Longevity and Lifetime Labor Input: Data and Implications*

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Abstract

The Ben-Porath (1967) model suggests that a rise in life expectancy, and the associated rise in the lifetime labor input, brings about a rise in investment in human capital. We incorporate the leisure decision into the model and develop a necessary condition regarding the lifetime labor input for the Ben-Porath mechanism to have a positive effect on investment in human capital. We show that this condition does not hold for American men born between 1840 and 1970. The data suggest similar patterns in Western Europe.

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1 Introduction

During the last 15 years, a plethora of research has investigated the intriguing transition from "stagnation" to "growth". For thousands of years of human existence, the living standards of most of the population were relatively constant at very low levels, as judged from the perspective of the contemporary developed economies. This long-lasting state of stagnation was interrupted, and a new era of rapid growth in living standards emerged, in 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 as causes of the immense increase in 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 human capital spurs investment in human capital and causes growth.[2] Hereafter, we refer to this mechanism as the "Ben-Porath mechanism," following the seminal work of Ben-Porath (1967). However, despite this mechanism's popularity, little is known about how much this mechanism can empirically explain the rise in investment in human capital, and thereby, the transition from stagnation to growth. Our purpose is to empirically investigate the relevance of this mechanism.

We 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. We examine therefore a crucial implication of the Ben-Porath mechanism. Specifically, we 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 input increases. Importantly, incorporation of leisure choice into a Ben-Porath (1967) type of model does not change the above statement.[3]

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

[2] See Ehrlich and Lui (1991), de la Croix and Licandro (1999), Kalemli-Ozcan, Ryder and Weil (2000), Boucekkine, de la Croix and Licandro (2002, 2003), Soares (2005), Cervellati and Sunde (2005), Boldrin, Jones and Khan (2005) among others. 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.

[3] This statement is true as long as schooling is used only for the production of output. In the Concluding

To see this, suppose that an individual maximizes lifetime utility from consumption and leisure by choosing consumption, leisure and schooling, taking as given the interest rate, the wage rate and the production function of human capital, which takes education as its input. Consider now the comparative statics of an increase in longevity. An increase in longevity would imply that the individual's lifetime labor input will increase as well. As a result, the returns to human capital would increase and hence the individual would invest more time in education. In turn, the increase in human capital would increase the individual's lifetime income. Suppose now that the income effect dominates the substitution effect in choosing leisure. This would imply that labor input per unit of time will decline, but this would only offset *part* of the increase in total labor input over a lifetime. Had the income effect more than offset the increase in total labor input over a lifetime, i.e., had lifetime labor input declined, the incentive to invest in education would not have increased in the first place, and hence education would not have increased. Section 2 of the paper formulates this argument.

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 input. We therefore suggest estimating the empirical counterpart of the lifetime labor input, i.e. the expected total working hours over a lifetime (Henceforth: ETWH) of consecutive cohorts of American men. 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.

It should be clarified that holding constant weekly hours and labor force participation rates, or taking as given the economic and political developments that led to the decline in weekly hours and participation rates, clearly the rise in life expectancy had, according to the Ben-Porath mechanism, a positive effect on lifetime labor input and thereby on investment in education. What we argue here is that taking into account both the reduction in weekly hours and in participation rates, and the rise in life expectancy, the latter had at most a partially offsetting effect on investment in education. That is, according to the Ben-Porath model, the total effect of the rise in life expectancy and the decline in weekly hours and participation rates on investment in human capital is negative. Thus, decomposing the observed change in educational attainment over the relevant period to its different sources, the total effect of the Ben-Porath mechanism enters with a non-

Remarks we discuss several other purposes of human capital which may reconcile the Ben-Porath mechanism with the findings of this paper.

positive sign, and it cannot provide, therefore, an explanation for the observed rise in education. This discussion makes clear that we do no intend, nor provide evidence on the causal effect of life expectancy on educational attainment.[4] At the same time, it also makes clear that the evidence showing a (positive) causal effect of life expectancy on educational attainment is not sufficient to assure the empirical relevance of the Ben-Porath mechanism for the observed rise in education during the transition from stagnation to growth.

Three factors determine the ETWH of each cohort of individuals. The first is the mortality rate at each age. Ceteris paribus, lower mortality rates at each age (i.e., higher longevity) imply higher ETWH. Figure 1 shows the life expectancies at age 20 of consecutive cohorts of American men born between 1840 and 1940, taken from both period life tables and cohort life tables. As can be seen from the figure, the life expectancy at age 20 has increased substantially. The data from the period life table suggest that 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. Figure 2, which presents the life expectancies at age 5 of successive cohorts of American men born between 1840 and 1940, shows a similar pattern.[5] The second factor is retirement rates at each age. Ceteris paribus, higher retirement rates at each age imply a lower ETWH. Higher retirement rates at each age are translated to lower labor force participation at each age. Figure 3 shows the labor force participation of men for different cohorts by age. As can be seen, while participation is rather constant until age 55, the younger the cohort is, the lower its labor force participation at older ages.[6,7] Finally, the third factor is the number of hours worked per week. Ceteris paribus, fewer hours per week imply a lower ETWH. Figure 4 plots men's average weekly hours over the time period 1860-2004. As can be seen from the figure, the average hours worked per week have declined monotonically by nearly 50 percent since the mid-nineteenth century, from

[4]Two recent papers present such evidence. Acemoglu and Johnson (2006) 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 the effect of adult mortality on economic development. While Acemoglu and Johnson find no effect of life expectancy on investment in human capital, Lorentzen, McMillan and Wacziarg find positive effects in some specifications and negative effects in others.

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

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

[7]See Costa (1998a) and Lee (2001) for a discussion on the trend in retirement and Kalemli-Ozcan and Weil (2005) for a theory that accounts for this trend.

about 60 hours a week to about 40.[8]

Before we present our estimates of the ETWH of consecutive cohorts of American males, it is important to discuss how individuals form expectations regarding mortality rates, retirement rates and hours they intend to work over the course of their lives. This importance springs from the fact that most of the investment in human capital predates entry into the labor market. At one extreme, we can assume that each cohort perfectly foresees its course of life and hence use the *actual* mortality rates, retirement rates and hours the members of this cohort worked at each age. Henceforth, we refer to these estimates as *cohort* estimates. At the other extreme, we can assume that each cohort has static expectations and hence use mortality rates, retirement 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.[9] In contrast, the period estimates require cross-sectional data, and hence 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 so on, ending with individuals born in 1970 as members of cohort 14.[10]

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 across the cohorts born between 1840 and 1920, total labor input has been declining substantially. Assuming that individuals calculate their expectations at age 20, our results suggest that while individuals born in 1840 were expected to work more than 117,000 hours over their lifetime, their counterparts born in 1920 were expected to work less than 90,000 hours. 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 results are weakened. 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 narrows somewhat, it is still substantial: while individuals born in 1840 were expecting at age 5 to work nearly

[8] See Vandenbroucke (2005) for a theory of the decline in weekly hours during the first half of the 20th century and Greenwood and Vandenbroucke (2005) for an explanation of the decline in hours over the last 200 years. In subsection 4.3 we discuss data sources and in subsection 4.3.1 we detail how we got to this series.

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

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

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.[11] Our period estimates tell a very similar story. Assuming that individuals calculate their expectations at age 20, individuals of cohort 1 were expected to work about 125,000 hours over their lifetime. Their counterparts of cohort 9 were expected to work less than 95,000 hours, and those of cohort 14 were expected to work even less, some 90,000 hours. Hence, while the period estimates of the ETWH are higher than the cohort estimates for all cohorts, the downward trend across cohorts is remarkably similar, independent of our assumptions about the way individuals form their expectations.

Parallel to the gains in longevity and the decline in ETWH, education in the US has been on the rise. Although comparing the educational achievements across these cohorts is not trivial, we provide some evidence that there has been some major progress in educational achievements across the cohorts in our samples. Figure 5 shows the fraction of high-school graduates among 17-year-olds. 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 the nine cohorts for which we have the cohort estimates, the fraction of high-school graduates has increased monotonically from a mere 2 percent to nearly 45 percent. A further increase is seen for cohorts younger than cohort 9.[12]

In sum, our estimates suggest that despite the major gains in life expectancy and the surge in educational attainment, ETWH have declined substantially during the process of development in the US. Moreover, in section 7 we provide some suggestive evidence that the decline in ETWH has not been unique to the US experience but is, rather, a common feature of the growth process in many European countries as well. Thus we conclude that the Ben-Porath (1967) mechanism cannot account for any of the immense increase in education during the transition from stagnation to growth.[13]

[11]Notice that regardless of the age at which expectations are calculated, all cohorts are *assumed* to enter the labor market at age 20. Thus our results do not stem from the fact that older cohorts in fact entered the labor market at younger ages. Hence the difference in ETWH across cohorts is downward biased.

[12]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 of that, 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.

[13]It should be clear that we do not argue that falling mortality rates or increasing life expectancies do not cause growth. Our paper sheds light on one particular channel through which longevity may affect human capital accumulation and hence growth. In the last section of the paper we discuss several such channels and their relation to the Ben-Porath (1967) mechanism.

The rest of the paper is organized as follows. In section 2, we present a prototype of the Ben-Porath model to explicitly derive the effect of an increase in life expectancy on education and lifetime hours worked. In section 3, we present our methodology for 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 explore the robustness of these results by using an alternative time series for hours and conducting a counterfactual experiment. In section 7, we provide brief evidence suggesting that our results are not confined to the US but are, rather, a robust feature of the growth process in the nineteenth and twentieth centuries and in section 8, we present some concluding remarks.

2 A Prototype of the Ben-Porath Model

In this section we present a prototype of the growth models that have utilized the Ben-Porath mechanism. The purpose of this section is to explicitly emphasize the implication of this type of model on the effect of an increase in longevity on total labor input over the lifetime and thereby on investment in human capital. For the purpose of comparison with the literature, we adopt the framework of Bils and Klenow (2000), which we extend to include leisure choice. Assume that preferences are defined over consumption of one final good, $c(t)$ and leisure, $l(t)$. 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 schooling is foregone earnings.[14] Hence, the optimization faced by the individual is:

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

s.t.

$$\int_s^T e^{-rt}(1-l(t))h(\bar{s})dt \geq \int_0^T e^{-rt} c(t)dt \tag{2}$$

where $u(\cdot)$ and $v(\cdot)$ are strictly increasing and strictly concave, T is the life expectancy at the age at which consumption, leisure and schooling decisions are taken, r is the interest rate and ρ is the subjective discount rate. $h(\bar{s})$ is the human capital of an individual who

[14]It can be verified that adding tuition cost as in Bils and Klenow (2000) would only strengthen the results below and hence they are robust to any combination of time and tuition costs.

spends s years in school and devotes $\bar{s}$ units of time to studying: $\bar{s} \equiv \int_0^s (1 - l(t))dt$. Henceforth we refer to s as the length of schooling and $\bar{s}$ as effective schooling.[15]

To illustrate the relationship between total labor input over the lifetime and investment in human capital in the simplest way, we make several simplifying assumptions. First, assume that there is no discounting by any agent in the economy, i.e., $r = \rho = 0$. This assumption ensures that consumption and leisure are constant throughout the individual's lifetime. This property is warranted because the Ben-Porath mechanism is silent with respect to life-cycle considerations of consumption and hours and because it allows derivation of the effect of longevity on total labor input without any specific assumptions on u and v. Secondly, we concentrate on an interior solution for the schooling choice. Finally, we assume that the production function of human capital takes the form:

$$h(\bar{s}) = e^{\theta(\bar{s})}. \tag{3}$$

Given these assumptions, the first-order condition with respect to length of schooling, s, is given by:

$$(1 - l)e^{\theta(\bar{s})} = \int_s^T (1 - l)e^{\theta(\bar{s})}\theta'(\bar{s})(1 - l)dt \tag{4}$$

where the term on the left-hand side (henceforth: LHS) is the marginal cost of postponing entry into the labor market and the term on the right-hand side (henceforth: RHS) is the marginal gain from postponing entry into the labor market.

Re-arranging (4), the first-order condition with respect to length of schooling, s, can be rewritten as:

$$\frac{1}{\theta'(\bar{s})} = (T - s)(1 - l) \tag{5}$$

Inspection of (5) suggests the following two propositions:

[15] The inclusion of leisure forces us to distinguish between the length of the schooling period, s and the units of time spent studying $\bar{s}$. Otherwise, if human capital was determined by s and not by $\bar{s}$, leisure would not bear its true cost during the schooling period. An alternative modeling strategy would assume that leisure is consumed only upon entering the labor market. This strategy, however, has the disadvantage that the first-order condition with respect to the length of schooling would involve an additional cost–the utility value of leisure at the date of entering the labor market–whereas the strategy followed here involves only marginal utilities.

