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MORTALITY RISK AND EDUCATIONAL ATTAINMENT OF BLACK AND WHITE MEN

Li Gan
Guan Gong

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ABSTRACT

This paper investigates to what extent the differences in education between black and white men can be explained by the differences in their mortality risks. A dynamic optimal stopping-point life cycle model is examined, in which group-level mortality risk plays an important role in determining individual-level mortality risk, health expenditure, and the amount of schooling. The model is calibrated to quantify the effect of mortality risks on schooling by taking the black and white male population as the respective reference groups for black men and white men. We find that the impact of mortality risk on schooling explains more than two-thirds of the empirical education differences between black and white males. This conclusion is robust to a set of plausible parameter values.

Li Gan
Department of Economics
University of Texas
Austin, TX 78712
and NBER
gan@eco.utexas.edu

Guan Gong
Department of Economics
University of Texas
Austin, TX 78712
ggong@eco.utexas.edu

I. INTRODUCTION

Black-white wage and income disparity is a persistent social problem in the United States. A significant body of work has attributed this disparity to forms of discrimination in market places.[2] Anti-discrimination legislation and programs enjoyed early success: Blacks reduced the gap with whites during the 1960s and early 1970s. However, the black-white gap stagnated from the 1980s through the early 1990s and widened in most of the 1990s. In the 1990s, a large body of literature tried to understand if the black-white gap is a result of factors other than discrimination. Among them, a series of papers found that wage differences between blacks and whites can be explained by differences in their pre-market conditions, especially by differences in their educational attainment. For example, O'Neill (1990) finds that black-white wage differences almost disappear when blacks have the same level of education and Armed Forces Qualifications Test (AFQT) scores as whites. Similar results are found in Maxwell (1994) and Neal and Johnson (1996); Winship and Korenman (1997) and Neal and Johnson (1996) provide convincing evidence that AFQT scores are heavily influenced by years of schooling.

Although there are many interpretations on the factors behind fewer years of schooling for blacks than for whites, in this paper we provide a different explanation through mortality risk. Intuitively, education as investment possesses risk. Although the market education return may be the same to people, higher mortality risks will lower the individual return of education and, therefore, might result in fewer years of schooling. Blacks have higher mortality risks than whites, which affords higher risk to reap the wage benefits of schooling. Fewer years of schooling could, then, become blacks' optimal choice.

A large body of studies finds that health and schooling are highly correlated. For example, the life expectancy at birth in England rose from 37.3 years to 48.2 years in the 19th century and further increased to 60.8 years by 1930. During the same period, the average years of schooling rose from 2.3 years to 9.1 years (see Livi-Bacci 1997 and Matthews, Feinstein and Odling-Smee 1982). Neoclassical growth literatures interpret the progress on health through the improvement of economic conditions such as gains in per capita income, and hence indirectly attribute the gain in health to the improvement of human capital and the relative increase of the amount of schooling. The basic idea of those literatures is that education raises income; a higher income improves nutrition and increase health expenditure, which reduces mortality. Nevertheless, other studies show that the strong relation between health and schooling could reflect the reverse causality; i.e., schooling could be responding to the anticipated amelioration in health. Particularly, some studies argue that health might also be a determinant force behind economic development with its large exogenous component that is unrelated to scientific knowledge and technological development. For instance, life expectancy in China and Sri Lanka exceeds 70 years, despite these nations having gross national products in 1994 of less than $1,000 per capita (Sen 1999). Preston (1980, 1996) relates life expectancy changes to income, calorie consumption and disease, and he concludes that approximately 50% of the changes in life expectancy were due to "structural factors" unrelated to economic development. Fries (1980) states that there is a genetically determined upper limit to life of 85 ± 7 years. Soares (2002) shows that recent reductions in mortality rates across countries were largely independent of improvements in economic conditions.

In this paper, we develop a dynamic optimal stopping-point life cycle model, in which group-level mortality risk plays an important role in determining individual-level mortality risk, health expenditure, and the amount of schooling. We posit that the mortality risks of the reference group have a negative externality effect on an individual's mortality. In our model, the mortality risks do not only depend on health expenditure, but also depend on the mortality risks of the reference group by which the individual is categorized. Our approach to studying the effect of mortality changes on education is related to the work of Ehrlich and Lui (1991), Kalemli-Ozcan, Ryder, and Weil (2000) and Soares (2002), each of which takes mortality as an exogenous constant to individuals. In contrast, we advance this model to integrate mortality risks into individual's choices. Although the mortality risks of the reference group for individuals are still taken as exogenous in our framework, the individual-level mortality risks and education are endogenously determined.

The ideas of the reference group and its effects on mortality risks are nothing new. While genetic traits and lifestyle are usually thought of as the predominant factors to explain health status and mortality, there is a growing consensus that the groups (such as the residential neighborhoods or local community where people live) play an important part in determining people's health. In a related way, a growing literature on social interactions claims that

[2] See a survey by Altonji and Blank (1999).

individual outcome is strongly influenced by reference group due to sociological and/or psychological factors (see Manski 1993 and Durlauf 2002). One bridge linking the reference group to health is the role model effect or peer group influence, in which an individual may desire to conform to the behaviors of older or contemporaneous members of his group and intend to mimic their behaviors. Among these behaviors, some are related to health, such as smoking, dietary habits and physical activity, and therefore have detrimental effects on health. Another linkage between reference group and health is the psychosocial stress caused by diseases or crimes, which may have adverse biological consequences on the individual's health. Empirical studies finding the relationship between the characteristics of the reference group and the individual's health outcomes are plentiful. Roux *et al*. (2001) find that living in a disadvantaged neighborhood will increase the incidence of coronary heart disease even after controlling for personal income, education and occupation. After investigating the influence of individual neighborhood socioeconomic status on mortality, Winkleby and Cubbin (2003) show that a person who lives in a poor neighborhood has 20% higher death rate than a person who lives in a rich neighborhood after controlling individual characteristics.

We apply the model to study the impact of differential mortality risks on the educational attainment of black and white men.[3] In particular, we consider an agent at the age of 16, having finished compulsory education, deciding (with his parents) how many additional years of schooling to obtain. The agent faces the probability of death in every period and maximizes the discounted value of the expected utility from consumption and leisure. We assume that a black man has the same utility, the same discount rate, the same return to education and the same living and working conditions as a white man. The only difference between a black man and a white man is the mortality risk of their reference groups. In this model, both the years of schooling and the life expectancy at the individual level are endogenously determined. The exogenous variable is the reference group's mortality risk.

It is important to point out that we do not claim here that factors such as labor market discrimination, differential opportunities in access to higher education, parental preferences and occupational preferences do not affect the life prospects of black and white men. What this paper

[3] We focus our attention only on men. Studying the effect of mortality on education is considerably more difficult for women than for men since women are more likely to face additional choices in leaving the labor force temporarily to have and raise children. Therefore, any meaningful analysis of the effect of mortality risk on education, fertility and labor force participation for black and white women requires separate treatment.

shows is that the mortality differences can explain the difference in schooling years when all other factors are the same for both black men and white men.

