the year at which this cohort was 20 years old were higher than in 1860 and 1870. This is also evident from figure 1.

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

[46]Since IPUMS is not available for 1890, we do not estimate the ETWH for cohort 4 who was 20 in 1890.

[47]Recall that in section 5.2 we discussed the data limitation that does not allow us to estimate $S(\cdot)$ for all cohorts till the actually leave the labor market.

that $S_c(80)$ is larger the older the cohort is (see figure 15) and that hours per year have been declining over time, we only underestimate the difference across cohorts when we estimate the ETWH until age 80 instead of till $S(t) = 0$. Figure 18 suggests that ETWH has been monotonically declining over all cohorts, at least till cohort 10 and then it has become rather constant. Note also that while the period estimates of the ETWH are higher than the cohort estimates for all cohorts for which we also have cohort estimates, the trend across these 9 cohorts is remarkably the same. Finally, as a robustness check on our period estimate due to the limitation imposed by the data on mortality rates above age 80 for older cohorts, we estimate period estimates of ETWH till age 80 and till each cohort actually has retired from the labor market for cohorts 5–14. The largest difference between the estimate till age 80 and till the cohort actually has retires is for cohort 5 and equals 1,412.[48]

5.5   Implications

Our cohort estimates show that despite a gain of almost 9 years in the expectations of life at age 20, and a surge in the investment in human capital, as projected by the increase in the fraction of 17 years old who become high school graduates, the ETWH have declined by nearly 25 percent between the cohort bern 1840 and that born 1920. Our period estimates tell the same story. As discussed in section 2, expected working hours over the lifetime should have been at least a non-decreasing to lend credence to the Ben-Porath mechanism. Hence, we conclude that the Ben-Porath mechanism have had a lesser effect than previously thought on the accumulation of human capital during the growth process.

6   Concluding Remarks

In this paper we have demonstrated that the commonly utilized mechanism according to which prolonging the period in which individuals may receive returns on their investment spurs investment in human capital and cause growth has an important implicit implication. Namely, that as life prolongs, total labor input increases. Hence we have argued that this mechanism has to pass this necessary condition. Utilizing data on consecutive cohorts of American men, born between 1840 and 1970, we have shown that this

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[48]In fact, we could present the ETWH for cohorts 1–3 by age 80 and for cohorts 5-14 the estimates till the actually retire and still show that ETWH has been monotonically declining.

mechanism has failed to pass its necessary condition. Interestingly, the two factors that outweigh the gains in life expectancies, namely, the sharp reduction of hours worked per week and the much lower labor force participation of relatively older workers are not unique to the American experience but are universal across many developed countries, such as England, France, Germany and the like.[49] Given the remarkable similarities, not only in trend but also in magnitudes, we believe that our main result that ETWH has declined is a robust fact of the process of development in the nowadays developed economies.

One should not conclude from this paper that gains in life expectancies are useless, nor that they do not affect growth. For one thing, they are desirable for their own sake, as long as individuals value life (over death). Secondly, longer life might affect growth through other channels. One such mechanism is stressed by Jones (2001). Thirdly, human capital can be thought of an input in home production and even more specifically in the production of leisure. Hence one can build a model in which an increase in longevity reduces market hours and increases total welfare. However, while such models can be built, we argue that from a quantitative perspective, the effect of longevity on home productivity is presumably of second order. Finally, over the 20th century and in parallel to the gains in life expectancies, female labor supply has increased substantially. One may argue that confining the discussion to ETWH by men is conceptually wrong, since the ETWH supplied to the market by the *household* has increased over time. While this last argument is probably true, changes in life expectancies do not seen to be an important determinant of either female investment in education nor of female labor force participation. A close look at investment in education of women in the United States reveals a remarkable gender neutrality, as early as the mid 19th century (Goldin and Katz 2003). Notwithstanding, female labor force participation, especially of married women, has been remarkably low prior to World War II (Goldin 1990).[50] Hence to be on the safe side, we have concluded that longevity have probably contributed less than previously thought to the transition from stagnation to growth.

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[49]See Vandenbroucke (2005) for data on weekly hours worked and Costa (1998a) for data on labor force participation.

[50]The main hypotheses for the increase in female labor force participation are (i) the narrowing of the gender wage gap (Galor and Weil 1996), (ii) technological progress in the household sector that freed women's time (Greenwood, Seshadri, and Yorukoglu 2005) and (iii) changes in social attitude to the participation of women in the labor market, (Hazan and Maoz 2002, Fernández, Fogli, and Olivetti 2004).