Proposition 1 *If $\theta(\cdot)$ is twice continuously differentiable, strictly increasing and strictly concave, an increase in longevity that induces an increase in effective schooling must also induce an increase in the total labor input over the lifetime.*

Proof: By the strict concavity of $\theta(\cdot)$, as long as a change in longevity increases the investment in effective schooling, $\frac{d\bar{s}}{dT} > 0$, the LHS of (5) increases with an increase in longevity. But note that the RHS of (5) is total labor input. Hence, an increase in longevity that induces an increase in effective schooling must also induce an increase in the total labor input over the lifetime. □

Proposition 2 *If $\theta(\cdot)$ is linear, a change in longevity has no effect on total labor input over the lifetime.*

Proof: The linearity of $\theta(\cdot)$ implies that the LHS of (5) is unaffected by a change in longevity. Once again, note that the RHS of (5) is total labor input. Hence a change in longevity has no effect on total labor input over the lifetime. □

It follows that if there are no diminishing returns to schooling (in producing human capital), changes in the length of the working period leave 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.[16] 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, which may drive the estimates toward linearity (Card 1995). Assuming that the returns to education are not strictly convex, the effect of an increase in longevity on total lifetime labor input that brings about an increase in the investment in education, is non-negative.

We 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 total labor input over the lifetime. We now proceed with our empirical exercise of estimating the ETWH of consecutive cohorts of American males to see whether their expected total lifetime labor input has indeed increased as the Ben-Porath mechanism predicts.

[16]Similarly, in the growth literature it is usually assumed that the production function is strictly increasing, but with diminishing returns with respect to time invested. See Galor and Weil (2000), Kalemli-Ozcan et al. (2000), Galor and Moav (2002), and Moav (2005), among others.

3 Methodology

In this section, we explain our methodology for estimating the ETWH of each cohort. Let TWH_c denote total lifetime working hours of a 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:

$$E(TWH_c|t \geqslant t_0) = \sum_{t=t_0}^{\infty} l_c(t) S_c(t|t \geqslant t_0) \tag{6}$$

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*, i.e. the rate of leaving the labor market in the age interval $[t, t+\Delta)$, 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 $[t, t+\Delta)$, 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*, the rate at which the representative member of cohort c leaves the labor market in the age interval $[t, t+\Delta)$ 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), we need data on mortality rate and retirement rate for each cohort c

at each age t, $t \geqslant t_0$. In the next section, we explain in detail our data sources and how we estimate these variables for each cohort. Finally, the survivor function, $S_c(t|t \geqslant t_0)$ is given by:[17]

$$S_c(t|t \geqslant t_0) = e^{-\int_{t_0}^{t} \lambda_c(z)dz} \tag{8}$$

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 regarding their future. Specifically, we are interested in the way each cohort anticipates its mortality rates at each age, $q_c(t)$, its retirement rates at each age, $R_c(t)$, and the hours it intends to work at each age, $l_c(t)$. At one extreme, we can assume that each cohort perfectly foresees its course of life and hence use the *actual* mortality rates, retirement rates and hours the members of this cohort worked at each age. As mentioned in the Introduction, these are the *cohort* estimates. At the other extreme, we 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 the expectations are formed. These are the *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, to estimate the ETWH we need data on three variables: the *expected* mortality rates, the *expected* retirement 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.[18] In what follows, each subsection begins by discussing data sources and a general description of the variable. It is then followed by a description of the data for the cohort estimates and the period estimates.

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

[18] 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.

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 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 and cohort life tables from 1900 to 2080.[19] For earlier periods, we use period life tables from Haines (1998). Note that we can construct cohort life tables from the period life table by culling mortality rates for different ages from different years.[20]

Looking across our cohorts we observe that mortality rates have been declining at all ages for men born in 1840 onward. Since our investigation aims to discover 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 at the "relevant ages". Since investment in formal education does not start prior to age five, and entrance into the labor market starts, on average, at age 20, we focus on mortality rates, conditioned on surviving to age 5 and to age 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 of summarizing mortality rates is to estimate the life expectancy. Graphically, this 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. In what follows, we present data of these three types.

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

[20] For example, for a cohort born in 1840-49, the mortality rates for the age interval 20-9 are taken from the 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 survived to age 20.[21] As can be seen from the figure, 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 life expectancy at age 20. Figure 1 plots the life expectancies at age 20 for all cohorts. As can be seen from the figure, the life expectancies have been increasing monotonically and quite significantly. While a 20-year-old who belongs to cohort 1 was expected to live for another 43.2 years, his counterpart who belongs to cohort 5 was expected to live for another 45.65 years and their counterpart who belongs to cohort 9 was expected to live for another 51.36 years. Overall, conditioned 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, conditioned 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 increase concentrated in the younger cohorts.

4.1.2 Mortality Rates–Period Estimates for Cohorts 1-14

Figure 1 plots the life expectancies 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 life expectancy at age 20 has increased quite significantly, though the estimates are lower than the cohort estimates and have a somewhat lower slope, reflecting the declining trend in mortality over time. It can be seen from the figure that while a 20-year-old belonging to cohort 1 was expected to live for another 40.3 years his counterpart who belongs 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, conditioned 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 and Retirement Rates

To estimate retirement rates, we 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 of change in

[21] Including all nine cohorts on the same graph hides more than it reveals. We chose cohort 1 because it is the oldest cohort 9 because it is the youngest and cohort 5 because it is right in the middle.

labor force participation between age t and $t+1$.[22] 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, 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 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. We employ the method suggested by Moen in our estimation, for the cohort as well as the period estimates.[23]

4.2.1 Labor Force Participation and Retirement 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.[24] Similar to Figure 6, Figure 3 presents labor force participation rates for cohorts 1, 5 and 9. As can be seen, for age 55 and over, the younger the cohort, the faster the decline in participation.[25] 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, 80 percent for cohort 5 and 78 percent for cohort 9. By age 70, the estimates are 61 percent, 48 percent and 31 percent, respectively. Thus, while the fraction of those who survive to each age has gone up, the fraction of those who have already retired has gone up as well. In subsection 5.1, we combine the survival and

[22] Although not participating at a given age does not necessarily imply permanent retirement, this is what we assume here. This is not a bad assumption since we assume that retirement does not start prior to age 45. For men age 45 and above, the flows out of the labor force and into it are 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 since we estimate variables at the cohort level. For expositional purposes, in this section we present the data for labor force participation rates.

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

[24] 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 over, the number of observations in each cell is too small. Hence we 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 cohort 9 were 84 years old in 2000. Hence for cohort 9 we used the participation rates of cohort 8 at ages 85-94.

[25] Recall that the rate of change in labor force participation is the retirement rate at each age. Hence, a faster decline of labor force participation is equivalent to higher retirement rates at each age.

retirement data to obtain the cohort estimates of the fraction of those who remain in the labor market at each age, $S_c(t|t \geqslant t_0)$, using (8).

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, starting from age 45. Figure 8 presents period estimates of 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 years 1860, 1900, 1940 and 1990. As can be seen, the trend resembles that of the cohort estimates. One noticeable feature of this figure is that the younger the cohort, the lower the participation at each age is.[26] Thus, similar to our conclusion in subsection 4.2.1, while the fraction of those who survive to each age has gone up, the fraction of those who have already retired has gone up as well. In subsection 5.2 we combine the survival and retirement data to obtain the period estimates of the fraction of those who remain in the labor market at each age, $S_c(t|t \geqslant t_0)$, using (8).

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 perspective. Whaples puts together the available aggregated time-series data from as early as 1830 to the present day. 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. Nevertheless, that Whaples writes:

[26]Notice, however, that our estimates of ETWH are *not* affected by the lower participation at age 45, since by assumption participation is constant between age 20 and age 45 and the hazard function, (7), is affected only by the retirement rate between age t and $t + 1$ which is the rate of change in labor force participation.

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

> 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 show 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)

Hence, due to the lack of 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 decline in hours worked had 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 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 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 John D. Owen series for non-student males in all sectors of the economy for the years 1900-1986.

Finally, from 1940 to the 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.[30]

[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 (n.d.).

[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.

[30]For a detailed analysis of hours worked in the US over the period 1950-2000, see McGrattan and Rogerson (2004).

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 work week was 62 hours in 1860, 61.1 hours in 1870 and 60.7 hours in 1880. The Aldrich series gives somewhat higher figures, suggesting that the average work week was 66 hours in 1860, 63 hours in 1870, 61.8 hours in 1880 and 60 hours in 1890.[31]

Using the data set that combines the nine micro data sets published by the aforementioned state Bureau of Labor Statistics, average hours worked by males yields an estimate of 10.2 hours per day, or 61.2 per week.[32] The micro data set allows us 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 week work of individuals whose wages are in the 10th percentile consisted of 62.15 hours while that of individuals whose wages are in the 90th percentile consisted of only 56.53 hours.

The Jones series for the manufacturing sector 1900-1957 and the Owen series for non-student males in all sectors of the economy 1900-1986 are presented in Figure 9. As can be seen, the two series are highly correlated although Owen's series is generally about three hours above that of Jones'.[33]

As already mentioned, starting with the 1940 Census, a question about hours worked the previous week or usual hours worked per week was asked.[34] Average weekly hours for all males declined from 43.32 in 1940, to 41.83 in 1950, 39.28 in 1960 and 38.15 in 1970.

[31] An alternative time series for hours exists in Kendrick (1961). We use this source in section 6 to check the robustness of our results.

[32] 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. Hence, similar to Costa, we assume a 6-day work week.

[33] The correlation between the two series is 0.98.

[34] The censuses of 1940, 1950, 1980 and 1990 asked a question about hours worked the previous week, the 1960 and 1970 censuses 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.

They then rebounded to 38.52 in 1980, 39.56 in 1990 and 39.92 in 2000.[35] In Figure 10 we look at the average hours worked by age group. Whereas 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 becomes more pronounced as we progress in time. Finally, Figure 11 plots weekly hours worked by males in the 10th, median, and 90th percentile of the wage distribution.[36] As can be seen, whereas in 1940 the poorer workers worked more, by 2000, the reverse held true.[37] 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 above discussion highlights 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 consists of men and women while in others it consists only of men. Second, some series consist of only part of the economy while others report on all sectors of the economy. Thirdly, over time, we see a change in the pattern of hours worked over a lifetime: while in the 1890s and in 1940, hours by age did not vary much, starting in 1950, hours by age varied substantially. These issues 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 make 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 the state Bureau of Labor Statistics (61.2 hours a week). For the years 1900-1986, we take the Owen series and for 1990-2000, our estimates are from the IPUMS data.[38] Second, we have to

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

[36]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 12th percentile of the wage distribution. Similarly ”median” refer to men between the 48th and 52nd percentile in the wage distribution and ”90th” to men between the 88th and 92nd percentile.

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

[38]For the period 1860-1900 we have only five observations. Hence we use a quadratic fitting curve 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 this is to ignore life-cycle and assume that regardless of age, in a given year, all men work the same average hours.[39] Under this assumption, the only difference in hours worked per year across cohorts arises from the year of entry and 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.

For our cohort estimates we use a subset of this series. For example, cohort 5 was born in 1880 and joined 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.[40] 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.[41] Finally, note that this series is expressed in terms of weekly hours worked. Since we aim to estimate the ETWH over a lifetime, we need to convert this series to a yearly one. 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.[42] 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 or the fraction of individuals who remain in the labor market, conditioned on being alive at age 5 and age 20.[43] This

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 a linear fitting curve between two adjacent data points to assign values for the missing data.

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

[40]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 in question, in practice, for all cohorts, at about the age of 80, $S_c(t|t \geqslant t_0)$ is sufficiently close to 0. Hence hours worked above this age have a negligible effect on the ETWH.

[41]In practice, since cohort 1 comprises individuals born between 1836 and 1845, we average across 10 years to generate the yearly hours for the period estimates. Hence, for cohort 1, we use the average of hours worked for the period 1856-1865, and so forth.

[42]This assumption is carefully examined in section 6.2.

[43]We use the terms "probability of surviving" and "the fraction of individuals who survived" interchangeably. Although from an individual point of view, the former is the appropriate term, for the representative member of each cohort the latter is relevant.

also enables us to present estimates on the expected number of years each cohort was 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 fraction of individuals who remain in the labor market at age t, conditioned on being alive at age t_0, for members of cohort c. Specifically, we let $t_0 = 20$ and assume that individuals of each cohort enter the labor market at age 20. We then estimate the fraction of those who remain in the labor market at all ages over 20. This estimation is done by estimating the hazard function,(7), and computing $S_c(t|t \geqslant 20)$ using (8).

Figure 12 shows the fraction of individuals who remain in the labor market conditioned 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 (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 we saw 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 cohorts 1, 5 and 9 intersect at about the age of 63.[44] Notice that the area under each such survival curve gives the expected number of years each cohort is expected to be working in the labor market. Figure 13 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.[45] As can be seen from this figure, the representative member of cohort 1 was expected to work for 37.38 years, whereas his counterpart in cohort 9 was expected to work for 40.77 years. We then redo this exercise, assuming that expectations are calculated at age 5 (i.e., $t_0 = 5$) and entering the labor market occurs at age 20. Since the probability of surviving to age

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

[45]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 education, 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 overestimates the difference in the expected number of years in the labor market between the oldest and youngest cohorts. This, in turn, underestimate the difference in ETWH.