The model is calibrated to quantify the strength of the effect of mortality risks on schooling. We let the black male population be the reference group for a black man while the white male population is the reference group for a white man. Under a set of reasonable parameter values, our baseline results show that the impact of mortality risk on schooling explains more than two-thirds of the empirical education differences between black and white males. This remains true with a series of sensitivity analyses. Each time we change one of the values of parameters while holding other parameters at their baseline values. We find that although the levels of educational attainment for both blacks and whites deviate from the observed years of schooling, the difference in years of schooling between black men and white men does not vary much. Since the only difference between blacks and whites is their reference groups' mortality risks, we claim that the observed difference in mortality risks between black men and white men can explain most of their differences in education.

Understanding why blacks have less education than whites has important policy implications. If education is the key reason for future wage differences, public policies designed to reduce the black-white wage gap should concentrate on helping blacks attain more education. If the higher mortality risk of blacks is a major cause of less education, then public policies should put more emphasis on improving access to health care and intervening in the composition of residential neighborhoods, such as making predominantly black neighborhoods safer (since part of the risk may result from living in high-crime neighborhoods).

The rest of paper proceeds as follows. Section II introduces a mortality production function and develops a dynamic optimal stopping-point model. In section III we calibrate the model and explore whether the difference of mortality risks between black males and white males is capable of generating the observed educational difference. A brief conclusion is given in Section IV.

II. The Model

In this section, we develop a dynamic optimal stopping-point model to analyze the effects of mortality risks on years of schooling. We start with the mortality risk production function since it explicitly illustrates the channel from mortality to schooling.

We assume that an individual's production function of mortality risk is:

$$m(t) = \mu\, \hat{m}(t) e^{-\beta d(t)}, \tag{1}$$

where m is the hazard rate of the individual, $\hat{m}$ is the hazard rate of the reference group and d is the health expenditure. The term "health expenditure" includes all expenditures that may affect an agent's mortality, such as time and money spent on health clubs, appropriate nutrition, medical insurance and other expenses related to health care. Spending on smoking can also be included as a negative expenditure. Health expenditure as an input into the production function of mortality has been broadly used in the literature of health economics since Grossman (1972a, 1972b). Individual-specific health characteristics, such as genetic traits and illness, are captured by a positive parameter μ. The exponential specification in (1) implies that health expenditure has a decreasing marginal effect on health, with β being the percentage gain in mortality reduction from one unit of health expenditure.

The negative externality of the reference group's mortality on individual health, as argued in Section I, has been substantiated in growing studies. Although the mortality risk of the reference group is taken as exogenous to the individual in the model, the current model does not offer any guidance as to how the reference group is selected. For example, a black male may choose the general black male population as his reference group. Alternatively, he may view a smaller group of people whom he is familiar with, such as his family and his friends, as his reference group. It is also possible for a black male living in a suburban white neighborhood to view the white male population as his reference group. In other words, identifying the reference group may be subjective.

It is worth noting that (1) assumes that an agent's mortality is only affected by his reference group's mortality and his health expenditure. The agent's education affects his mortality only by health related expenditure. However, previous literature shows that a better-educated agent can be more effective in using the money he spends on reducing mortality (productive efficiency). In addition, since a better educated agent may have more knowledge on the adverse effects of some activities (smoking, bad diet, etc.) and the positive effects of other activities (exercise, appropriate diet, etc.), he is more likely to allocate resources to improve his health (allocative efficiency).[4] Modeling these two efficiencies in the current framework is beyond the scope of the paper.

With the mortality risk production function in (1), the survival rate for the individual is given by:

$$p(t) = \exp\left\{-\mu\int_0^t \hat{m}(t)\exp[-\beta d(t)]dt\right\}. \tag{2}$$

Equation (2) implies that the level of survival rate for an individual is a positive function of his current and past health expenditure.

Now we turn to the dynamic optimal stopping-point model. We consider an individual who is 16 years old. After finishing his compulsory years of schooling, he (with his parents) chooses how many additional years of schooling he will undertake. Let the instantaneous utility at time *t* be $u(c(t), l(t))$, where $c(t)$ is consumption and $l(t)$ is leisure (the labor supply is *1*- $l(t)$). The function $u(\cdot,\cdot)$ is assumed to be strictly concave, increasing in each argument, twice continuously differentiable. The lifetime utility maximization problem is, in the formulation of Yaari (1965):

$$\max_{S,\, d(t), c(t), l(t)} \int_0^S u\left(c(t), \bar{l}\right)p(t)e^{-\theta t}dt + \int_S^T u\left(c(t), l(t)\right)p(t)e^{-\theta t}dt + \int_T^N u\left(c(t), 1\right)p(t)e^{-\theta t}dt \tag{3}$$

where choice variable *S* is the amount of additional schooling after 9 years of compulsory schooling; θ is the time discount rate; *T* is the time of retirement and *N* is the maximum longevity. In this model, we let the retirement age and maximum longevity be exogenous. We assume that the individual retires at age 65, thus *T*= 49 (i.e. age 65 minus the initial age 16). And we let the maximum age to which the individual could survive be 110, thus *N*=94 (i.e. age 110 minus the initial age 16). The only uncertainty that the agent faces at any future date comes from the possibility of death.

The lifetime utility in (3) consists of three parts, representing three stages of the individual's life cycle. The first part in (3) is the expected utility from schooling. At the schooling stage, we assume that schooling is structured such that leisure from schooling in each period is a constant, $l(t) = \bar{l}$ for $t<S$. The individual chooses additional years of schooling, *S*, and a consumption profile at this stage. The life cycle model in (3) assumes irreversibility: if an

[4] For a survey on productive efficiency, see Grossman (2000); the survey on allocative efficiency can be found in Kenkel (2000).

individual has started to work, he cannot come back to school again at later time in his life cycle. The second part in (3) is the expected utility from working. At this stage, the individual chooses a profile of consumption and leisure. At time *T*, the agent retires from work. The third part in (3) describes the expected utility from retirement. At this stage, the agent only chooses a consumption profile. His leisure after retirement is 1.

Corresponding to the life cycle utility function in (3), the agent's wealth (or asset) accumulation equation is divided into three parts:

$$\begin{aligned} t\in[0,S): \quad & \dot{A}(t)=rA(t)-c(t)-\xi\left(1-\bar{l}\right)wh(t)-d(t), \\ & \dot{h}(t)=g(t)h(t); \\ t\in[S,T): \quad & \dot{A}(t)=rA(t)+wh(t)(1-l(t))-c(t)-d(t), \\ & \dot{h}(t)=0; \\ t\in[T,N]: \quad & \dot{A}(t)=rA(t)-c(t)-d(t); \\ & A(0)=A(N)=0, \; h(0)\,\text{given.} \end{aligned} \tag{4}$$

where $A(t)$ is wealth at time t, $h(t)$ is the human capital at time t and w is wage rate per unit of human capital. The market interest rate r is assumed to be constant. At the first stage, the individual accumulates human capital with the rate $g(t)$ at each t. Function $g(\cdot)$ is increasing and concave in the amount of schooling. Following Bils and Klenow (2000), we assume that the cost of education (including tuition, room and board) increases with the level of education. The parameter $\xi(>0)$ is the ratio of schooling cost to the opportunity cost of student time. At the second stage, the agent goes to work and earns the labor income: per unit of labor wage ($wh(t)$) multiplied by his labor supply ($1-l(t)$). For convenience, we assume that there is no accumulation and depreciation of human capital at this stage. At the third stage, the agent retires and consumes the wealth he accumulated when he worked. The initial and end wealth are assumed to be zero, and the initial human capital is given.