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The Expectations of Life at Age 20
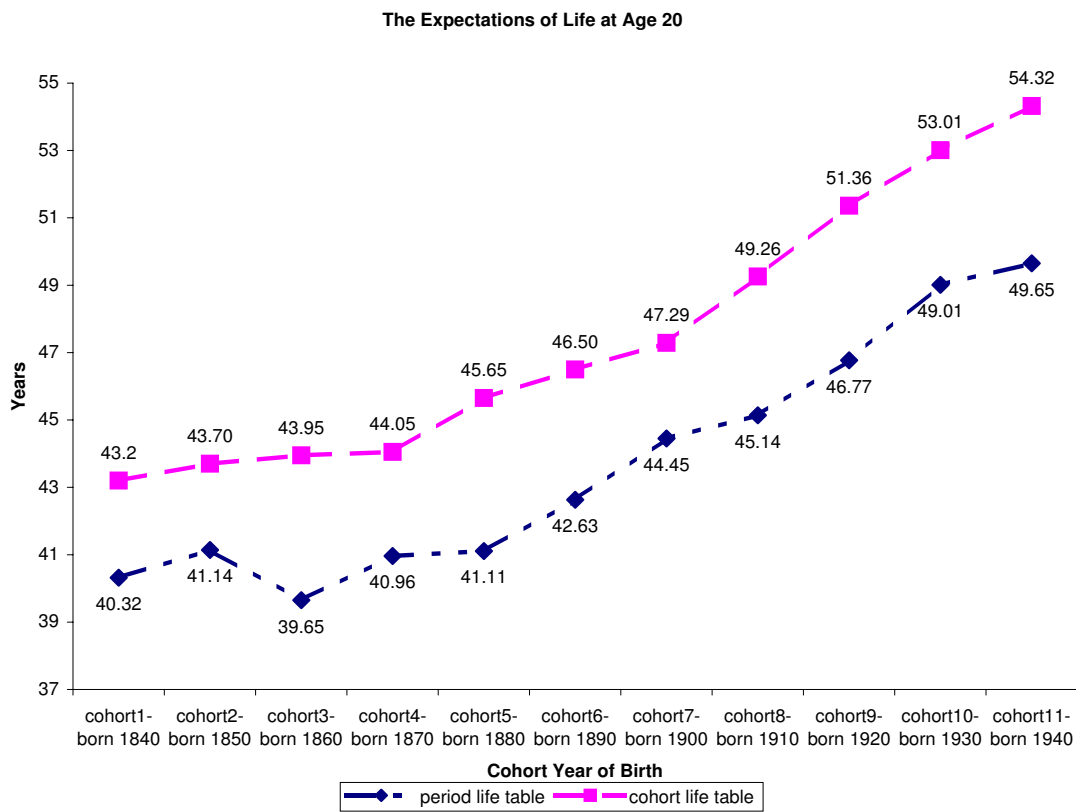
Figure 1: The Expectations of Life at Age 20 for Individuals born 1840–1940. Cohort and Period Estimates. See text for sources
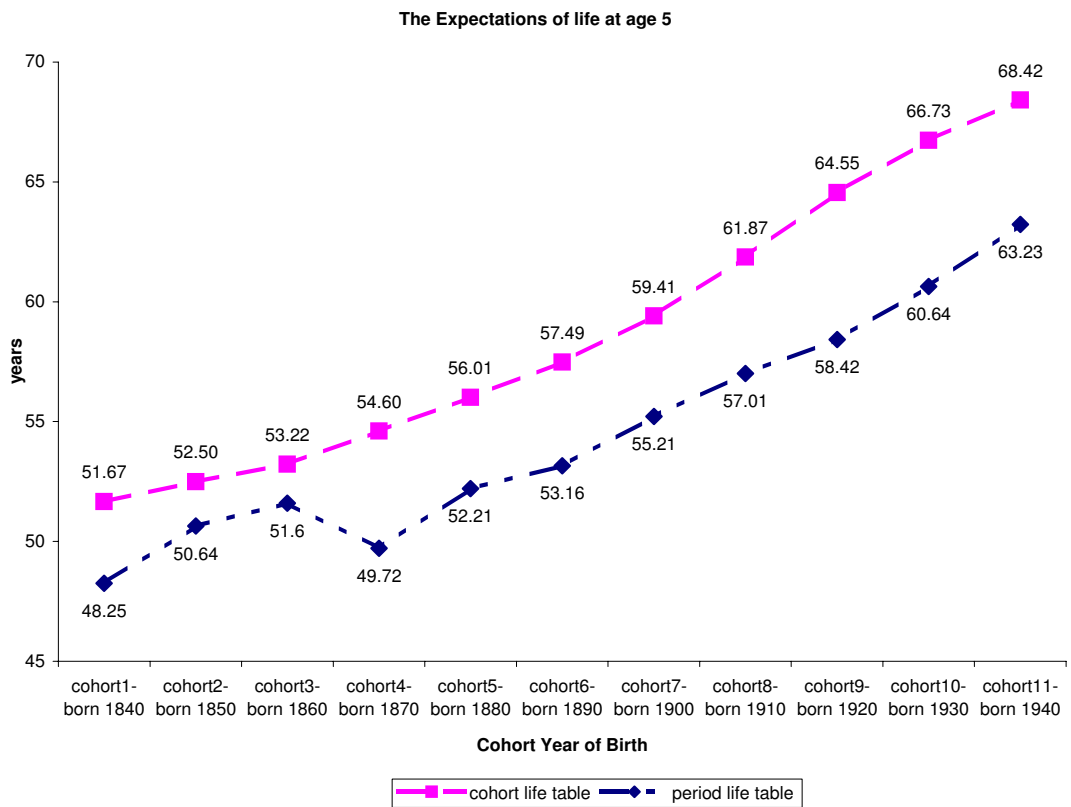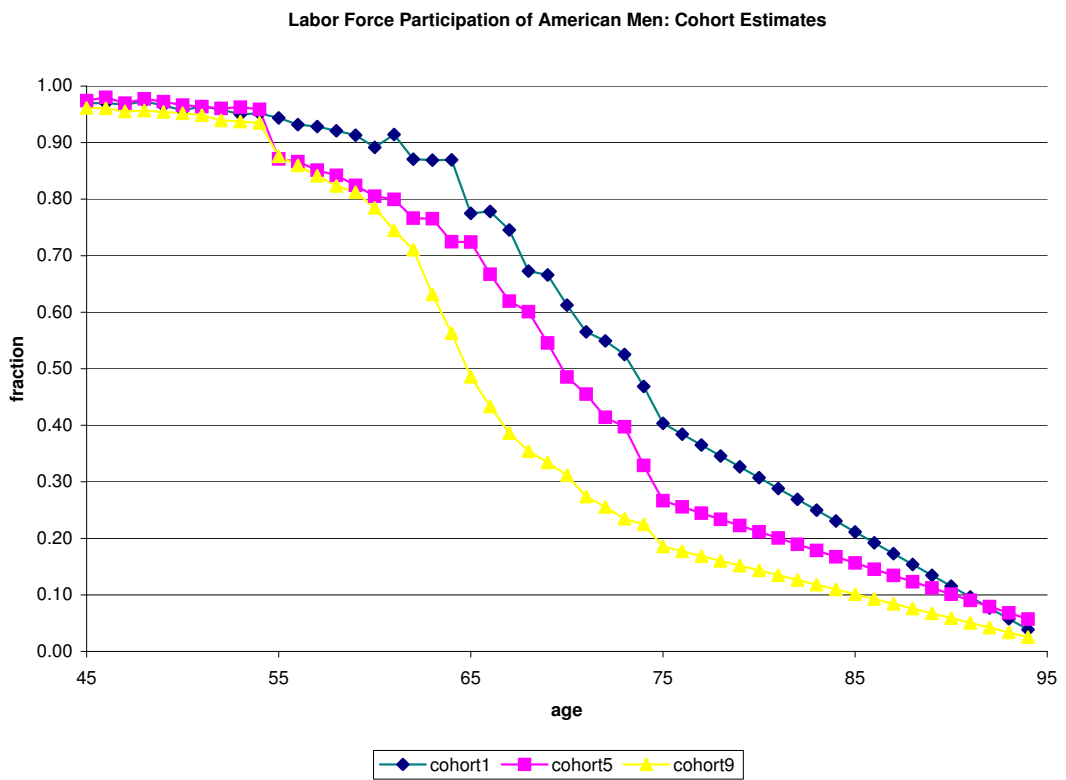
Figure 2: The Expectations of Life at Age 5 for Individuals born 1840–1940. Cohort and Period Estimates. See text for sources