20, conditioned on surviving to age 5, increases across cohorts, the difference in the expected number of years across the cohort is somewhat larger: while the representative member of cohort 1 was expected to work for 34.39 years, his counterpart of cohort 9 was expected to work for 39.51 years. Notice that the prolongation of working life is rather modest across these nine cohorts, on the order of about 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 fraction of individuals who remain in the labor market at age t, conditioned on being alive at age t_0, for members of cohort c. Specifically, we let $t_0 = 20$, and assume that individuals of each cohort enter the labor market at age 20. We then estimate the fraction of those who remain in the labor market at all ages over 20. We use the same estimation procedure as in section 5.1, only now we utilize period estimates for retirement and mortality rates.

Figure 14 reports the number of years that each cohort was expected to work in the labor market, conditioned on being alive at age 20 and on entering the labor market at that age. As can be seen, it resembles Figure 13, with two differences. First, it utilizes the period estimates. Second, it is based on the probability of surviving in the labor market only until age 80.[46] As can be seen, the expected number of years in the labor market increases for all cohorts younger than cohort 11 and then declines.[47]

5.3 The ETWH: Cohort Estimates for Cohorts 1-9

It is now time to present our main results. Figure 16 presents the cohort estimates of the ETWH of successive cohorts born between 1840- and 1920, cohorts 1-9. We begin by presenting the estimates 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 in its lifetime. In contrast, the youngest cohort, born in 1920, was expected to work less than

[46]This is because the period life tables in Haines (1998) do not report the death rate for individuals over 80. This is not a major problem, however, and it can be addressed in several ways. Since $S(\cdot)$ is non-increasing, we show in Figure 15 that $S_c(80)$ is decreasing across cohorts. Hence when we use $S_c(t)$ to estimate the expected number of years in the labor market we overestimate the differences across cohorts, whereas when we use $S_c(t)$ in the estimation of ETWH, we underestimate the differences across cohorts.

[47]This statistic also declines 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.

90,000 hours. This amounts to a decline of more than 24 percent between cohort 1 and cohort 9, an average decline of 3.4 percent between two adjacent cohorts. Figure 7, however, shows that the probability of surviving to age 20 from age 5 has increased from 0.92 for cohort 1 to 0.97 for cohort 9. Since investment in education begins at age 5, one can rightfully argue that the age at which expectations should be calculated is age 5.[48] 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 expected 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 over 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 between two adjacent cohorts. Finally, note that in both figures, the decline in ETWH is 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.[49] Figure 18 presents the period estimates for the ETWH until age 80.[50] Note, however, that since the function $S(\cdot)$ is non-increasing, that the older the cohort, the larger the $S_c(80)$ (see Figure 15) and that hours per year have been decreasing over time, we only underestimate the difference across cohorts when we estimate the ETWH until age 80 instead of an older age, say $\tilde{t}$ such that $S(\tilde{t}) = 0$. Figure 18 suggests that ETWH has been monotonically declining over all cohorts, at least till cohort 10 and then 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 nine cohorts is remarkably the same. Finally, due to the limitation imposed by the data on mortality rates above age 80 for older cohorts, as a robustness check on our period estimate, we estimate period estimates of ETWH till age 80 for cohorts 1-14 and till each cohort actually retires from the labor market for cohorts 5-14. The largest difference between the estimate till age 80 and till the cohort actually retires is for cohort 5 and equals only 1,412 hours.[51]

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

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

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

[51] In fact, we could present the ETWH for cohorts 1-3 by age 80 and for cohorts 5-14 till all their members have retired and still show that ETWH has been monotonically declining.

5.5 Implications

Our cohort as well as period estimates suggest that the Ben-Porath (1967) mechanism failed to meet its necessary condition: despite the substantial gains in longevity and the surge in investment in human capital, successive cohorts of American men have been decreasing their lifetime labor input. This negative correlation between lifetime labor input and investment in education suggests 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.[52]

6 Robustness of the Results

In this section we explore the robustness of our estimates for the ETWH. Some scholars argue that in nineteenth century America, most employment, particularly that in agriculture, was seasonal (Atack and Bateman 1992, Engerman and Goldin 1994).[53] Since seasonality in employment declined over time, our assumption that workers of all cohorts work 52 weeks a year biases the difference across cohorts in the ETWH upward. Further, correcting for seasonality may change our results even qualitatively, namely that the ETWH may not decline across cohorts. To explore this possibility we conduct two types of robustness checks. First, we utilize a time series for annual hours worked from Kendrick (1961). Second, we conduct a counterfactual experiment where we try to answer the hypothetical question: how many weeks of employment a year does the representative member of cohort c, $c = 1, 2, \ldots$ expect to work so that his ETWH would be equal to that of the representative member of cohort 14 and then compare the answer to the estimates in Engerman and Goldin (1994).

6.1 ETWH based on Kendrick's Series

We adopt two time series from Kendrick (1961): (i) Manhours by Sector and Industrial Division, Key Years, 1869-1957 (Table A-XI, p. 314) and (ii) Persons Engaged, by Sector and by Industrial Division, Key Years, 1869-1957 (Table A-VII, p.308), where each series contains data in ten-year intervals. By dividing the former series by the latter, we

[52]The growth literature provides numerous alternative explanations for the observed dynamics of education and growth. See the survey by Galor (2005).

[53]Atack, Bateman and Margo (2002) argue, however, that by 1870 in manufacturing, the typical establishment operated for 12 months a year, and that the full time equivalent months of employment was nearly 11 months a year both in 1870 and 1880.

obtain average annual hours per worker. Although this series does not account for compositional effect due to part time and full time employment, age, gender, etc., it has the advantage that it is corrected for the ratio of employment to labor force participation (See Kendrick 1961, p. 256). Since this series ends in 1957, it does not allow us to get cohort estimates for cohorts younger than cohort 4. Hence, we use the Kendrick's data to get period estimates of the ETWH for cohorts 2-11 and show them in figure 19. As can be seen from the figure, although the difference in the ETWH across cohorts is somewhat smaller, the general pattern is maintained: between cohort 2 and cohort 11, the ETWH declined by more than 18 percent.

6.2 A Counterfactual Experiment

A question about weeks worked last year was introduced by the census in 1940. Hence we can correct our period estimates presented in section 5.4 for the number of weeks worked last year for cohorts 9-14. We can then ask the question: how many weeks of employment a year does the representative member of cohort c, $c = 1, 2, \ldots, 8$ expect to work so that his ETWH would be equal to that of the representative member of cohort 14. For example, the representative member of cohort 1 should have expected to work 2,044 hours a year so that his ETWH would equal that of the representative member of cohort 14. In 1860, the year at which the representative member of cohort 1 was 20 years old, the weekly average hours of work was 62.2. Hence, to work 2,044 annual hours the representative member of cohort 1 should have expected to be employed for about 33 weeks a year. The answer for this hypothetical question for cohorts 1-8 is presented in figure 20. As can be seen, for all cohorts that entered the labor market by 1900 (cohorts 1-5), an employment of 33-35 weeks a year was enough to expect a lifetime labor input that is equal to that of cohort 14. Note that these numbers imply an expected length of unemployment of about 4 months a year, which is above the findings of Engerman and Goldin (1994) and Atack et al. (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. Taken these two findings together, it follows that the expected months of unemployment did not exceed 2. Atack, Bateman and Margo find that the full time equivalent months of employment was nearly 11 months a year both in 1870 and 1880.[54]

[54]Out of the nine data sets which we combined to generate the average weekly hours for the 1890s, three of them, Michigan stone workers in 1888, Michigan railway workers in 1893 and Wisconsin mechanics and workingmen in 1895, explicitly asked about employment status around the year. The questions are

7 The European Experience

Was the American experience unique? Have the ETWH of European men displayed a different time trend? In this section we briefly discuss the data on the determinants of the ETWH in some European countries and compare them to the US data.[55] Although the data in this section are somewhat suggestive, our purpose is to show that our results are not unique to the US experience, but rather a robust feature of the process of development of today's developed economies. To this end, we provide evidence for the long-run time series of (i) the life expectancies for males at age 5 (Figure 21), (ii) the labor force participation of men aged 65 and over (Figure 22) and (iii) hours worked per person (Figure 23).[56] Figures 19-21 demonstrate the remarkable similarities across these countries in the determinants of the ETWH, not only in terms of the trends but also in terms of magnitudes.[57] We therefore conjecture that our result that ETWH has declined across cohorts is not unique to the American experience but a robust feature of the process of development in today's developed economies.

8 Concluding Remarks

In this paper we 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 input must increase as well. Hence, we argue that this mechanism has to pass this necessary condition. Utilizing data on consecutive cohorts of American men, born between 1840 and 1970, we showed that this mechanism fails to pass its necessary condition. Interestingly, we provide suggestive evidence that the two factors that outweigh the gains in life expectancies, namely, the sharp

"months employed each year", "number of months worked and lost" and "number of months employed", respectively. These three data-sets encompass 8,260 out the 13,515 individuals in the combined nine surveys. The average months of employment of these workers is 10.34, pretty much in line with the findings of Engerman and Goldin (1994).

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

[56] Note that hours per *person* differs from hours per working males as we used above. However, for the purpose of comparison across countries, the similarity in this time trend seems suggestive enough.

[57] Rogerson (2006) compares hours per person across the OECD in 2003 and the time trend since the mid 1950s. On average, the data presented by Rogerson shows that while 50 years ago hours per person were quite similar across the OECD countries, today Europeans work much less than their American counterparts. See also Alesina, Glaeser and Sacerdote (2005). These findings support the conjecture we make in this section.

reduction of hours worked per week and the much lower labor force participation of relatively older individuals are not unique to the American experience but are common across many developed countries, such as England, France, Germany, the Netherlands and the like. Given the remarkable similarities, not only in trends but also in magnitudes, we conjecture that our main result that ETWH has declined is a robust fact of the process of development in today's developed economies.

At this point, a caveat is in place. Our analysis was conducted for a representative member of each cohort. However, it could be that ETWH have increased for more educated individuals while they have declined for less educated workers and that the latter dominate. While this is plausible, data limitation precludes us from estimating ETWH in different segments of the skill distribution. In particular, weekly hours worked by wage or education cannot be estimated prior to 1940, with the exception of the last decade of the 19th century for which micro data are available (see section 4.3). In addition, mortality rates by wage or education are also not available.

Furthermore, 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 an economic framework for valuing 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 America.[58] Secondly, longer life might affect growth through other channels. One lesson from the current paper is that the expected length of retirement has increased much over the last 150 years. Since a substantial length of retirement requires the accumulation of wealth to provide for the retirement period, longevity has probably affected growth via the its effect on total savings. Thirdly, human capital can be thought of as an input in home production in general or in the production of leisure in particular. Further, human capital might also provide social status. Hence, one can build a model in which an increase in longevity reduces total lifetime labor input and increases education and total welfare. This is one way to

[58]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 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 bridges between health and longevity. In Colombia, most of the malarious 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, estimates indicated no such gains from eradicating *falciparum*.

reconcile our findings with the Ben-Porath (1967) model. Finally, throughout the 20th century and in parallel to the gains in life expectancy, 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 seem to be an important determinant of either female investment in education through the Ben-Porath (1967) mechanism or of female labor force participation. A close look at investment in education of women in the US reveals a remarkable gender neutrality, from as early as the mid-19th century (Goldin and Katz 2003). Notwithstanding, female labor force participation, especially of married women, was remarkably low prior to World War II (Goldin 1990). Hence, relating gains in life expectancy to growth in labor force participation of women seems a little far-fetched.

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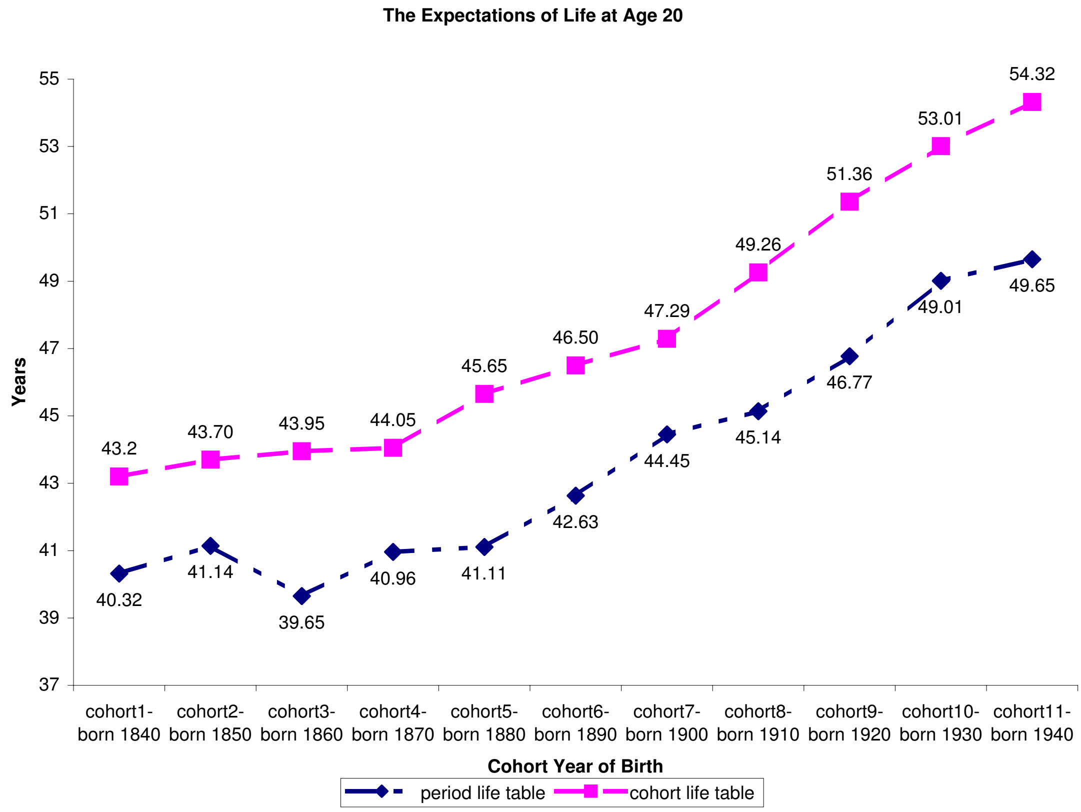

Figure 1: Life Expectancies at Age 20 for Individuals Born in 1840-1940. Cohort and Period Estimates. See text for sources.