The first-order conditions yield the differential equations for consumption:[5]

$$t\in[0,S): \; \frac{\dot{c}(t)}{c(t)}=-\frac{u_c\left(c(t),\bar{l}\right)}{c(t)u_{cc}\left(c(t),\bar{l}\right)}\left(r-\theta-m(t)\right) \tag{5a}$$

$$t\in[S,T): \; \dot{c}(t)=\frac{u_{cl}(c(t),l(t))u_l(c(t),l(t))-u_{ll}(c(t),l(t))u_c(c(t),l(t))}{u_{cc}(c(t),l(t))u_{ll}(c(t),l(t))-\left[u_{cl}(c(t),l(t))\right]^2}\left(r-\theta-m(t)\right) \tag{5b}$$

[5] For solving dynamical optimization problem with switches in the state equations, see Kamien and Schwartz (1991).

$$t \in [T,N]: \ \frac{\dot{c}(t)}{c(t)} = -\frac{u_c(c(t),1)}{c(t)u_{cc}(c(t),1)}(r-\theta-m(t)). \tag{5c}$$

Equations (5a)-(5c) are the ordinary Euler equations respectively corresponding to different stages. These three equations describe necessary conditions that have to be satisfied on any optimal path. At any $t \in [S,T)$, the optimal consumption and leisure make the marginal rate of substitution equal to the marginal rate of transformation:

$$\frac{u_l(c(t),l(t))}{u_c(c(t),l(t))} = wh(t). \tag{6}$$

At the time *S* and *T*, there are jumps in consumption and leisure. The consumption and leisure at these two points satisfy the conditions:

$$u_c\left(c(S^-),\bar{l}\right) = u_c\left(c(S^+),l(S^+)\right), \text{ and } u_c\left(c(T^-),l(T^-)\right) = u_c\left(c(T^+),1\right), \tag{7}$$

where S^- is defined as $t < S$ and $t \to S$ while S^+ is defined as $t > S$ and $t \to S$. The variables T^- and T^+ are analogues to S^- and S^+. Equation (7) says that the optimal consumption and leisure will make the marginal utility of consumption be the same at the time when the agent switches from one stage to another stage (i.e. from schooling to working and from working to retirement).

The optimal health expenditure satisfies

$$\beta \int_t^N u(c(v),l(v))p(v)m(v)e^{-\theta(v-t)}dv = u_c(c(t),l(t))p(t). \tag{8}$$

where the left-hand side (divided by the right-hand side) is the change (in monetary unit) of the present value of utility from increases in current and future survival rates caused by health expenditure. Therefore, equation (8) implies that the necessary condition for optimal health expenditure equates the marginal gain from an extra unit of health expenditure to its marginal cost, which is 1.

Finally, the necessary condition for the optimal amount of schooling is,

$$\begin{aligned}\frac{u\left(c(S^-),\bar{l}\right)-u\left(c(S^+),l(S^+)\right)}{u_c\left(c(S^+),l(S^+)\right)} &= \left(c(S^-)-c(S^+)\right) \\ &\quad + wh(S)\left[\xi\left(1-\bar{l}\right)+1-l(S^+)-g(S)\int_S^T (1-l(t))e^{-r(t-S)}dt\right]\end{aligned} \tag{9}$$

Equation (9) implies that marginal gains equal to marginal costs from an extra year of schooling. The marginal gains include gain in utility, $\left[u\left(c\left(S^{-}\right),\bar{l}\right)-u\left(c\left(S^{+}\right),l\left(S^{+}\right)\right)\right]/u_c$, and gain in future earnings discounted to present, $-wh(s)g(s)\int_S^T (1-l(t))\exp(-r(t-S))dt$. The marginal costs of schooling include consumption $\left(c(S^{-})-c(S^{+})\right)$, tuition $\xi\left(1-\bar{l}\right)wh\left(S\right)$, opportunity cost from forgoing working $\left(1-l\left(S^{+}\right)\right)wh\left(S\right)$ by staying in school. The gap between the utility from attending schooling and that from going to work enters because of the jumps of consumption and leisure at the time of the switch in stages. The same reason applies to the gap of consumptions in equation (9).

The individual optimal amount of schooling and hazard rate are not explicit functions of the model's parameters and the mortality risks of the reference group. In the next section, we apply the model to the calibration method and explore to what extent the difference in educational attainment between black and white males can be attributed to the difference in their mortality risks. It is important to recognize that when studying the differential mortality risks between black and white men, it is necessary that the model can work with age-varying mortality risks since black and white men have different mortality risk patterns over their life cycles.

III. Mortality Risk and Educational Attainment of Black and White Men

In this section, we apply our earlier model to study the main objective of the paper: to what extent the differences in education between black men and white men can be explained by their difference in mortality risks.

It is well-known that mortality risks are different for black and white men. In the 1979-1981 U.S. decennial life tables, the life expectancy (conditional on surviving to age 16) is 66.2 years for a black male and 72.1 years for a white male. Relative average mortality risks vary for different age groups. For example, for people ages 21-30, the average yearly mortality risk is .311% for black men, which is 75% higher than the mortality risk of white men, or .178%. For people ages 31-40, the average yearly mortality risk for black men is .440%, which is 159% higher than the mortality risk for white men, or .167%.

In our framework, since an agent's reference group is subjective, it is difficult for researchers to determine an agent's exact reference group.[6] However, in some cases researchers should be able to determine what an agent's reference group is most likely to be. For example, given that blacks are very likely to live in neighborhoods with few whites (Massey and Denton, 1989), researchers should be confident that the reference group of a black male is likely to consist of a majority of population of black male; similarly, a white male's reference group should have a preponderance of white males.[7]

We use the U.S. decennial life tables in 1979-1981 to represent the mortality risks that people in an age group observe when they make their decisions about years of schooling. The years of schooling are based on 1990 census data. The average years of schooling for black men ages 26-36 who were in the labor force in 1990 were 12.74 years, while the same group of white men averaged 13.50 years. We concentrate on men ages 26-36 in 1990 for two reasons. First, people in this age group have already finished their education. Second, since people with less education have higher mortality rates, selecting a relatively young group will minimize that sample-selection problem.

The rest of this section includes three parts. In the first part, we set the baseline parameter values for the model to calibrate the optimal years of schooling. In the second part, we report the results from calibration compared with the observed years of schooling. In the third part, we conduct a series of sensitivity analyses by letting parameters deviate from baseline parameter values.

A. *Baseline Parameters and Utility Functional Forms*

Applying the model to explore the effect of mortality differences between black men and white men on their education difference requires parameterized functional forms for the mortality risk, utility and human capital. We first begin by calibrating the production function for mortality risk.

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[6] Some authors argue that groups can be endogenously determined. For example, Fernandez and Rogerson (1997) show that individuals endogenously select themselves into different communities or groups according to income.

[7] This paper does not investigate why exogenous difference in mortality between blacks and whites exist. One possibility is that rampant discrimination in the labor force before the civil rights movement in 1960s caused a lower return to education for blacks than for whites. As a consequence, blacks took less education and spend less in health care than in whites, resulting in a higher mortality risk than whites.