Figure 3: Labor Force Participation of of Cohorts 1, 5 and 9: Cohort Estimates. See text for sources
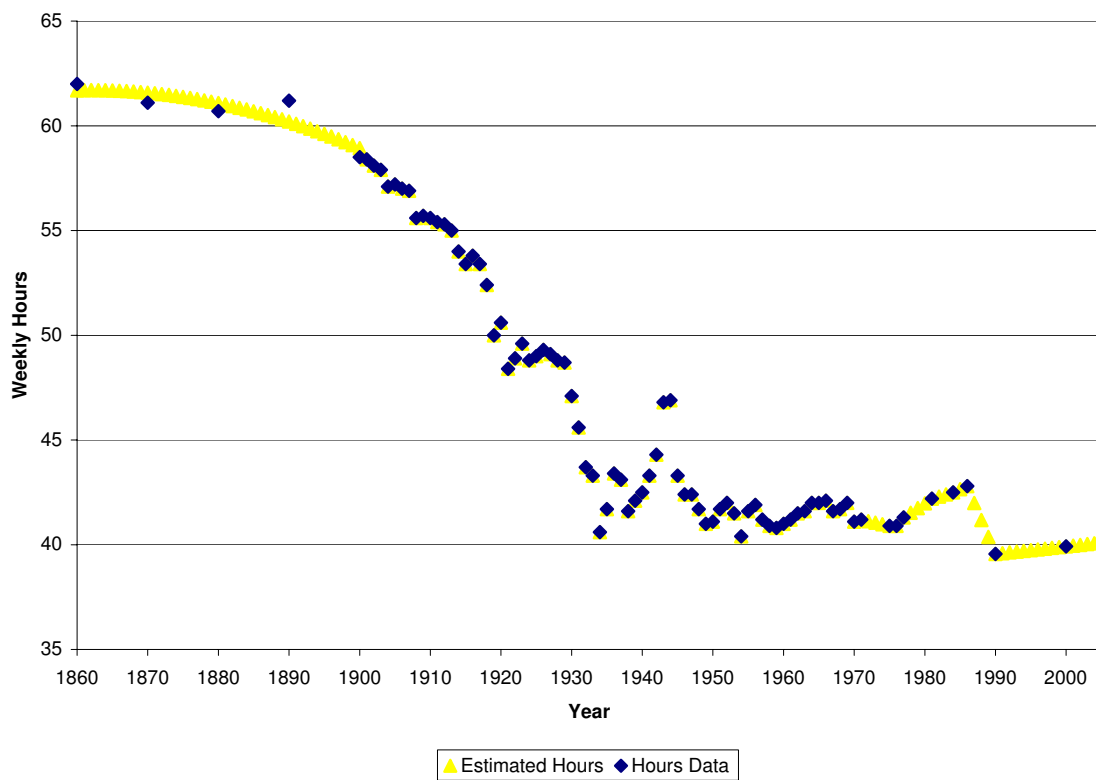
Figure 4: Weekly Hours worked 1860–Present. See text for sources

Fraction of High School Graduates
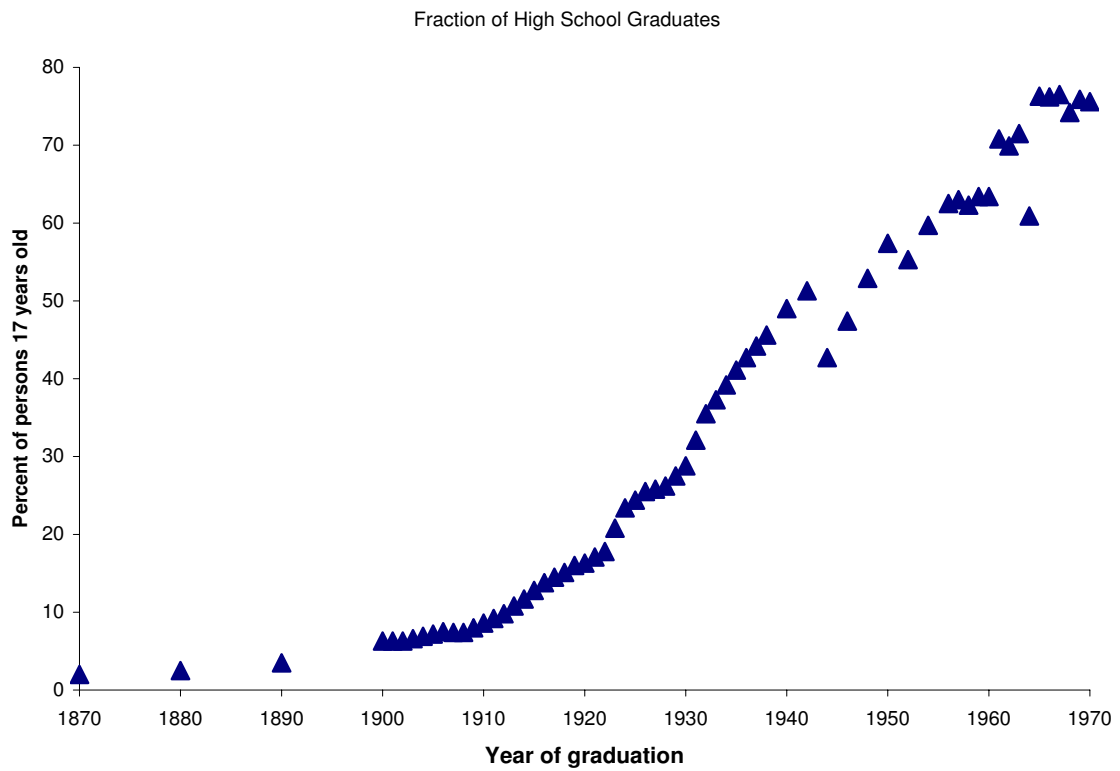
Figure 5: The Fraction of 17 years old who are High-School Graduates source: US Department of Commerce, Bureau of the Census, 1975, "Historical Statistics of the U.S., Colonial times to 1970", Part 1, Washington, D.C. series H 598-601

Survival to Each Age: Cohort Estimates
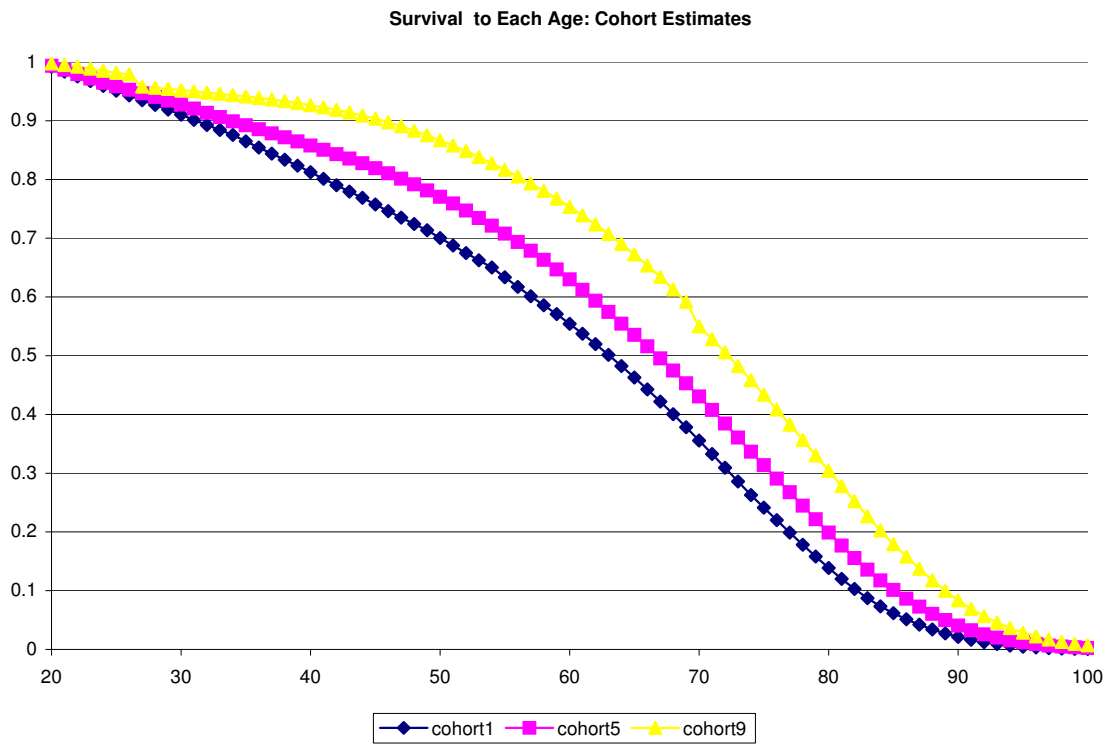
Figure 6: The Probability of Remaining Alive, conditional on reaching age 20 for Cohorts 1, 5 and 9: Cohort Estimates. See text for sources