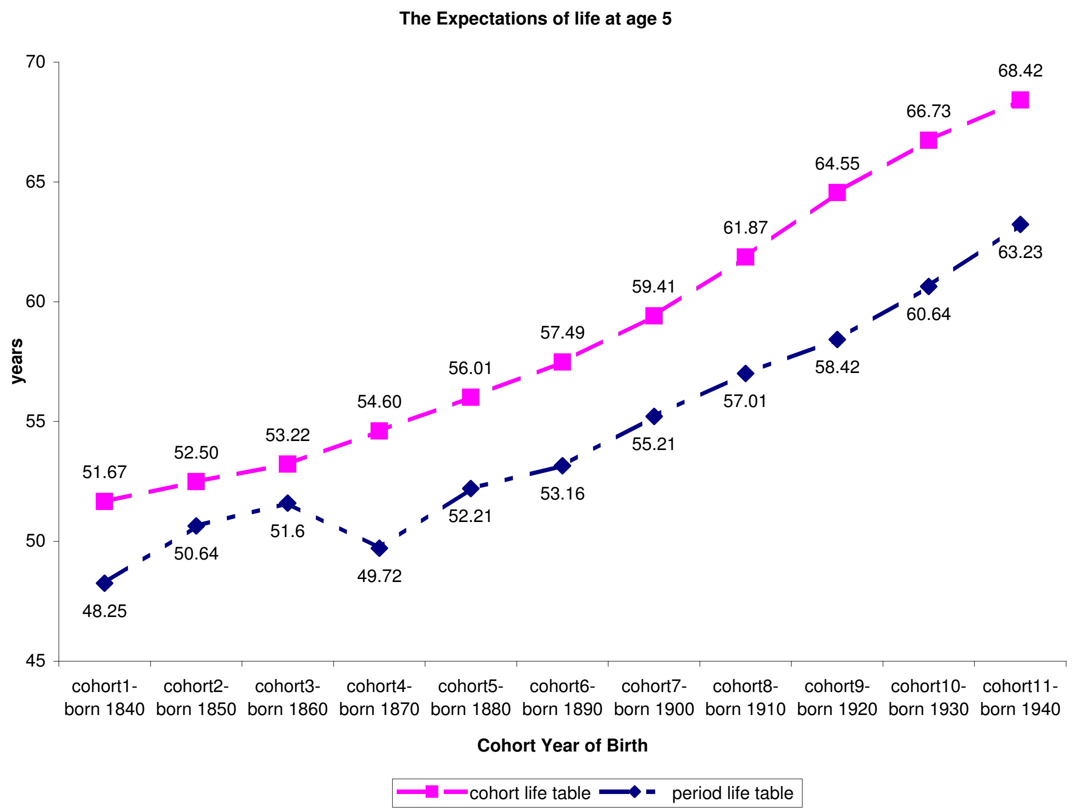

Figure 2: Life Expectancies at Age 5 for Individuals Born in 1840-1940. Cohort and Period Estimates. See text for sources.

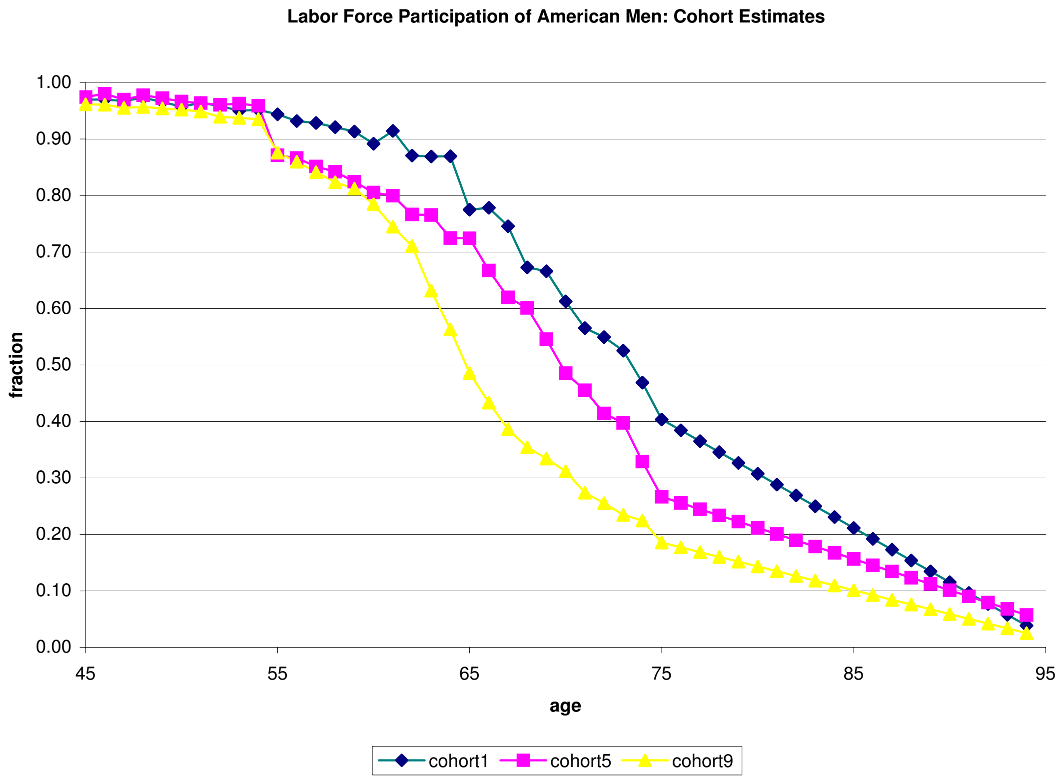

Figure 3: Labor Force Participation of Cohorts 1, 5 and 9: Cohort Estimates. See text for sources.

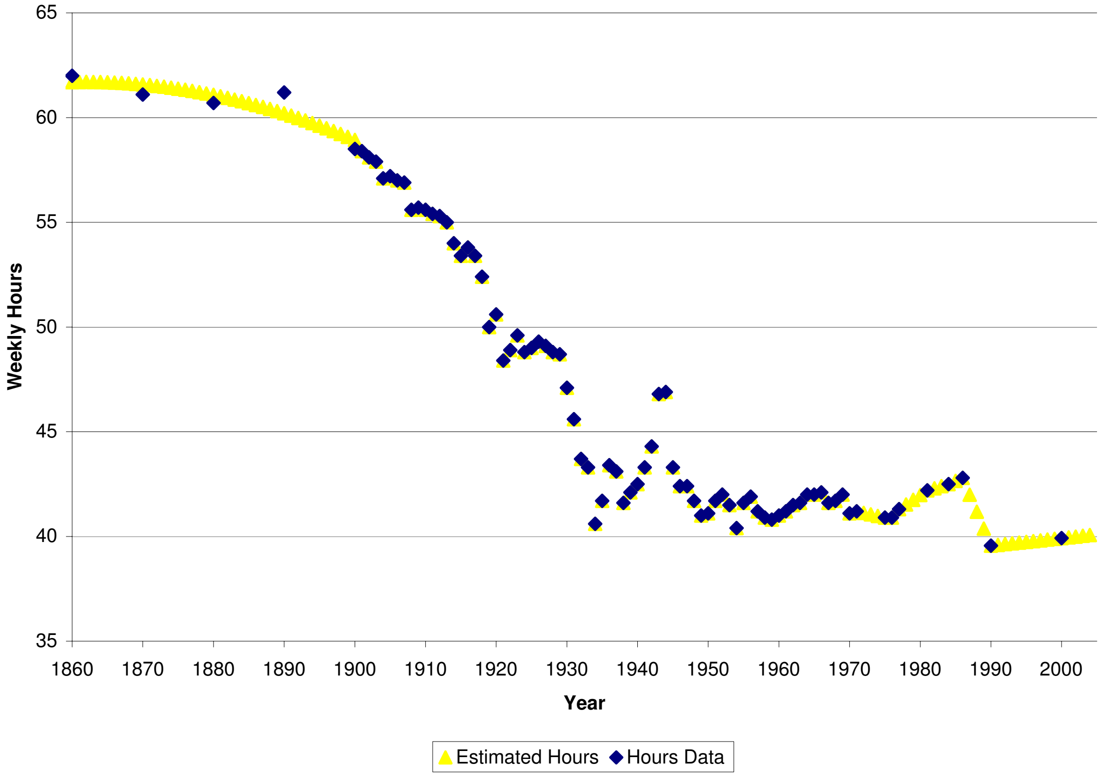

Figure 4: Weekly Hours Worked 1860-Present. See text for sources.

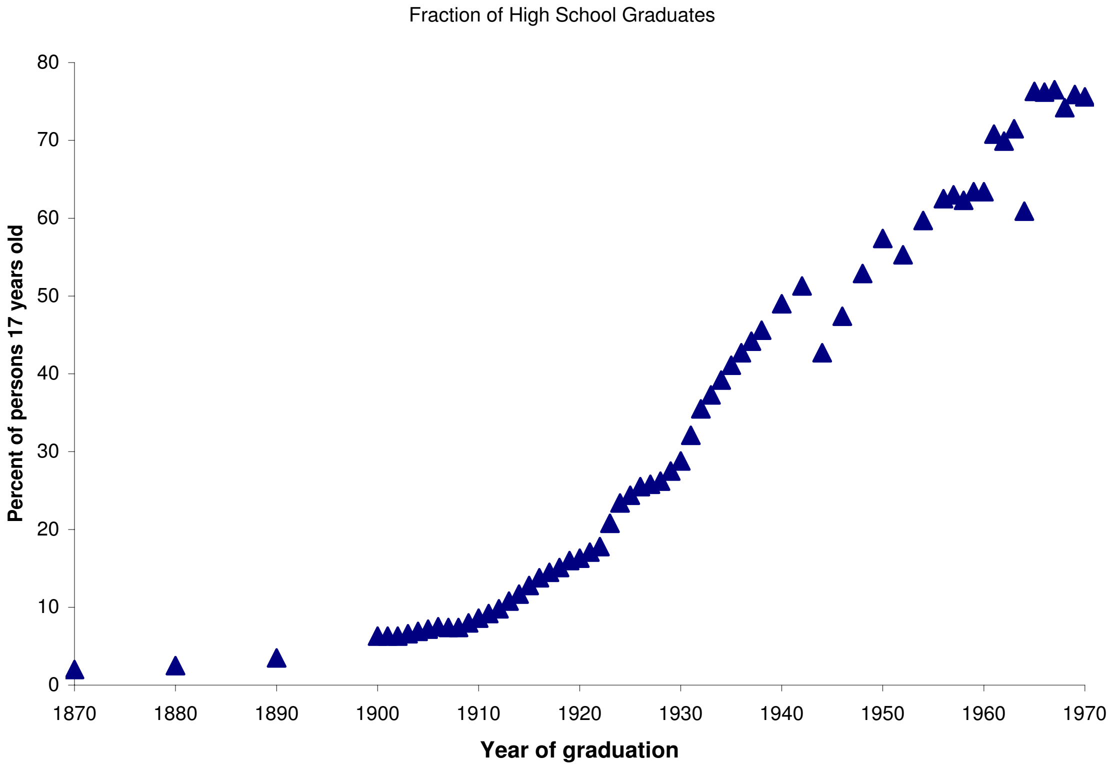

Figure 5: The Fraction of 17-Year-Olds Who Are High-School Graduates source: US Department of Commerce, Bureau of the Census, 1975, "Historical Statistics of the U.S., Colonial times to 1970", Part 1, Washington, D.C. series H 598-601.