In equation (1), the parameter β is the percentage reduction in the average mortality risk from one unit of health expenditure. According to Jones (2002), the life expectancy in the U.S. is 66.6 years in 1960 and 73.9 years in 1997. Thus, the average yearly mortality risk is approximately lowered from 1/66.6 in 1960 to 1/73.9 in 1990, a reduction of about 9.88%. In the meantime, the U.S. per capita health expenditure rose from $504.6 in 1960 to $2,127 in 1997. Therefore, a $10,000 increase in health expenditure will, on average, reduce mortality risk by: 9.88%*10,000/(2,727 – 504.6) = 0.445. We take the value of parameter β as 0.445, meaning that $10,000 health expenditure will reduce mortality risk by 44.5%. Note that the current calculation of β assumes that the group mortality $\hat{m}(t)$ is constant over time. If we let $\hat{m}(t)$ be a function of health expenditure such that $\partial \hat{m}(t) / \partial d(t) > 0$, the value of β is overestimated. In the sensitivity analysis in Section IIIC, we discuss how the outcomes of the model vary when β varies.

To calibrate the value of parameter μ, we rewrite equation (1) as the following log form,

$$\ln m(t) = \ln \mu + \ln \hat{m}(t) - \beta\, d(t)\,. \tag{10}$$

The value of μ can be calculated by taking the mean on the natural log of mortality risks across individuals in the reference group. Since $\hat{m}(t)$ is the group mortality, i.e., $E[m(t)] = \hat{m}(t)$, we must have $E[\ln m(t)] = \ln \hat{m}(t) - c$ where $c>0$ (Jensen's inequality). Since no guidance is offered in the literature on the value of the c, we calibrate the baseline value μ by assuming that $c = 0$. In particular, when $c = 0$, the ratio $ln(\mu)/\beta$ matches the mean health expenditure in the reference group. The baseline value of μ is calculated using the U.S. health expenditure ($2,166.5 or 12 percent of GDP) in 1990.[8] In this case μ=1.101. That is to say that if the individual's health expenditure is zero, his mortality risk is around 10% higher than that of his reference group. If the constant $c>0$, the parameter μ is smaller. Therefore, the baseline parameter values μ is larger than the real parameter value μ. We discuss how the outcomes of the model vary if μ changes in the sensitivity analysis in Section IIIC.

Then, we come to the utility function, which is given by:

$$u(c,l) = \frac{\left(c^{\alpha} l^{1-\alpha}\right)^{1-\sigma} - 1}{1-\sigma}, \tag{11}$$

[8] U.S. health expenditure data are from the Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group, National health expenditures, 2001. Internet address: www.cms.hhs.gov/statistics/nhe.

where the relative risk aversion parameter, *σ,* is set to 2 and the consumption share in utility, *α,* is set to equal 0.33, as in Backus, Kehoe and Kydland (1994).

Based on the utility function in (11), the first-order conditions (5)-(7) say that for any $t \in [0, S)$, the consumption is

$$c(t) = c(0)p(t)^{\frac{1}{1-\alpha(1-\sigma)}} e^{\frac{(r-\theta)}{1-\alpha(1-\sigma)}t} \; ; \tag{12}$$

at the switching point from staying-in-school to going-to-work, *S*, the consumption satisfies:

$$c(S^+) = \left(\frac{1-\alpha}{\alpha \bar{l} w h(S)}\right)^{\frac{(1-\alpha)(1-\sigma)}{\sigma}} c(S^-)^{\frac{1-\alpha(1-\sigma)}{\sigma}} \; ; \tag{13}$$

for $t \in [S, T)$, the leisure *l(t)* and consumption *c(t)* are given by equations (14) and (15):

$$l(t) = \frac{1-\alpha}{\alpha w h(S)} c(t), \tag{14}$$

$$c(t) = c(0)^{\frac{1-\alpha(1-\sigma)}{\sigma}} p(t)^{\frac{1}{\sigma}} \left(\frac{1-\alpha}{\alpha \bar{l} w h(S)}\right)^{\frac{(1-\alpha)(1-\sigma)}{\sigma}} e^{\frac{(r-\theta)}{\sigma}t} \; ; \tag{15}$$

at the switching point from working to retirement, *T*, the consumption satisfies:

$$c(T^+) = \left(\frac{1-\alpha}{\alpha w h_S}\right)^{\frac{(1-\alpha)(1-\sigma)}{\alpha(1-\sigma)-1}} c(T^-)^{\frac{\sigma}{1-\alpha(1-\sigma)}} ; \tag{16}$$

for $t \in [T, N]$, the consumption is:

$$c(t) = c(0)p(t)^{\frac{1}{1-\alpha(1-\sigma)}} \bar{l}^{\frac{(1-\alpha)(1-\sigma)}{\alpha(1-\sigma)-1}} e^{\frac{(r-\theta)}{1-\alpha(1-\sigma)}t} . \tag{17}$$

The optimal amount of schooling satisfies the equation:

$$\frac{1-\alpha(1-\sigma)}{\alpha(1-\sigma)} c(S^-) - \frac{\sigma}{\alpha(1-\sigma)} c(S^+) = w h(S)\left[1 + \xi(1-\bar{l}) - g(S)\int_S^T (1-l(t)) e^{-r(t-S)} dt\right] \tag{18}$$

Finally, following Bils and Klenow (2000), we let $g(t) = \eta(t+9)^{-\varphi}$. The term $(t+9)$ reflects the fact that the agent has finished 9 years of compulsory schooling. The human-capital accumulation is given by:

$$h(t) = \exp\left(\frac{\eta}{1-\varphi}(t+9)^{1-\varphi}\right). \tag{19}$$

where $\eta=0.32$, and $\varphi=0.58$, as in Bils and Klenow (2000). In this setup, the marginal return of schooling is decreasing. At the given parameter values, the return of an additional year of education is about 9% if a person has just finished 9 years of compulsory schooling.

Other parameters used in the calibration are chosen as the following values: the time discount factor is $\theta = 0.032$; interest rate r is 0.04; the parameter governing the education cost ξ is 0.5 as in Bils and Klenow (2000). The wage rate per hour for one unit of human capital is $1.47, at which a person with 9 years of compulsory schooling will earn $10 per hour.[9] Since there is no guidance in the literature about the value of leisure during schooling, we let $\bar{l} = 0.4$, i.e., when a person is in school, he uses 60% of his expendable time on studying.

B. *Results*

Given the baseline values for various parameters, we can then obtain the optimal quantity of schooling, paths for consumption and mortality, and optimal levels of health expenditures based on equations (12)-(18). However, solving this optimization problem with morality risk turns out to be numerically challenging. We restrict the analysis to a time independent health expenditure, i.e., $d(t) = d$. This assumption greatly simplifies the solution.[10]

The results from the baseline parameters are denoted as baseline results. Before we present our baseline results, a simple normalization is worth mentioning here. In our analysis, the unit of time is one year, denoted as 1. All reported parameter values in our paper (in Tables 1 and 2 and in Figures 1 and 2) correspond to this. In order to discuss our result in more intuitive dollar values, we assume that the total hours that an agent can allocate between leisure and work in a year is 5,000, reflecting about 13.7 hours per day.[11] The upper panel of Table 1 lists the baseline parameter values and the lower panel reports the baseline results. The baseline results show that the optimal years of schooling is 12.6 years for black men and 13.12 years for white men. Compared to the observed 12.74 years of schooling for black men and 13.50 years for white men, the predicted schooling years are a little lower and the predicted gap in schooling is 68.4%

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[9] Based on Census 1990, the average hourly rate for men with only nine years of schooling is $9.95.