The Probability of Surviving from age 5 to age 20: Cohort Estimates
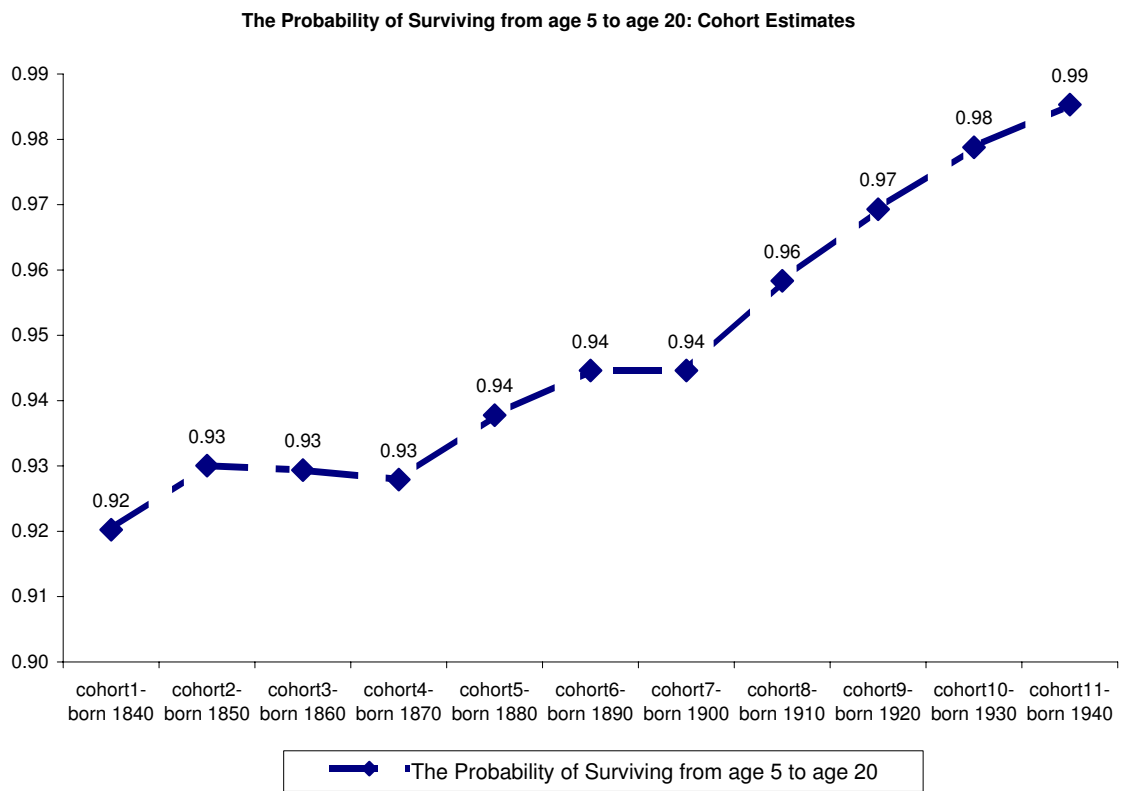
Figure 7: The Probability of Surviving from Age 5 to Age 20: Cohort Estimates. See text for sources
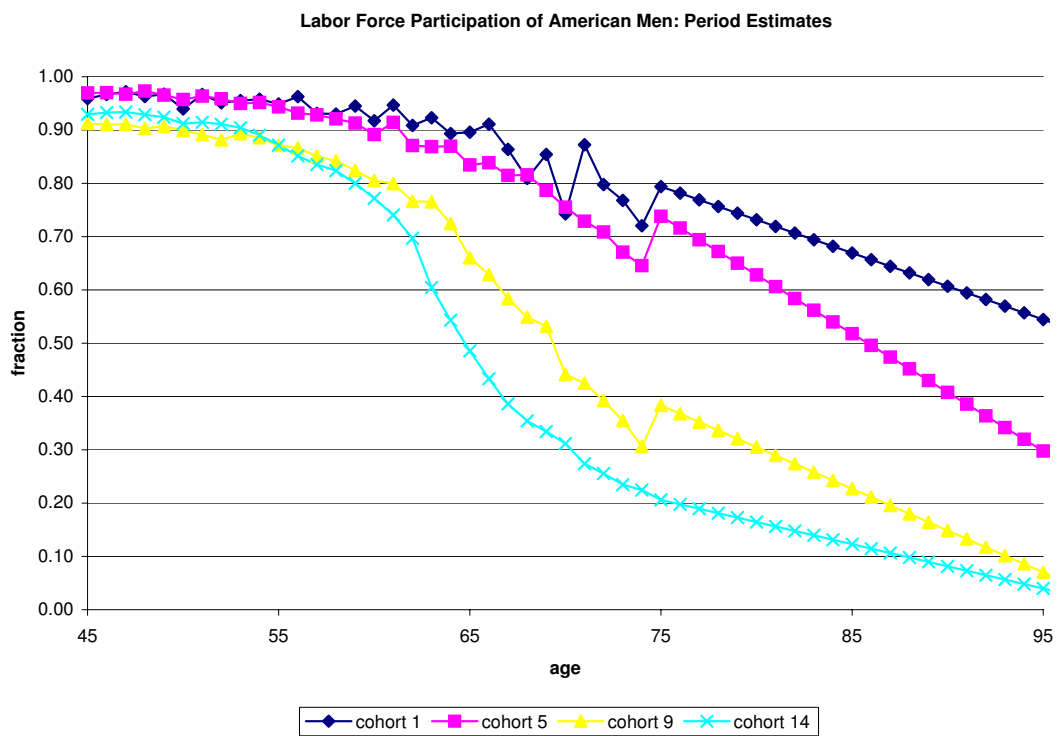
Figure 8: Labor Force Participation of of Cohorts 1, 5, 9 and 14: Period Estimates. See text for sources