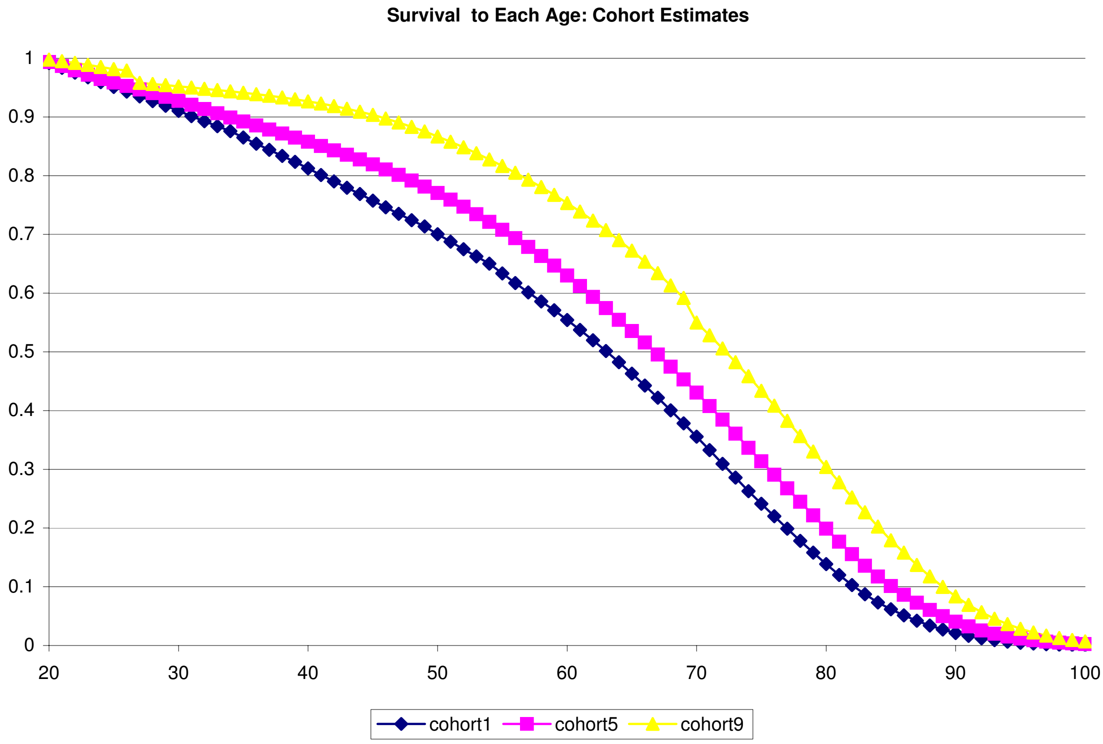

Figure 6: The Probability of Remaining Alive, Conditional on Reaching Age 20 for Cohorts 1, 5 and 9: Cohort Estimates. See text for sources.

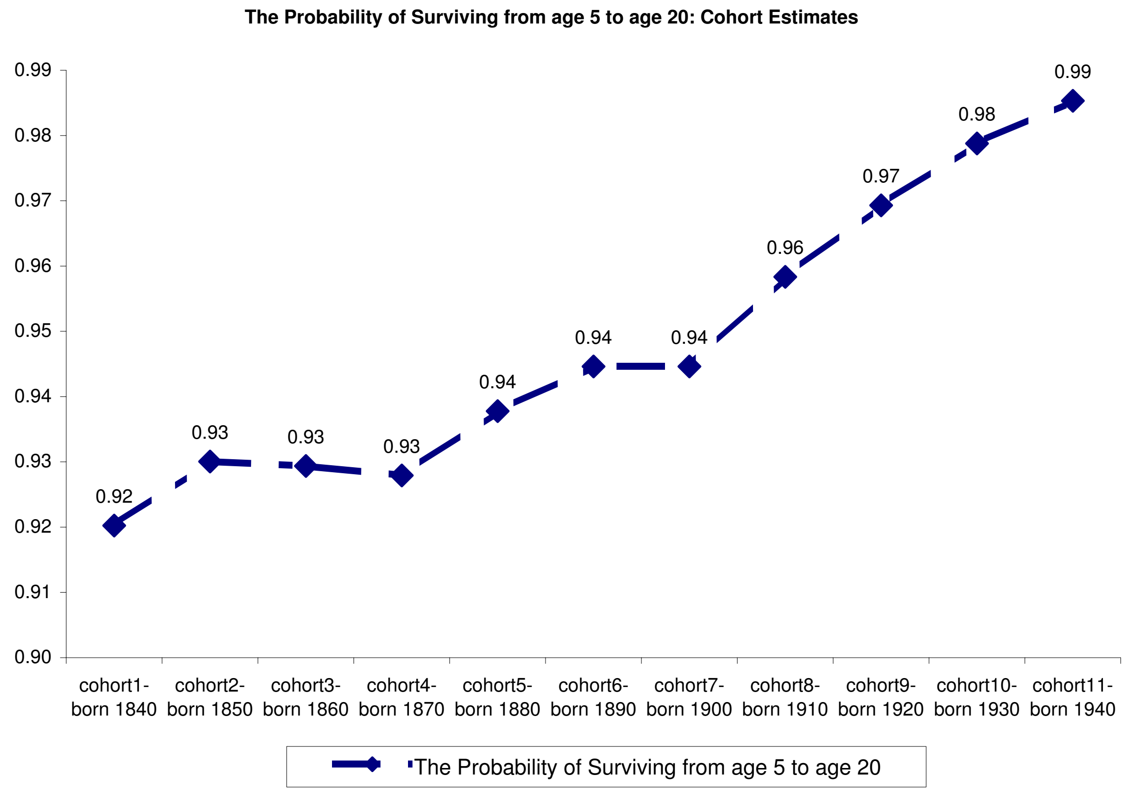

Figure 7: The Probability of Surviving from Age 5 to Age 20: Cohort Estimates. See text for sources.

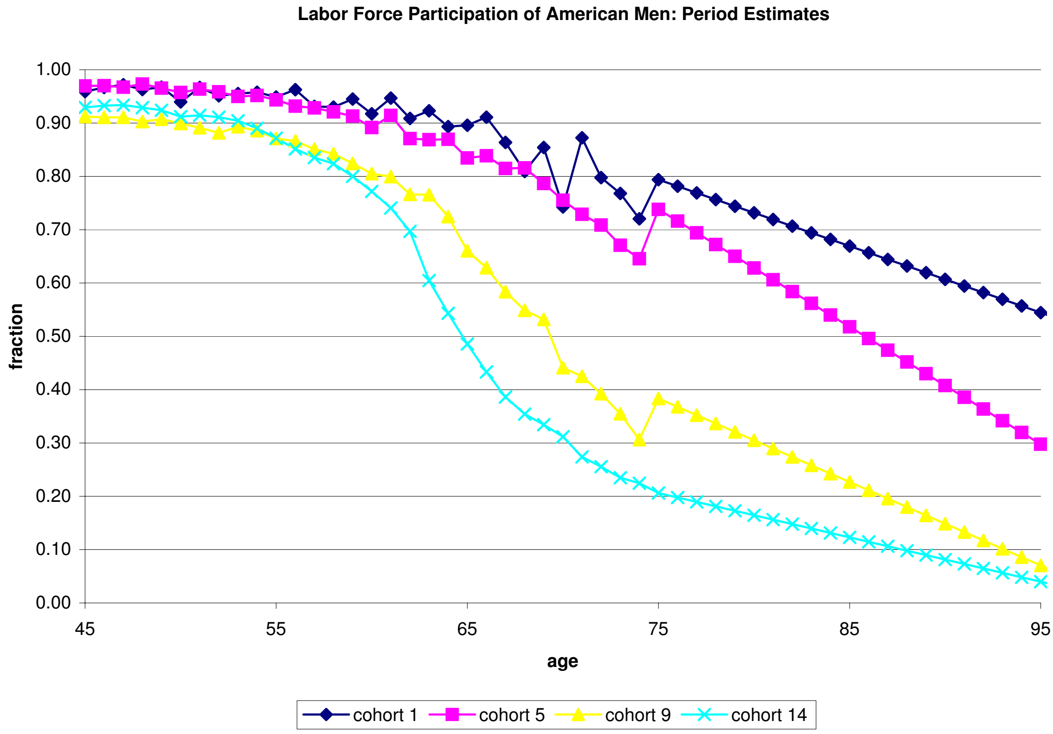

Figure 8: Labor Force Participation of Cohorts 1, 5, 9 and 14: Period Estimates. See text for sources

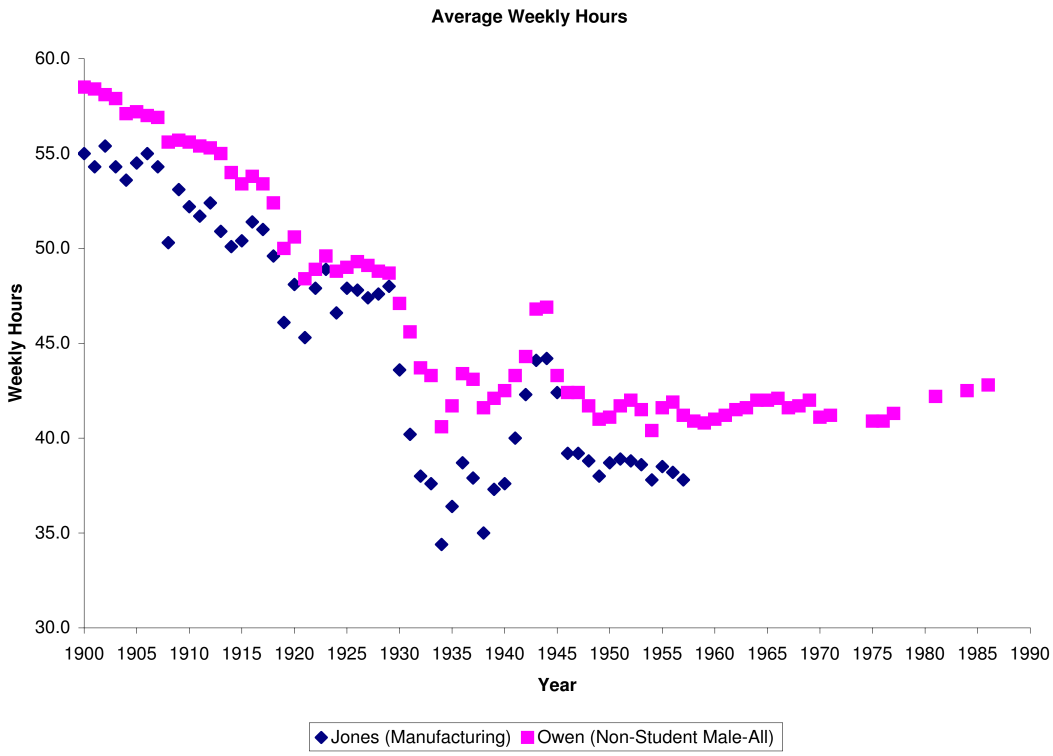

Figure 9: Average Weekly Hours: Manufacturing Sector (Jones Series), All Non-Student Males (Owen Series). Source: Whaples (1990), Table 2.1A.

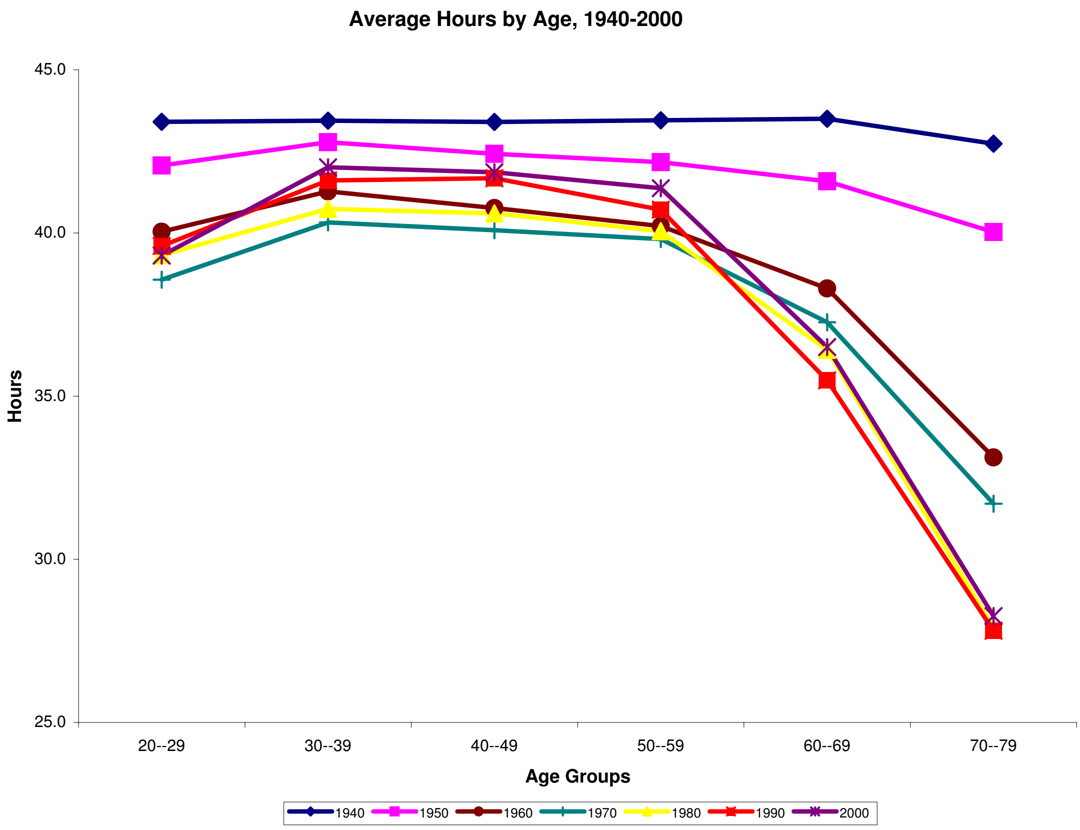

Figure 10: Average Weekly Hours by Age, 1940-2000. See text for sources.