[10] When the health expenditure d is constant across ages, the necessary for the optimal health expenditure is given by:

$$\beta r \int_0^N u(c(v), l(v)) p(v) \ln[p(v)] e^{-\theta v} dv = u_c(c(0), \bar{l})(e^{-rN} - 1)$$

[11] If one assumes that the total hours per year are 4,000, then all the dollar values reported in Table 1 and Table 2 will be proportionally lower. However, the schooling years are not affected by the total hours per year assumed in the model.

of the observed gap. The average hourly wage rate at the predicted years of schooling is $13.38 for blacks and $13.89 for whites.

The predicted health expenditures from the model are $1,584 for blacks and $1,802 for whites. This suggests that white men spend about 20% more than black men in health expenditures. Given that the predicted schooling years are lower than the observed schooling years, it is not surprising that predicted health expenditures from the model are lower than the U.S. per capita health expenditure in 1990 ($2,167).

Figure 1 illustrates the predicted lifetime trajectories of income, consumption, leisure and wealth. In Figure 1a where the consumption trajectories are shown, one interesting observation is the large drop in consumption level at the time of retirement. Based on equation (7), the marginal utility just before retirement should equal the marginal utility just after retirement. Since leisure and consumption are substitutable in the given utility function, an increase in leisure due to retirement is compensated by a lower consumption of goods. In Table 1, blacks spend an average $12,500 in consumption per year, while whites on average consume $13,471 per year. Whites consume 7.77% more than blacks.

Figure 1b shows lifetime trajectories for net incomes, defined as the labor income minus the sum of health expenditures and the cost of schooling. At the working stage, blacks' average labor income is $18,850, while whites' average income is $20,059. Whites' labor incomes are 6.4% higher than blacks' labor incomes. For the reason of simplicity, our model does not include returns of experience in the accumulation of human capital. In our setup, wages for both blacks and whites do not increase after they finish school.

The wealth trajectories in Figure 1c show a familiar life cycle pattern: both the black agent and the white agent borrow to finance their education, save when they work, and dissave after they retire. The black agent's wealth level is lower than the white agent's during most of the life span. The only period when the black agent's wealth exceeds the white agent's wealth is the period immediately after schooling, since the black agent starts to work earlier than the white agent. The maximum wealth for both blacks and whites occurs at age 65 when they are about to retire. The maximum wealth level is $307.1K for blacks and $360.1K for whites. The lifetime mean wealth level is $97,890 for blacks and $116,970 for whites. White men have 19.5% more wealth than black men.

In the trajectories of leisure in Figure 1d, schooling requires more studying hours (or less leisure) than working. During the second stage when people work, the labor supply of black men is slightly lower than the labor supply of white men, indicating that black men not only have less education, but they also work less. During the working stage, the labor supply for the black agent is 2,272 hours per year, while the labor supply for the white agent is 2,314 hours.

In summary, in this model, blacks and whites are the same except in the mortality risks of the reference group by which they are categorized. Therefore, all the differences in economic outcomes, including consumption, income, wealth and labor supply, are attributed to the differences in mortality risks from the reference groups. More than two-thirds of the black-white educational difference can be explained by their difference in mortality risk.

C. *Sensitivity Analysis*

In the previous subsection, we show that when parameters are given their baseline values, the predicted schooling difference is over two-thirds of the observed difference between black men and white men. In this subsection, we study if the baseline results hold beyond the particular set of parameter values.

The sensitivity analysis is conducted according to the following procedure. We let one parameter vary at a time while holding other parameters constant at their baseline values. For any new set of parameter values, we re-optimize the whole life-cycle model to obtain optimal years of schooling for blacks and whites. For each parameter, we must determine a parameter interval in which we may conduct a sensitivity analysis. Selecting the parameter interval involves two steps. First, we search the boundary parameter value. When the parameter is beyond the boundary value, the additional years of schooling for blacks are negative (i.e. the total years of schooling are fewer than the minimum nine years of schooling assumed in the paper); or, no solution can be found. Second, we let the middle point of the interval be the baseline parameter value, and we let one end of the interval be the boundary parameter value we just selected in the first step. Obviously the interval is determined after one end point and the middle point of the interval are chosen. For example, for the time discount rate θ, the baseline parameter is $\theta = 0.032$. First, we find out that when $\theta > 0.034$, optimal years of schooling for blacks would be negative. Second, when we let $\theta = 0.034$ be the upper boundary of the parameter interval and let $\theta = 0.032$ be the middle point, the lower boundary of the interval is then $\theta = 0.030$. Thus, the interval to conduct sensitivity analysis for the time discount rate is [0.030, 0.034]. This interval is then divided into twenty equally spaced sub-intervals. There are twenty-one end points of these twenty sub-intervals. We let θ be each of these twenty-one end points. For each different θ, we obtain optimal schooling years and health expenditure. We obtain twenty-one sets of schooling years and health expenditures for both black men and white men, one of which is the baseline result.

With these twenty-one sets of schooling years and health expenditures, we calculate the mean differences and their standard errors in schooling years and in health expenditures between black men and white men. This process repeats for other parameters: leisure in school $\bar{l}$, cost of education parameter ξ, risk averse parameter σ, mortality production parameter β and μ and the interest rate r. The returns of education are calculated at nine years of schooling. From Equation (19), there are two parameters that determine the return of education. For simplicity, we only let the parameter φ in (19) change to obtain the parameter interval for the return of education.

From Table 2, we see that the mean differences in years of schooling under various experiments are very similar. The observed black-white difference is 0.76 years. When we let the time discount rate θ vary between 0.030 and 0.034, the mean difference in years of schooling is 0.59, which is a little higher than 2/3 of the observed difference. In fact, the mean differences range from 0.537 to 0.646 when all parameters except the interest rate vary in their parameter intervals. When the interest rate varies in its parameter interval, the mean difference in schooling years is 0.890, which is larger than the observed difference in schooling years. We conclude that the impact of mortality risk on schooling explains more than two-thirds of the empirical education difference in schooling years between black men and white men.

The baseline parameter values for the mortality production function in (1) are β=0.445 and μ=1.101. In Section IIIA, we show that the baseline values likely overestimate the actual parameter values. Here we discuss the outcomes of the model if either of the two parameters have lower values. We consider lowering the parameter μ. For example, if μ is lowered by 20%, i.e., $\mu=0.9$, the schooling years are 13.10 for blacks and 13.62 for whites. The difference between blacks and whites remain the same as the baseline case. In fact, if we let $\mu \in [0.701,\ 1.501]$, the average difference in schooling years between blacks and whites is 0.565 with a standard deviation of 0.185. The difference in schooling years is quite robust to the value of μ. However, the schooling years is more sensitive to the parameter β. For example, if we lower β by 20%

(other parameters are at their baseline values) i.e. β=0.356, the schooling years are 12.463 for whites and 12.077 for blacks. Although the difference in schooling years is reduced to 0.386 years, it represents a significant portion (50%) of the observed difference in schooling years.