Average Weekly Hours
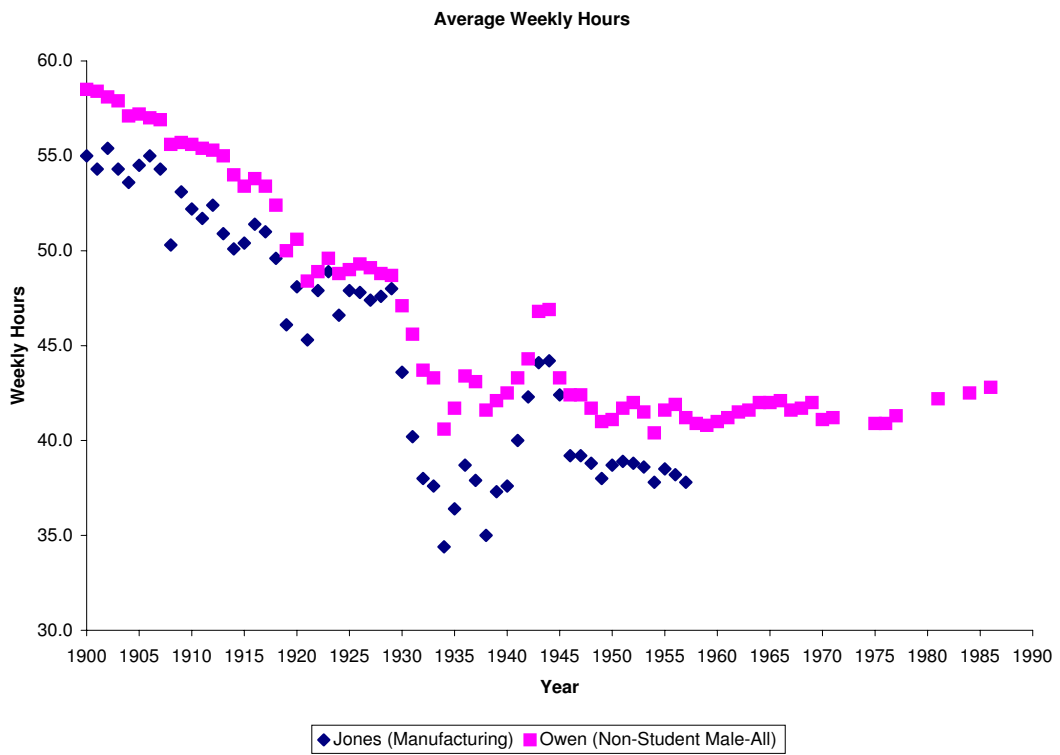
Figure 9: Average Weekly Hours: Manufacturing Sector (Jones Series), All Non-Student Males (Owen Series). Source: Whaples (1990), Table 2.1A
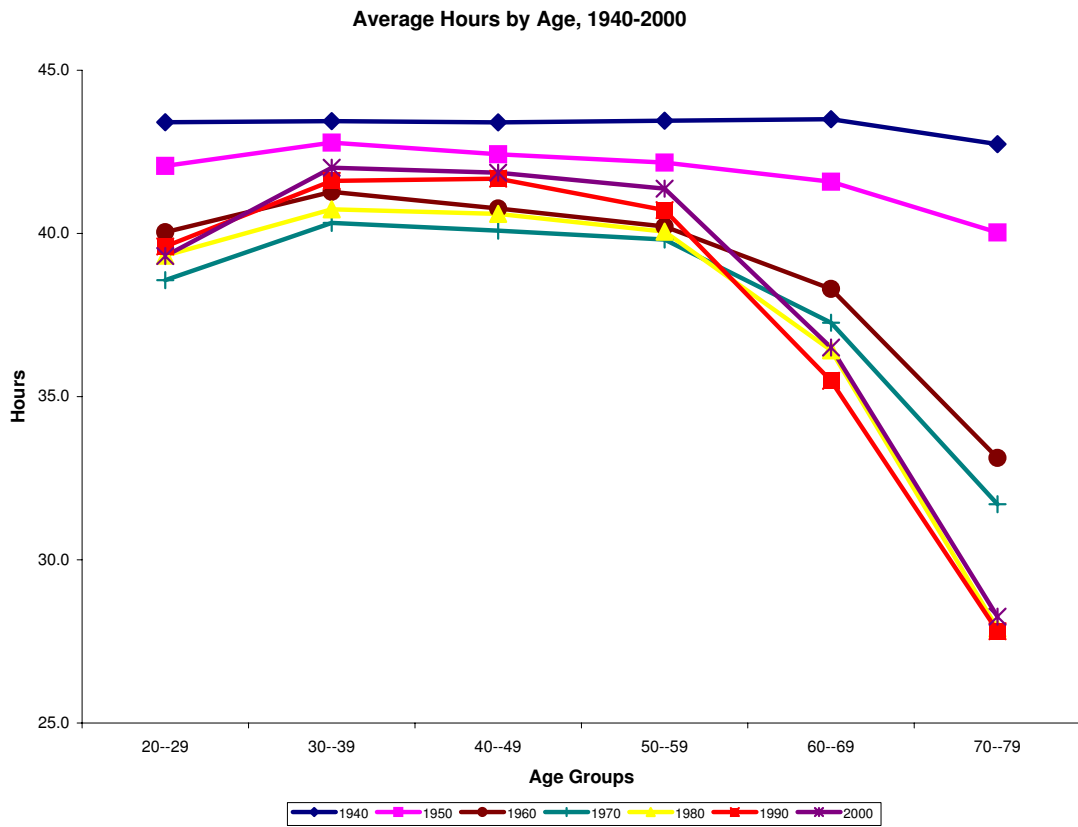
Figure 10: Average Weekly Hours by Age, 1940–2000. See text for sources

Average Hours Worked by Men in the 10th 50th and 90th Percentile of the Wage Distribution
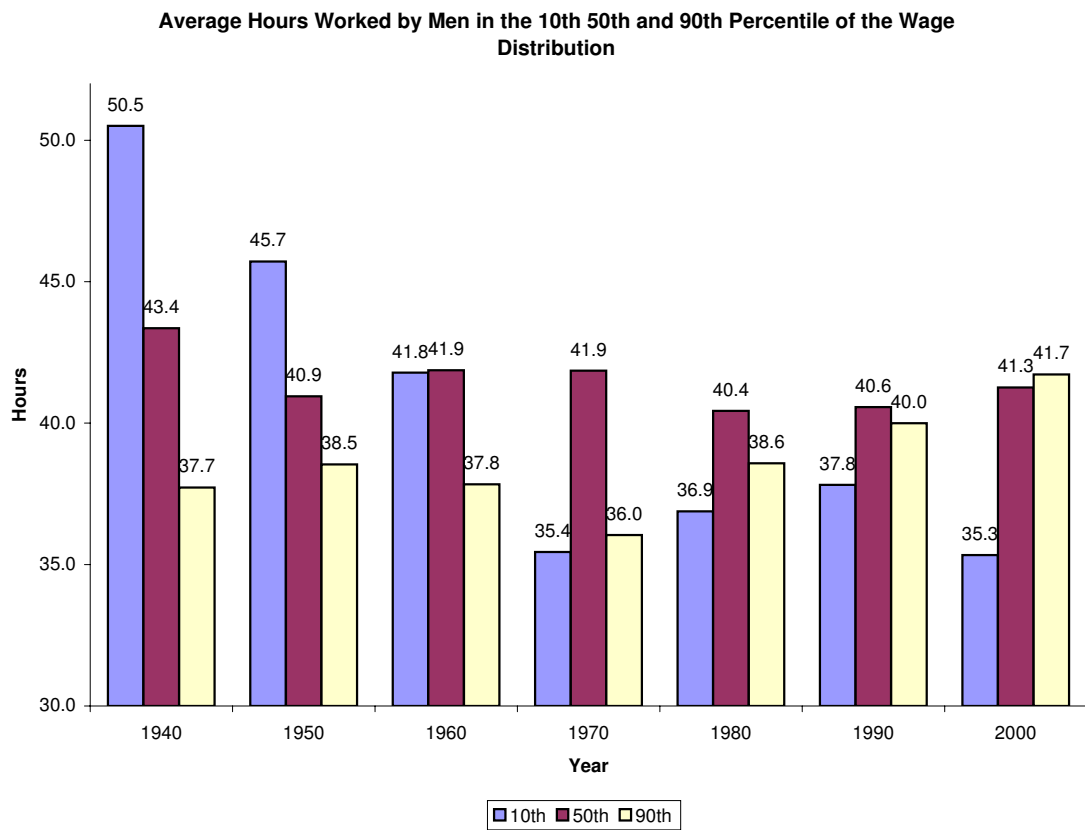
Figure 11: Average Hours Worked by Men in the 10th, 50th and 90th Percentile of the Wage Distribution, 1940–2000. See text for sources