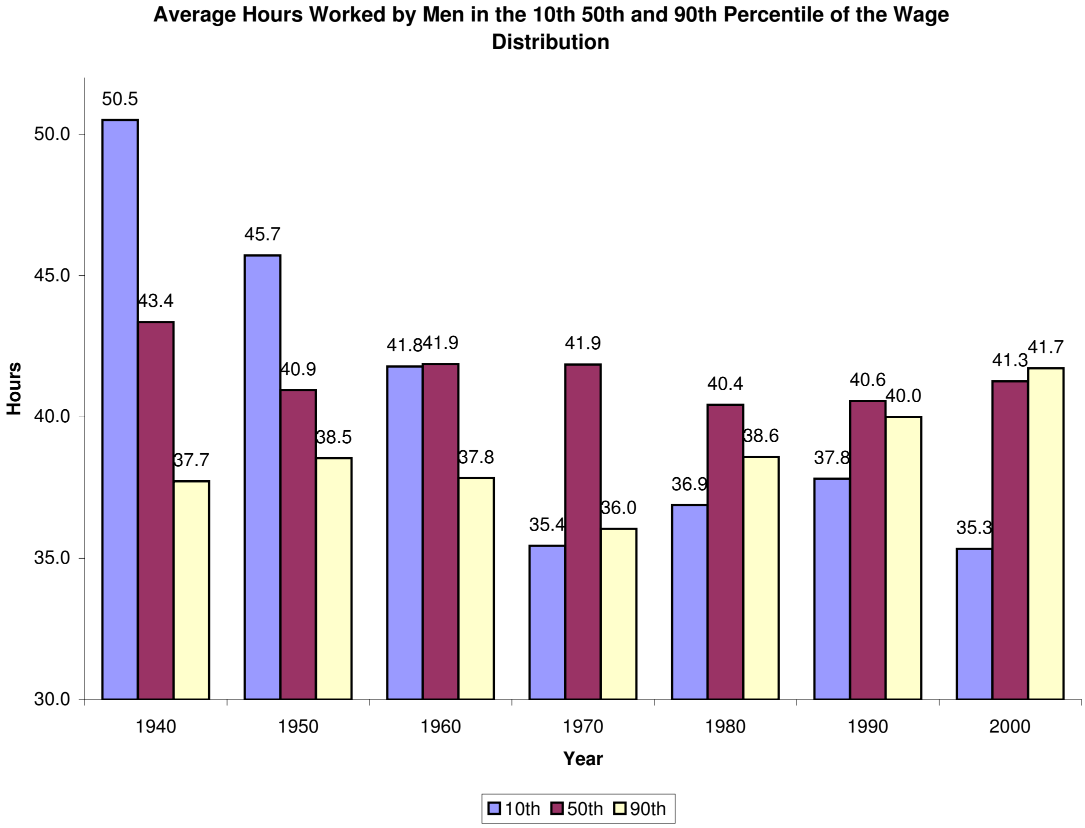

Figure 11: Average Weekly Hours Worked by Men in the 10th, 50th and 90th Percentile of the Wage Distribution, 1940-2000. See text for sources.

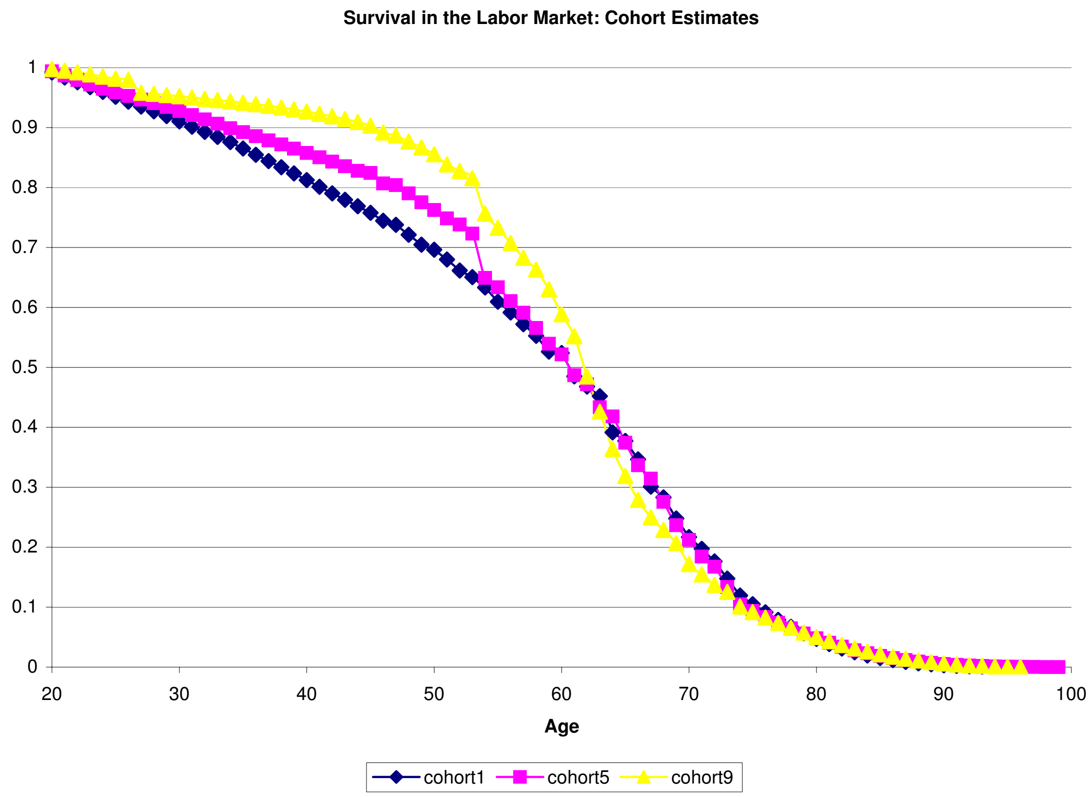

Figure 12: The Probability of Surviving in the Labor Market, Conditional on Entry into the Labor Force at Age 20: Cohort Estimates. See text for sources.

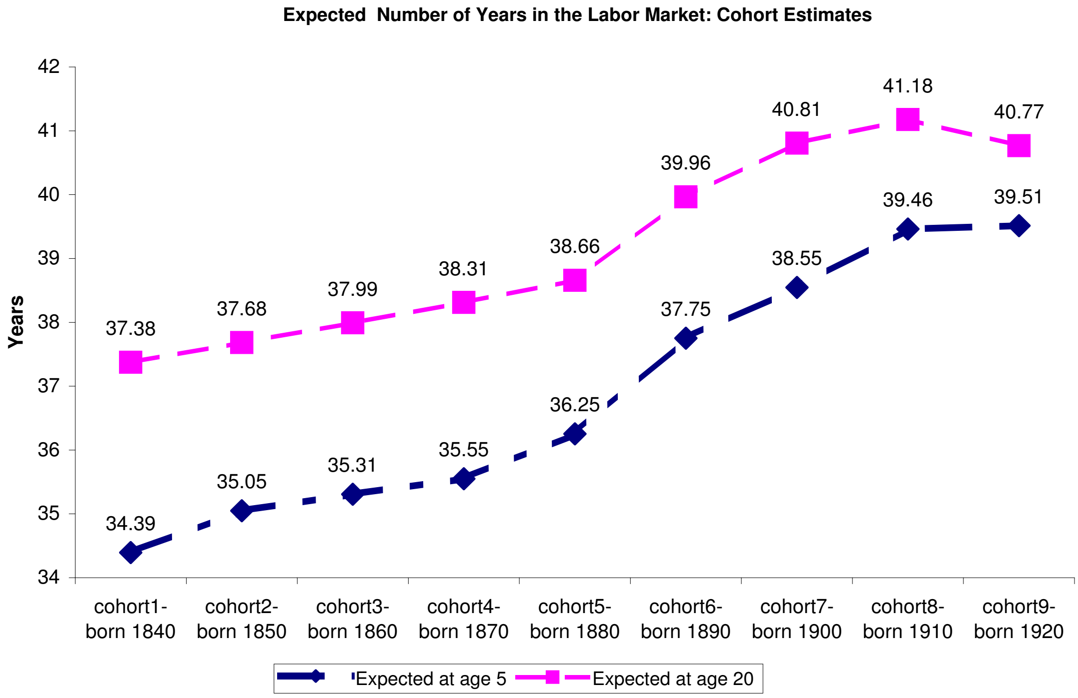

Figure 13: Expected Number of Years in the Labor Market at Age 5 and Age 20, Conditional on Entry into the Labor Force at Age 20: Cohort Estimates. See text for sources.

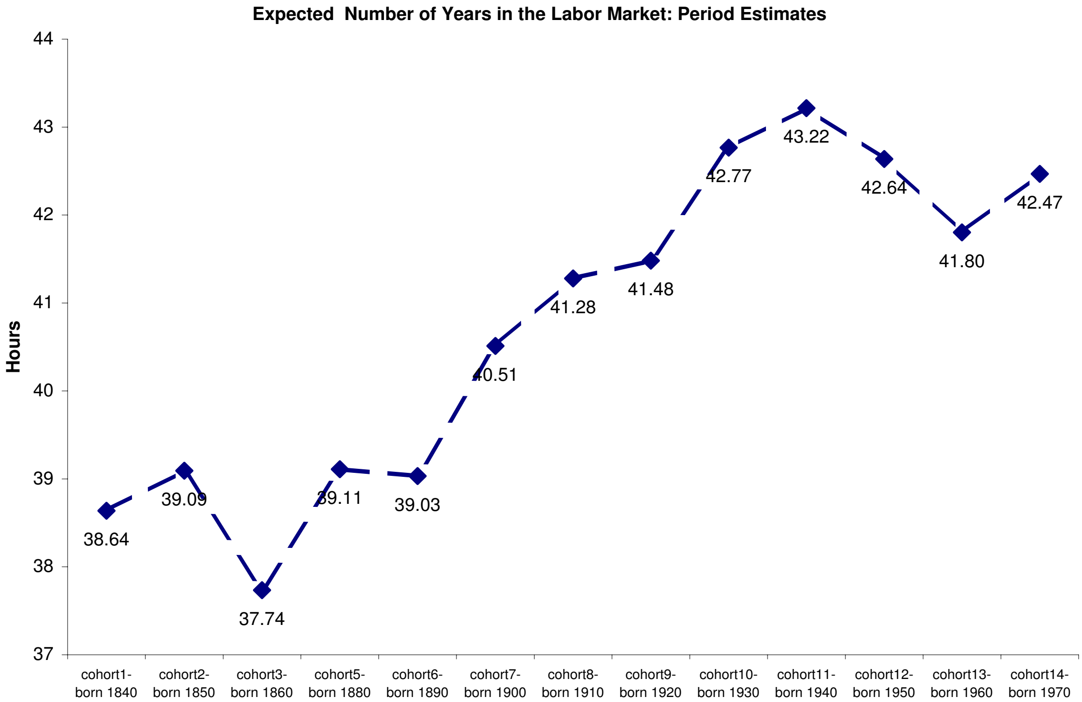

Figure 14: Expected Number of Years in the Labor Market at Age 20, Conditional on Entry into the Labor Force at Age 20: Period Estimates. See text for sources.

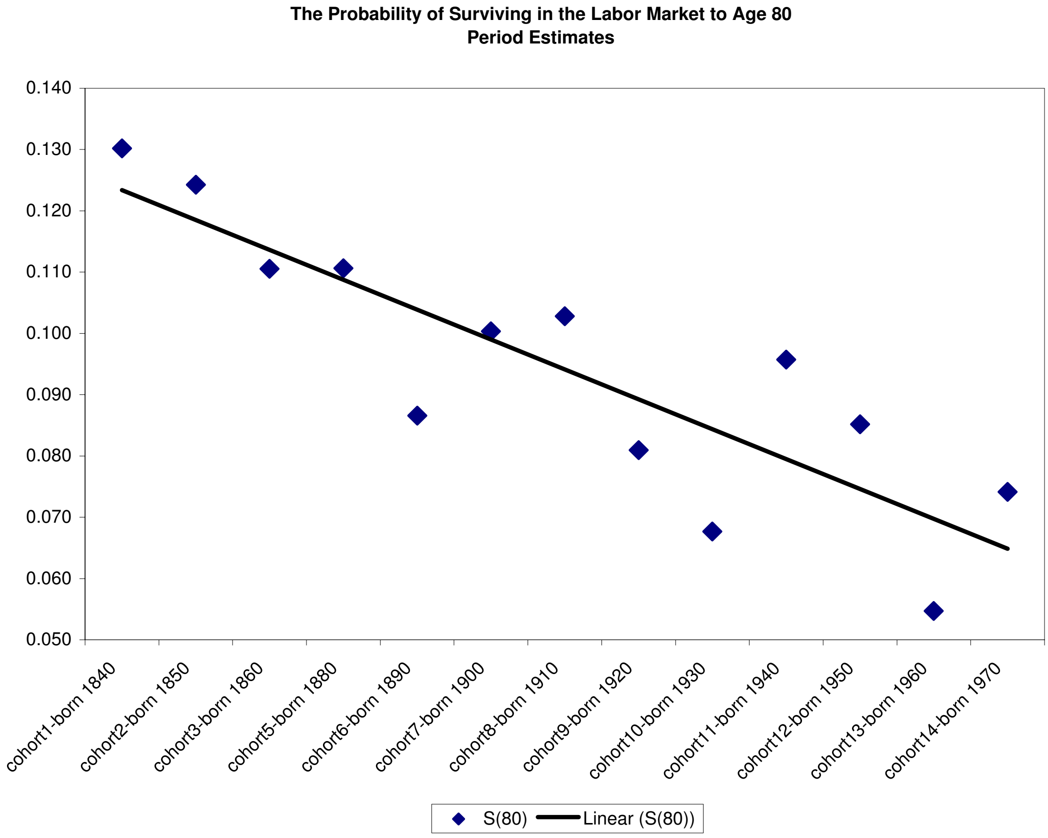

Figure 15: The Probability of Remaining in the Labor Market by Age 80, Conditional on Entry into the Labor Force at Age 20: Period Estimates. See text for sources.