In addition to the differences in schooling years, Table 2 also lists mean differences in health expenditures and their standard errors for all other parameters. For example, when the time discount rate varies in the interval [0.030, 0.034], the health expenditures for blacks vary from \$826 (when $\theta = 0.030$) to \$1,698 (when $\theta = .034$). The whites' health expenditure varies from \$1274 (when $\theta=0.030$) to \$2,119 (when $\theta=0.034$). The mean difference in health expenditures, when the time discount varies, is \$556 with a standard error of \$152. In fact, a different set of parameters produces a different set of health expenditures for both blacks and whites.

Figure 2a – Figure 2h illustrate schooling years of blacks and whites when each of the parameters varies in its parameter interval. For example, Figure 2a draws schooling years when the time discount rate θ varies in its parameter interval, [0.030, 0.034], while other parameters are held at their baseline values. The schooling years for whites lie above the schooling years for blacks. Although the level change of schooling years is rather large, from 10.66 years to 13.86 years for blacks and from 11.25 years to 14.62 years for whites, as the time discount rate increases from 0.030 to 0.034, the difference in years of schooling stays roughly the same. The standard error of the average difference in schooling years between whites and blacks is 0.038, only about 6% of its mean. Therefore, when the time discount rate varies in its parameter interval, the level of schooling years is no longer consistent with the observed years of schooling. However, the black-white difference in schooling years from our model is consistent with the observed difference.

Similar patterns repeat for four other parameters: leisure in school (Figure 2b), mortality function parameter μ (Figure 2c), the return of education (Figure 2d) and the cost of education (Figure 2e). When one of these four parameters varies in its respective parameter intervals, levels of schooling years vary greatly; however, the mean differences (with relatively small standard errors) in black-white schooling years match with the observed difference. Therefore, the result that the difference in mortality risks can explain much of the black-white difference in schooling years is robust for these four parameters.

For the remaining two parameters, the risk averse parameter σ, the mortality production parameter β, and the interest rate r, schooling years for whites always lie above those for blacks, indicating that whites always complete more schooling years than blacks. In addition, the mean differences match with observed differences in schooling years when each of these parameters varies in its respective parameter intervals. However, these mean differences in schooling years have a larger variation. For the risk averse parameter σ, the difference in black-white schooling years varies from 0.115 (σ = 2.26) to 0.843 (σ = 1.74). The average difference is 0.537 years with a standard error of 0.203. For the mortality production parameter β, the difference in black-white schooling years varies from 0.103 (β = 0.245) to 0.815 (β = 0.645); the average difference is 0.638 with a standard error of 0.253. Finally, when the interest varies from 0.026 to 0.054, the average difference is 0.890 with a standard error of 0.733. Since the mean differences in schooling years from our model are consistently around two-thirds of the observed difference in schooling years, we claim that the difference in schooling years for black and white men can be substantially explained by the mortality risks. However, such a claim is less robust for three out of the eight parameters discussed in the paper.

Finally, from Figure 2a – Figure 2h, one can find out how choices in schooling years change when one of the parameters changes. Figures are rather intuitive. When the leisure in school is higher, staying in school becomes more appealing and years of schooling increase (Figure 2b). In Figure 2c, when the mortality production parameter varies, the marginal gain from health expenditures increases. Therefore, it is beneficial to have more education in order to afford better health expenditures. The similar reason applies to Figure 2g. A higher return of education raises years of schooling (Figure 2d), while a higher cost of education lowers years of schooling (Figure 2e). In Figure 2h, a higher interest rate lowers years of schooling since it raises the opportunity cost of schooling. The intuition in other figures is only slightly more complicated. In Figure 2a, a higher discount rate lowers years of schooling since current utility is valued higher. In Figure 2f, a more risk averse person has lower years of schooling since he has a higher tendency to avoid risky investment of education.

IV. Conclusion

Tremendous resources have been devoted to reduce the black-white gap. This paper investigates to what extent the difference in educational attainment between black and white men can be explained by the differences in their mortality risks. We develop a dynamic life-cycle model with optimal stopping-point in which group-level mortality risk plays an important role in determining individual-level health expenditure, mortality risk and amount of schooling. In the model, an agent's mortality is a function of his own health expenditure and his reference group's mortality risks. In such a framework, both the agent's years of schooling and mortality risks are endogenous while the reference group's mortality risks are exogenous.

We let the black male population be the reference group for a representative black male and let the white male population be the reference group for a representative white male. The resulting years of schooling for black and white men are then compared with observed schooling for black and white men, respectively.

We calibrate the model by finding a set of baseline parameter values such that optimal schooling years match a large part of the observed years of schooling for both black men (12.74 years) and white men (13.50 years). The optimal health expenditures are $1,584 per year for a black male and $1,802 per year for a white male. Blacks spend about 12% less in health expenditure than whites. We then conduct various sensitivity analyses by locally varying parameters. We find that although levels of schooling years are sensitive to various parameter values, the difference in schooling years between blacks and whites is relatively robust in various parameter values. We conclude that the mortality difference between blacks and whites is capable of explaining their difference in educational attainment.

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Table 1: Baseline Parameter Values and Results

Parameter description and notation	Values	
Mortality production function:		
parameter β	0.445	
parameter μ	1.101	
Utility function:		
relative risk averse σ	2.0	
share of consumption α	.33	
Human capital function:		
parameter φ	0.58	
parameter η	0.32	
Opportunity cost of education ξ	.5	
Leisure at school $\bar{l}$	0.40	
Time discount rate θ	0.032	
Interest rate r	0.04	
Wage rate per unit of human capital w	1.47	
Outcomes of the model	**Blacks**	**Whites**
Years of schooling	12.60	13.12
(Observed years of schooling)	(12.74)	(13.50)
Health expenditure (in $1,000)	1.584	1.802
Average lifetime wealth (in $1,000)	100.9	120.1
Average lifetime consumption (in $1,000)	12.500	13.471
Average labor income when working (in $1,000)	18.850	20.059
Average labor supply when working (in hours)	2,272	2,314
Average hourly wage rate (in $)	13.38	13.89

Table 2: Sensitivity Analysis

	Parameter values		Outcome of the model	
Parameter description and notation	Baseline	Parameter Intervals	Schooling Years Difference	Medical Expenditure Difference
Time discount rate θ	0.032	[0.030, 0.034]	0.590	$565
			(0.038)	($152)
Leisure at school $\bar{l}$	.40	[0.386,0.414]	0.610	$589
			(0.081)	($44)
Mortality production parameter μ	1.101	[0.701, 1.501]	0.565	$609
			(0.185)	($300)
Return of education at 9 years of schooling	0.0913	[0.0888, 0.0938]	0.640	$588
			(0.034)	($177)
Opportunity cost of education ξ	0.50	[0.47, 0.53]	0.646	$589
			(0.0217)	($140)
Relative risk averse parameter σ	2.0	[1.74, 2.26]	0.537	$612
			(0.203)	($358)
Mortality production parameter β	0.445	[0.245, 0.645]	0.638	$653
			(0.253)	($451)
Interest rate r	0.04	[0.026, 0.054]	0.890	$624
			(0.733)	($567)