Survival in the Labor Market: Cohort Estimates
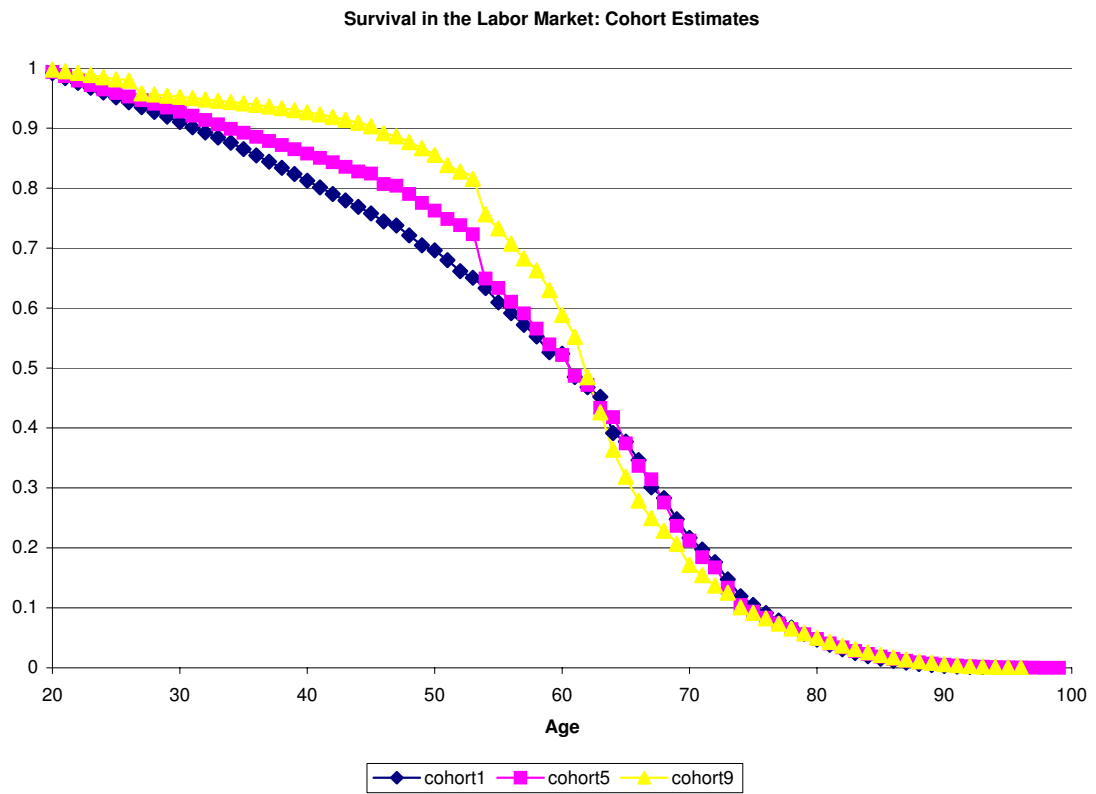
Figure 12: The Probability of Surviving in the Labor Market, Conditional on Entry to the Labor Force at age 20: Cohort Estimates. See text for sources
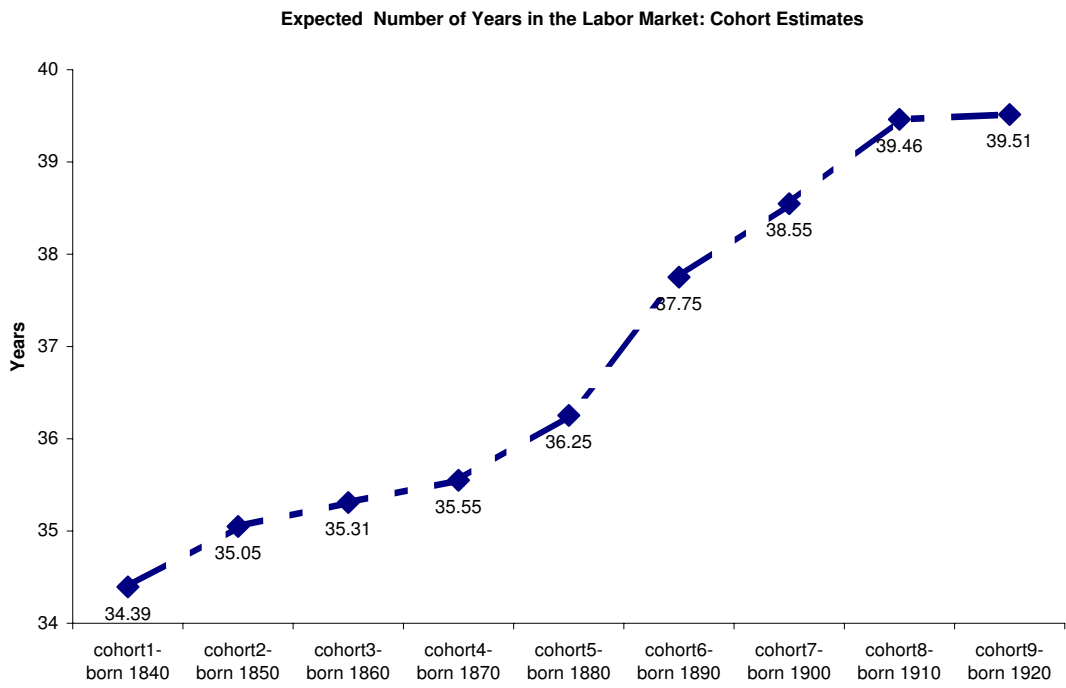
Expected Number of Years in the Labor Market: Cohort Estimates