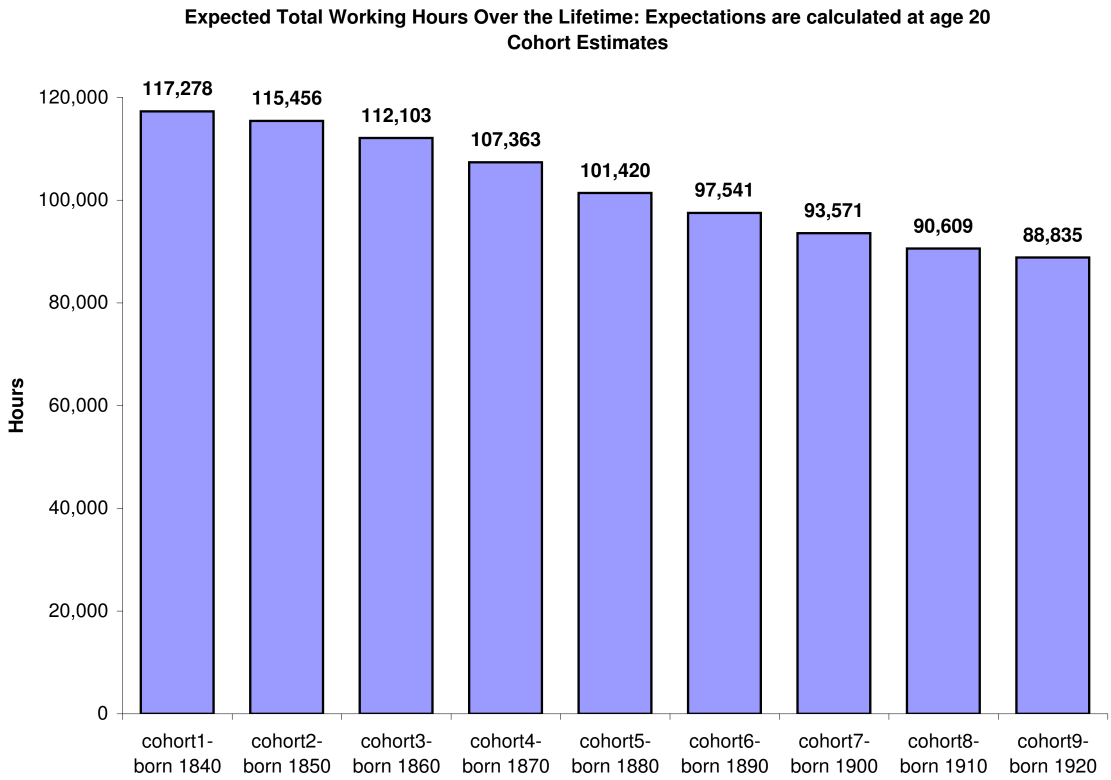

Figure 16: The Total Expected Working Hours over the Lifetime of Consecutive Cohorts Born in 1840-1920. Individuals Are Assumed to Enter the Labor Market at Age 20: Cohort Estimates Calculated at Age 20. See text for sources and estimation procedure.

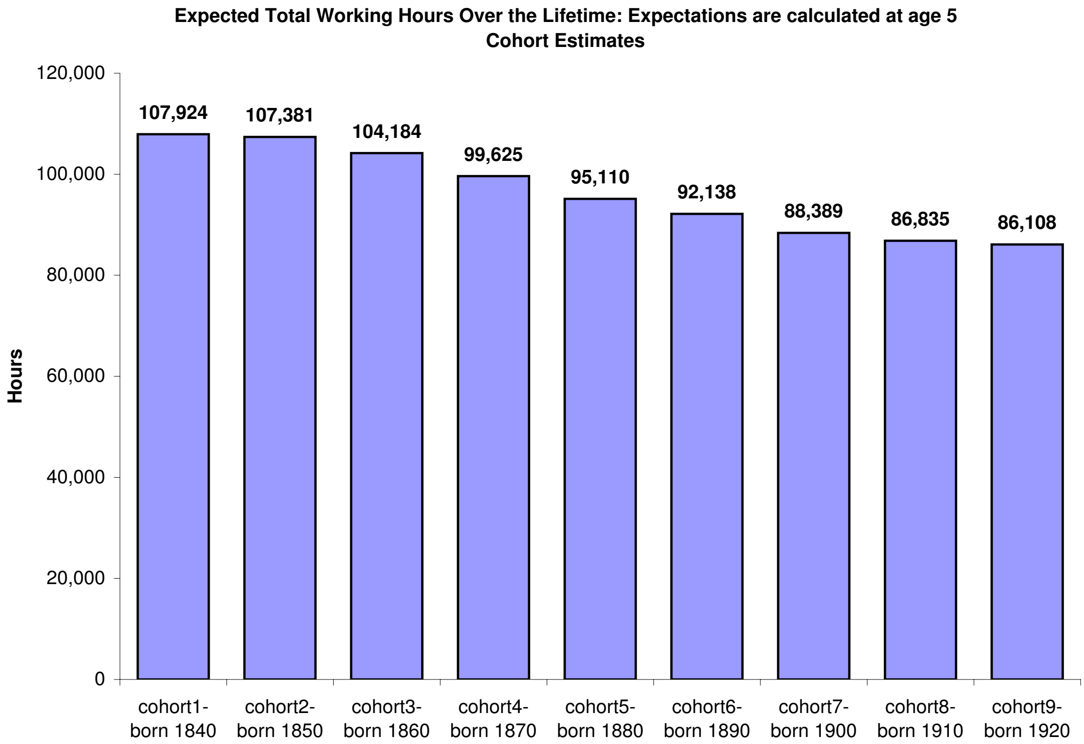

Figure 17: The Total Expected Working Hours over the Lifetime of Consecutive Cohorts Born in 1840-1920. Individuals Are Assumed to Enter the Labor Market at Age 20: Cohort Estimates Calculated at Age 5. See text for sources and estimation procedure.

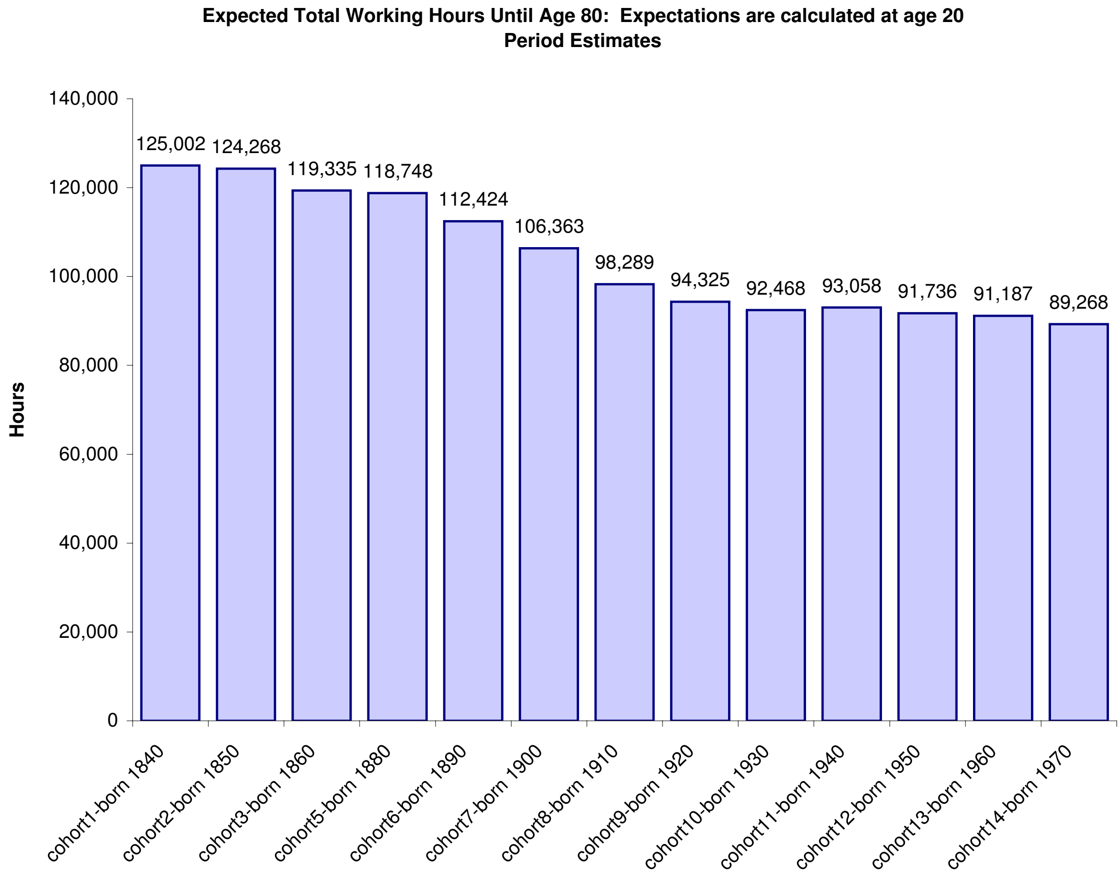

Figure 18: The Total Expected Working Hours by Age 80 of Consecutive Cohorts Born in 1840-1970. Individuals Are Assumed to Enter the Labor Market at Age 20: Period Estimates Calculated at Age 20. See text for sources and estimation procedure.

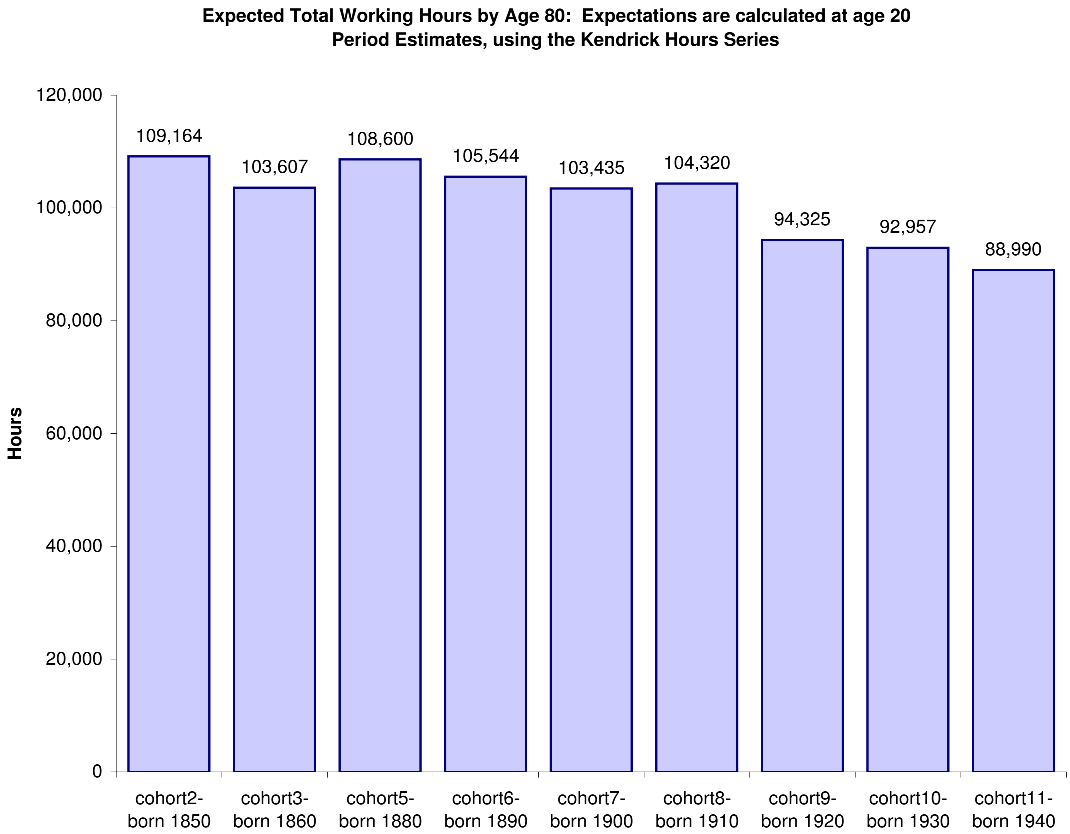

Figure 19: The Total Expected Working Hours by Age 80 of Consecutive Cohorts Born in 1850-1940. Individuals Are Assumed to Enter the Labor Market at Age 20: Period Estimates Calculated at Age 20, using the Kendrick Hours Series. See text for sources and estimation procedure.