Figure 1a: Lifetime Consumption Trajectories

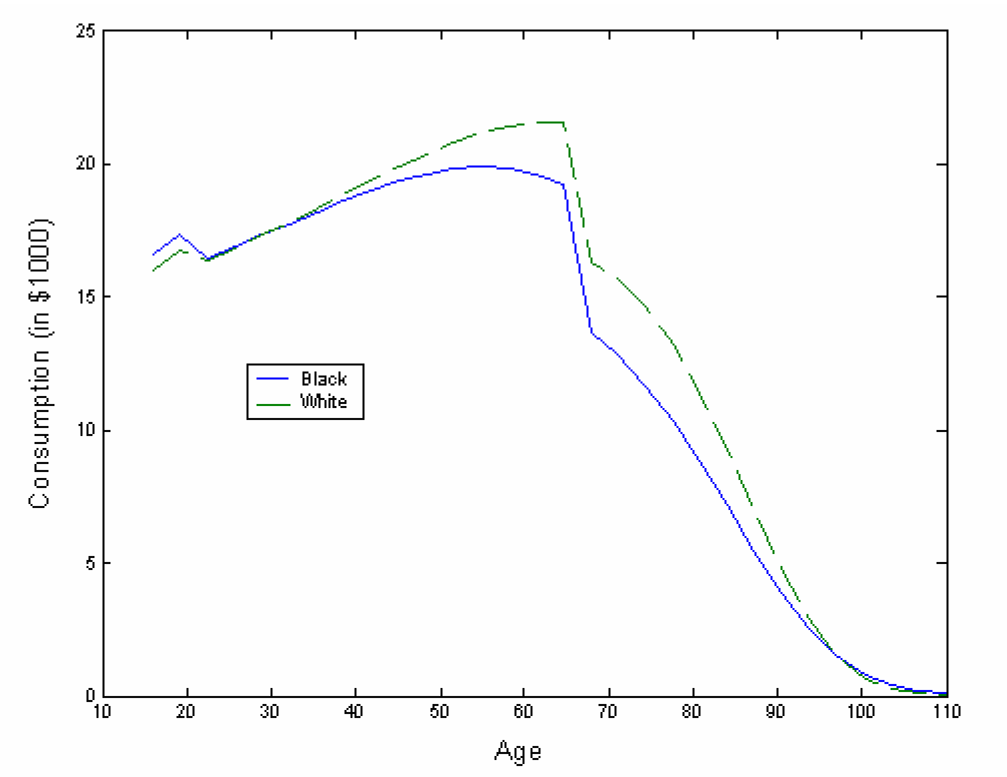

Figure 1b: Lifetime Net Income Trajectories

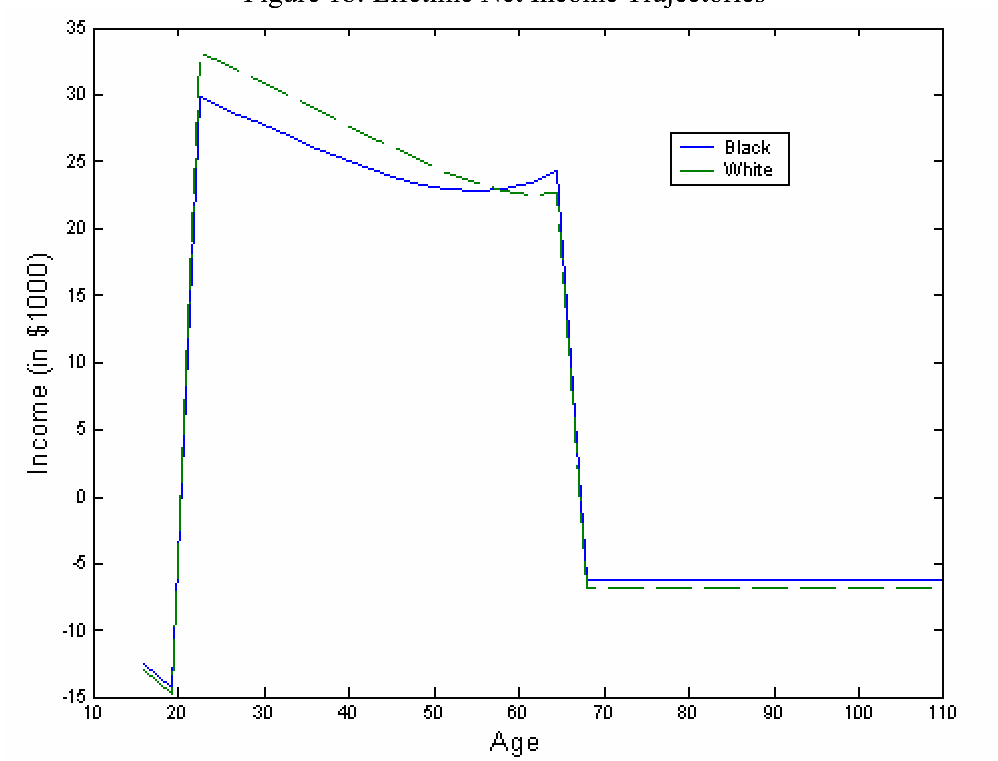

Figure 1c: Lifetime Wealth Trajectories

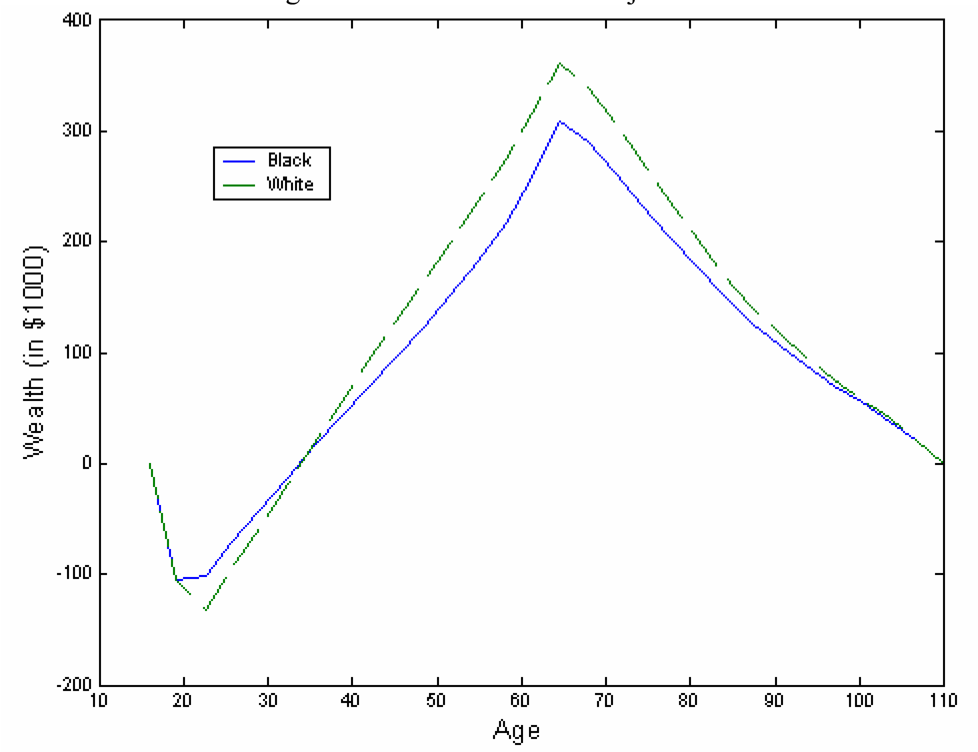

Figure 1d: Lifetime Leisure Trajectories

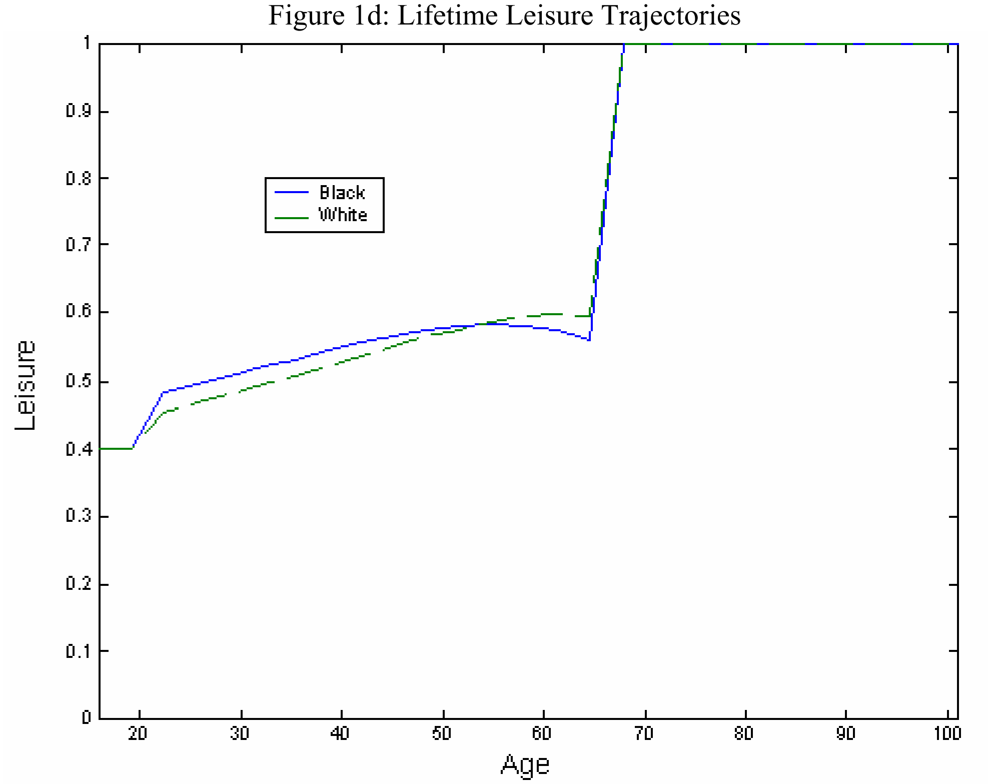

Figure 2: Schooling Years as One of the Parameters Varies

Figure 2a: When time discount rate varies

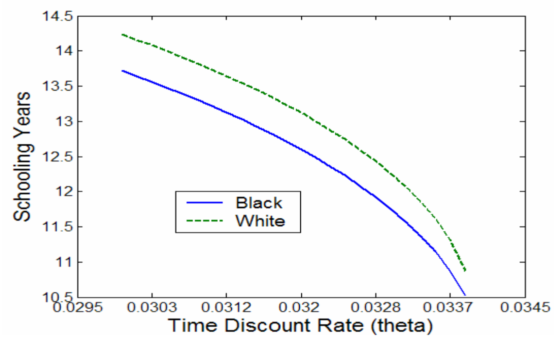

Figure 2b: When leisure in school varies