Figure 13: Expected Number of Years in the Labor Market at age 20, Conditional on Entry to the Labor Force at age 20: Cohort Estimates. See text for sources
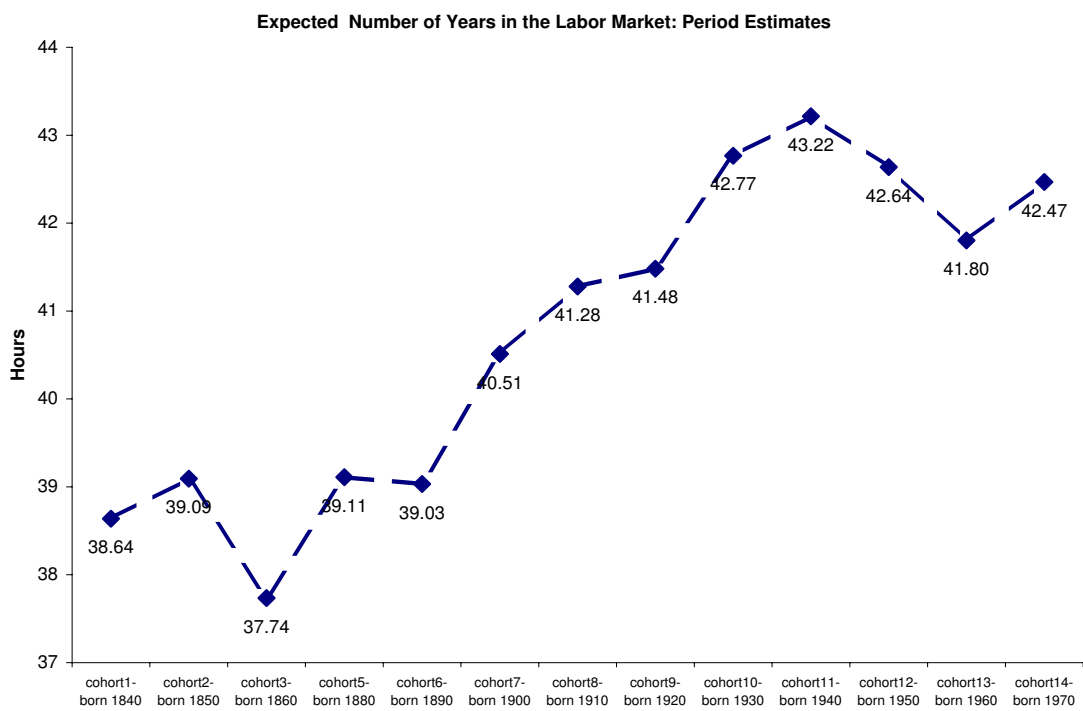
Expected Number of Years in the Labor Market: Period Estimates

Figure 14: Expected Number of Years in the Labor Market at age 20, Conditional on Entry to the Labor Force at age 20: Period Estimates. See text for sources
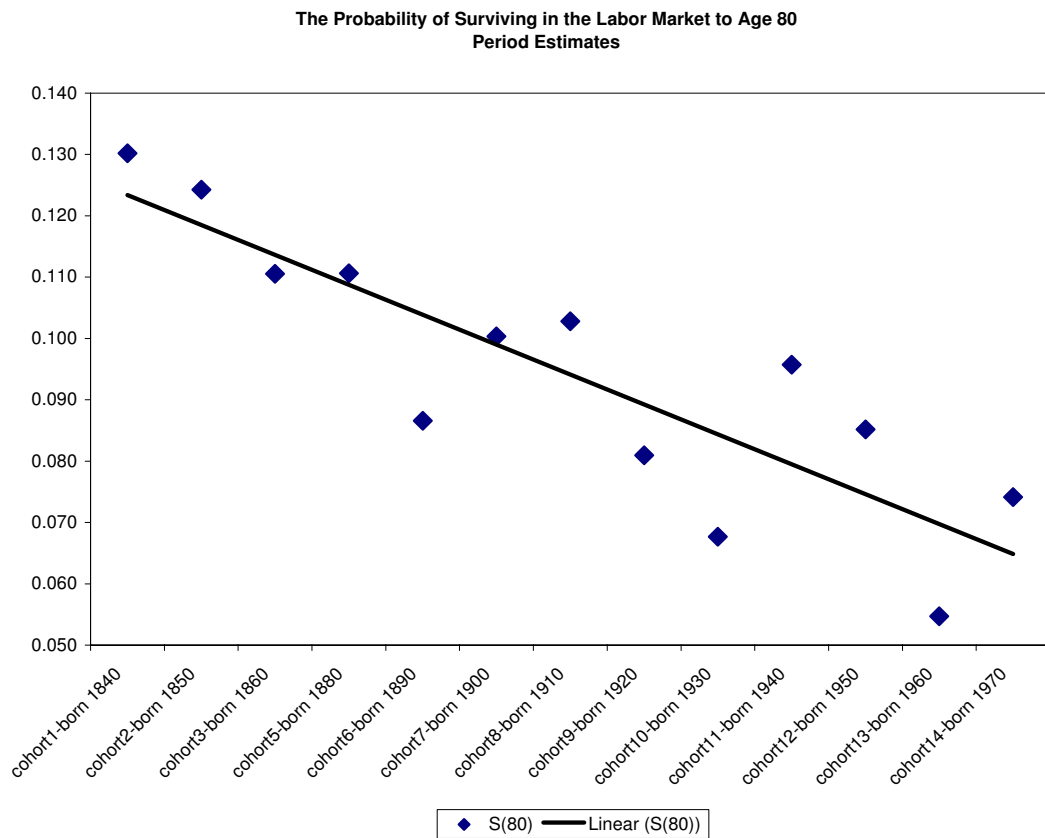
Figure 15: The Probability of Remaining in the Labor Market by age 80, Conditional on Entry to the Labor Force at age 20: Period Estimates. See text for sources

Expected Total Working Hours Over the Lifetime: Expectations are calculated at age 20
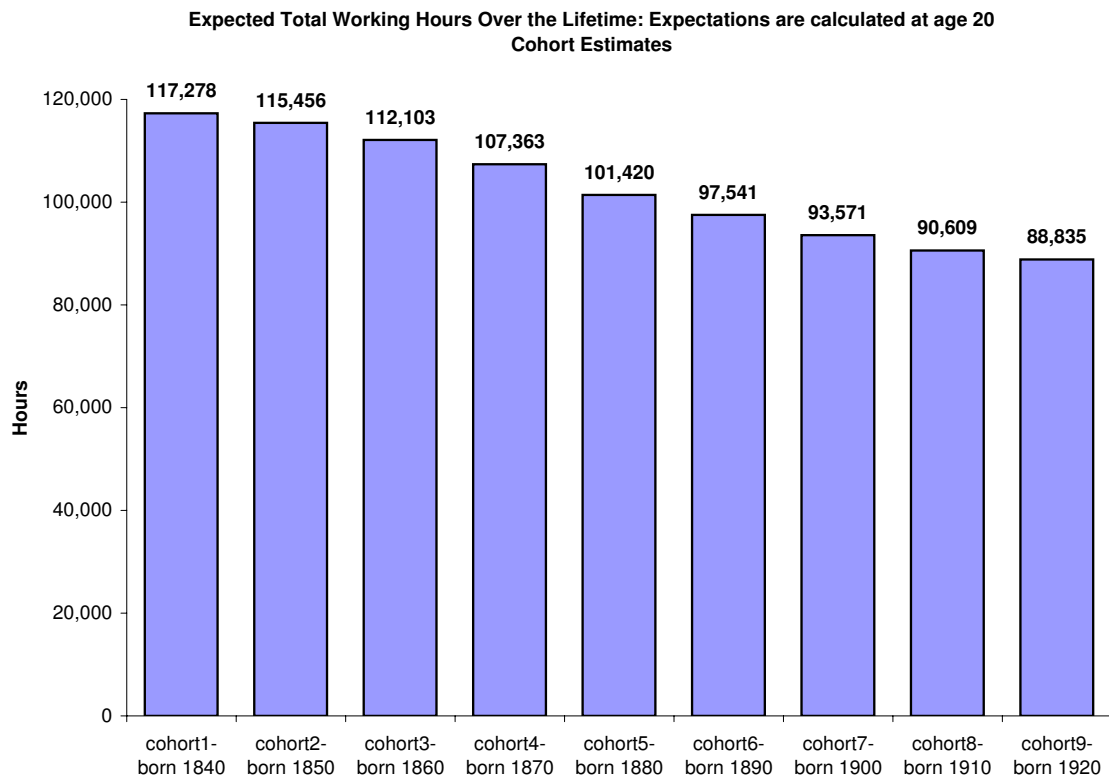**Cohort Estimates**

Figure 16: The Total Expected Working Hours over the Lifetime of Consecutive Cohorts born 1840–1920. Individuals are Assumed to Enter the Labor Market at Age 20: Cohort Estimates calculated at Age 20. See text for sources and estimation procedure.