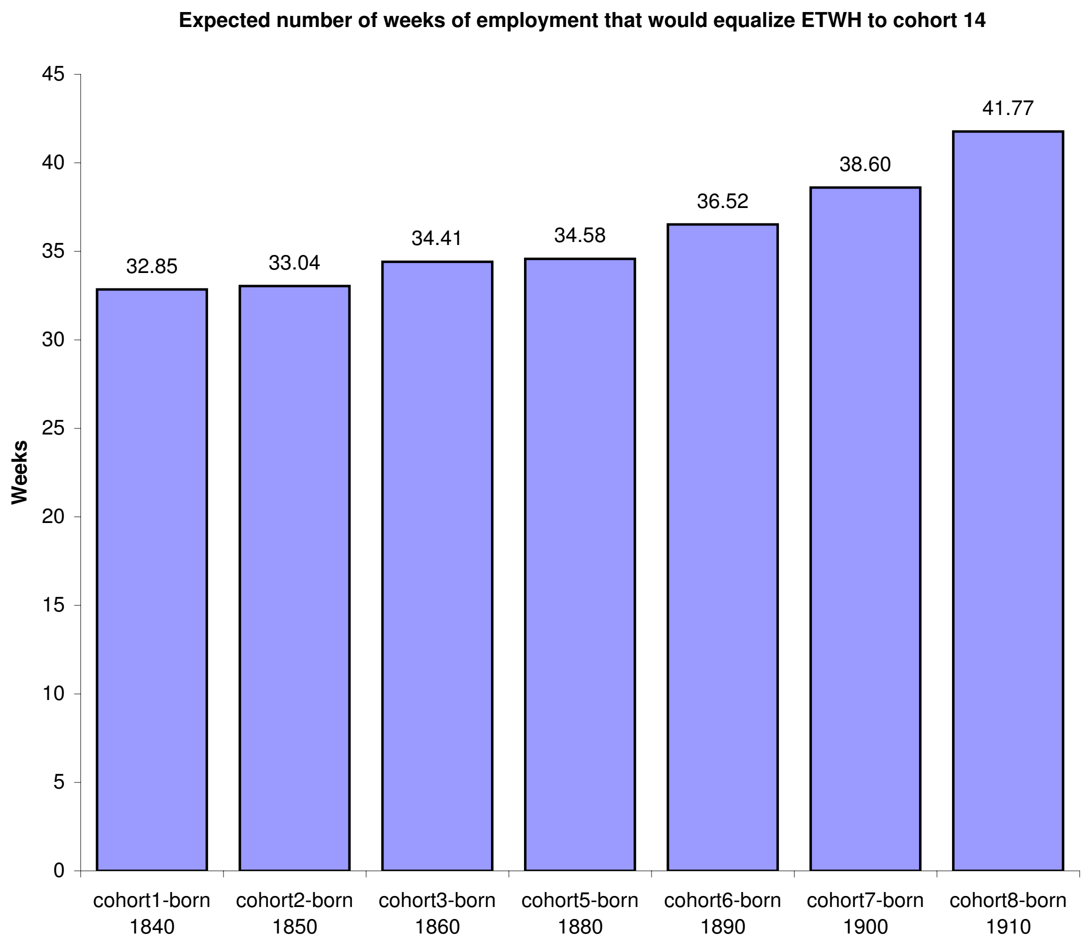

Figure 20: Counterfactual Experiment: The Expected number of Weeks of Employment that would equalize the ETWH to that of Cohort 14. See text for the derivation of these estimates.

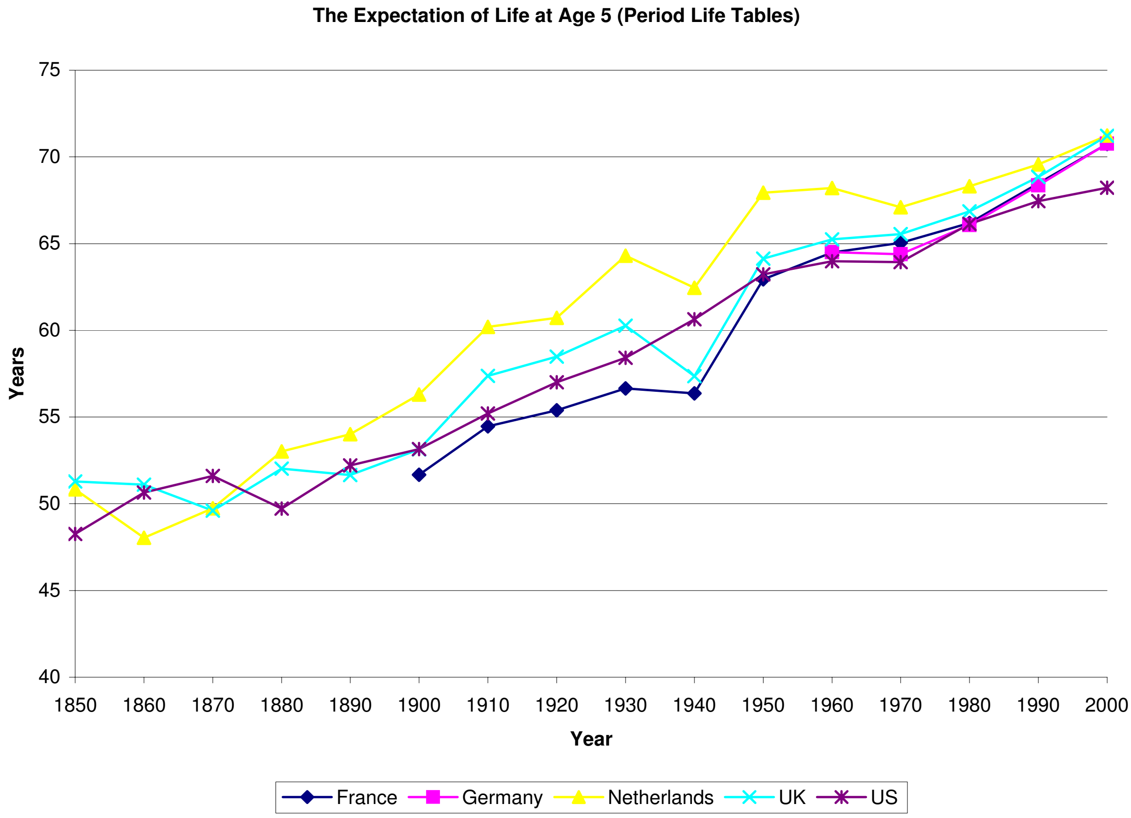

Figure 21: Life Expectancies at Age 5 for Males in Selected Countries, Period Life Tables. Sources: Data for France, Germany, Netherlands and UK are from the Human Mortality Database. For the US data sources as in Figure 2.

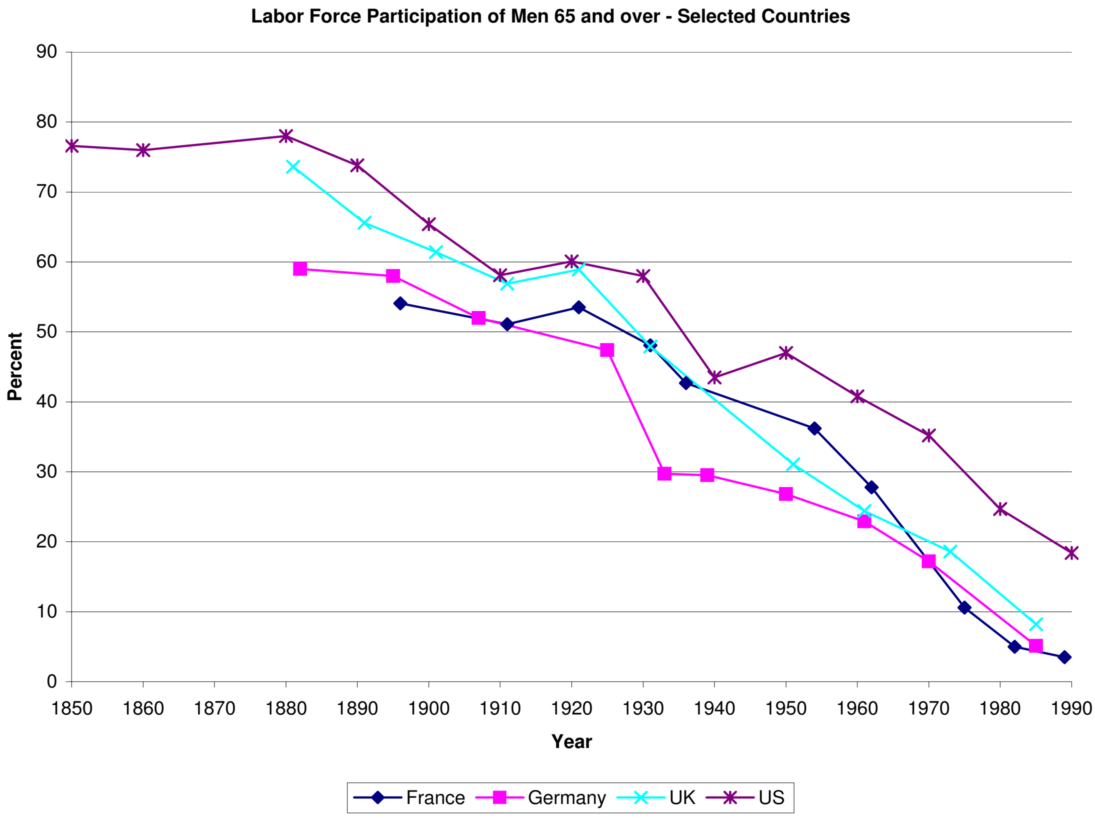

Figure 22: Labor Force Participation of Men Aged 65 and over in Selected Countries. Source: Costa (1998a), Table 2A.2.

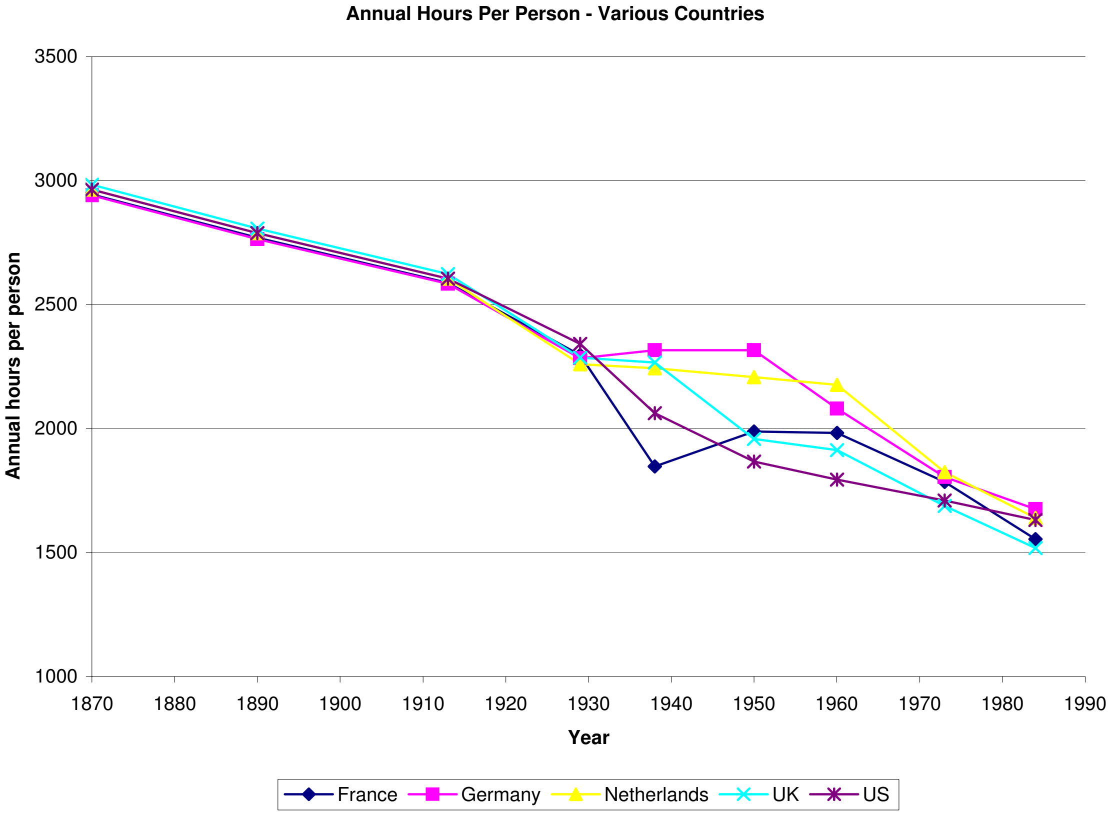

Figure 23: Annual Hours Worked per Person in Selected Countries. Source: Maddison (1987), Table A-9.