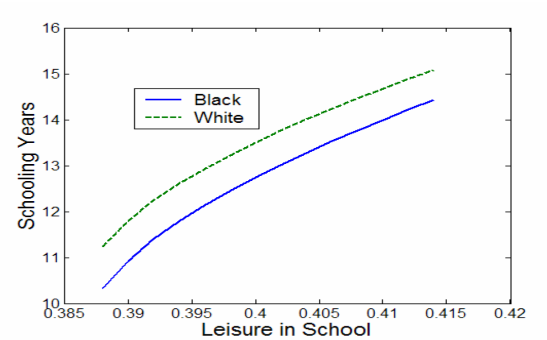

Figure 2c: When mortality production parameter μ varies

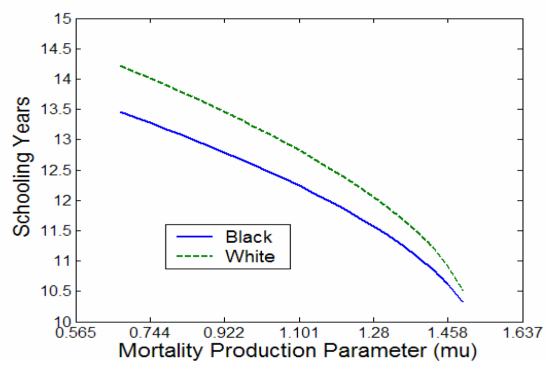

Figure 2d: When return to education varies

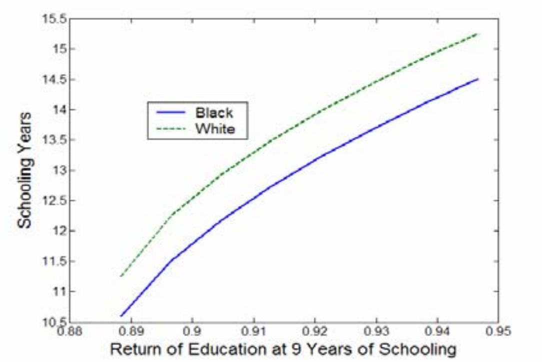

Figure 2e: When cost of education varies

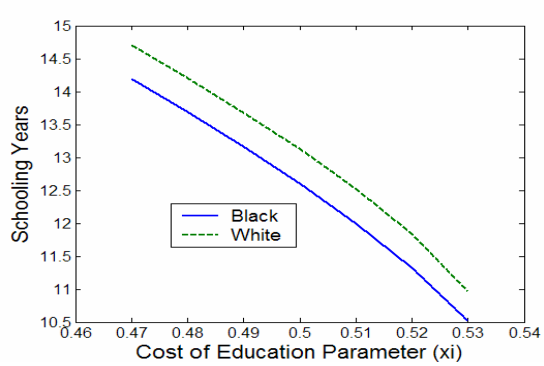

Figure 2f: When risk averse parameter varies

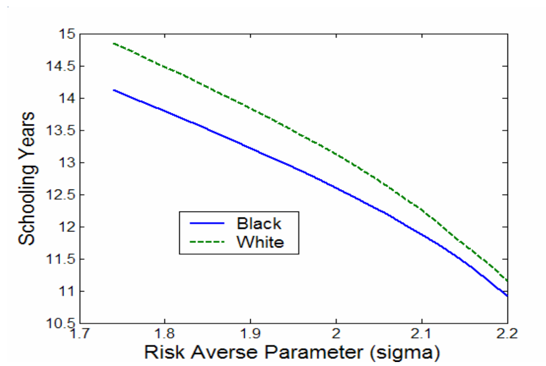

Figure 2g: When mortality production parameter β varies

Figure 2h: When interest rate varies