Expected Total Working Hours Over the Lifetime: Expectations are calculated at age 5
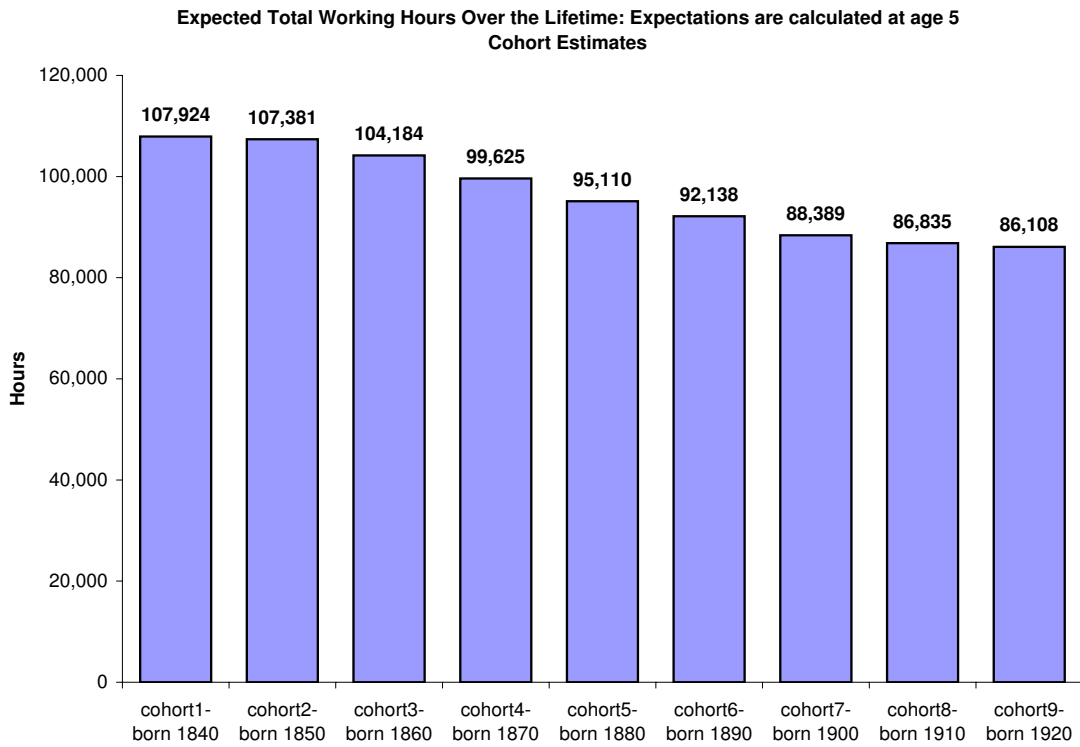**Cohort Estimates**

Figure 17: The Total Expected Working Hours over the Lifetime of Consecutive Cohorts born 1840–1920. Individuals are Assumed to Enter the Labor Market at Age 20: Cohort Estimates calculated at Age 5.See text for sources and estimation procedure.

**Expected Total Working Hours Until Age 80: Expectations are calculated at age 20
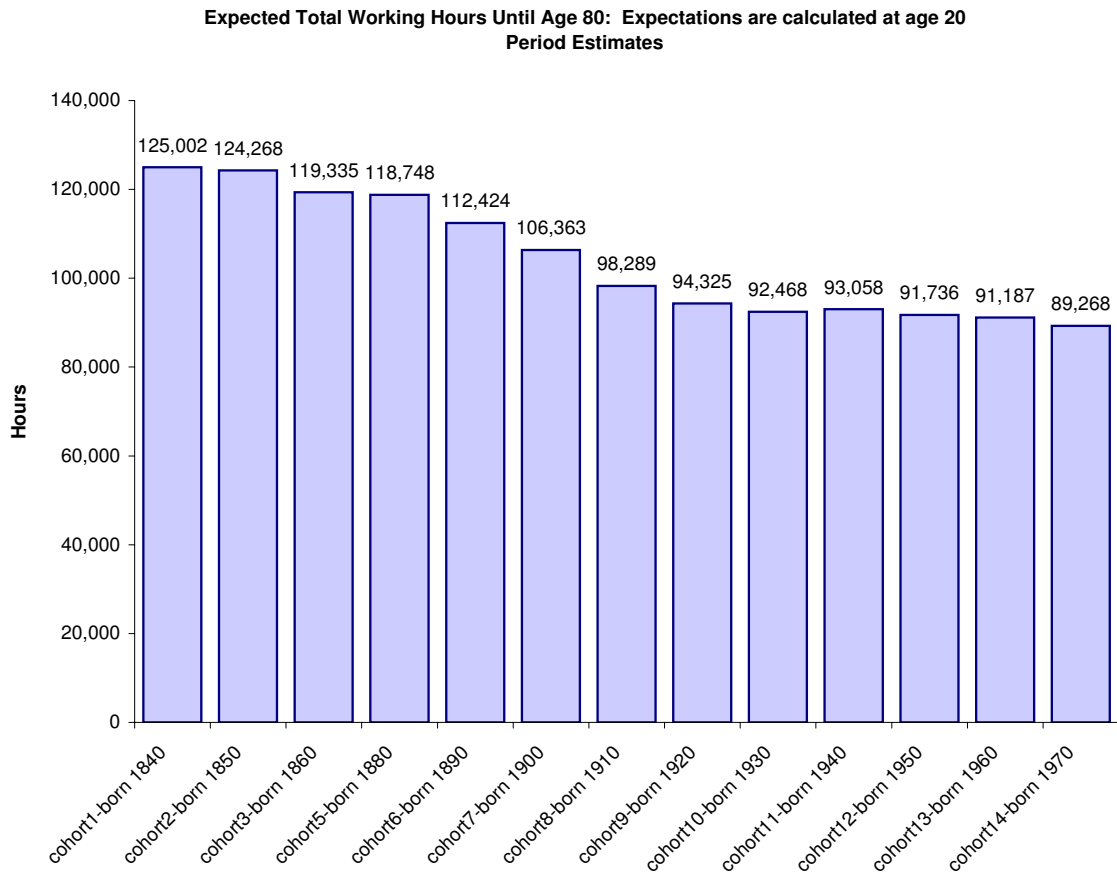Period Estimates**

Figure 18: The Total Expected Working Hours by Age 80 of Consecutive Cohorts born 1840–1970. Individuals are Assumed to Enter the Labor Market at Age 20: Period Estimates calculated at Age 20. See text for sources and estimation procedure.