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ABSTRACT

We propose a model that combines statistical discrimination and educational sorting that explains why blacks get more education than do whites of similar cognitive ability. Our model explains the difference between blacks and whites in the relations between education and AFQT and between wages and education. It cannot easily explain why, conditional only on AFQT, blacks earn no more than do whites. It does, however, suggest, that when comparing the earnings of blacks and whites, one should control for both AFQT and education in which case a substantial black-white wage differential reemerges. We explore and reject the hypothesis that differences in school quality between blacks and whites explain the wage and education differentials. Our findings support the view that some of the black-white wage differential reflects the operation of the labor market.

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1 Introduction

In a highly influential article, Derek Neal and William Johnson (1996) argue that wage differentials between blacks and whites can be explained by productivity-related personal characteristics (premarket factors). They show that the black-white differential is dramatically reduced, and in some cases eliminated, by controlling for performance on the Armed Forces Qualifications Test (AFQT). Since, for their sample, AFQT was administered before the individual entered the labor market, it cannot be affected directly by labor market discrimination. Therefore, either premarket factors explain wage differentials or AFQT must be affected by anticipated discrimination in the labor market. However, Neal and Johnson (hereafter NJ) show that the effect of AFQT on the earnings of blacks is at least as large as on the earnings of whites. Therefore blacks should not anticipate a smaller return to investment in cognitive skills. Thus they conclude that premarket factors and not labor market discrimination account for black-white earnings differentials.[1]

This paper shows that in comparison with controlling for AFQT alone, wage differentials are substantially larger when we control for both education and AFQT. The reason is that conditional on AFQT, blacks get significantly more education than do whites. This raises two questions. Why do blacks obtain more education than whites with the same AFQT? Can we attribute the wage differential to labor-market discrimination.

We focus primarily on the first question. One possible explanation for the additional education obtained by African Americans is that they attend lower quality schools than whites do. If AFQT is mostly determined by school inputs, and blacks get less of an AFQT benefit from schooling than do whites, then for a given amount of schooling, blacks will have lower AFQT scores. This means that for a given AFQT score, blacks will have more education than whites. We test this hypothesis directly by controlling for measurable differences in school quality, and we find that school quality cannot explain the education differential.

We therefore explore an alternative hypothesis: that education is generally a more valuable signal of productivity for blacks than for whites. As a result blacks invest more heavily in the signal and get more education for a given level of ability. Our signalling model, developed below, implies that blacks within a broad range of intermediate ability levels should obtain more education than equally able whites, though blacks with either low or high levels of ability should obtain the same education as whites do. This is confirmed in the data when we use an appropriate measure of AFQT as a proxy for ability.

In interpreting these results, we do not consider the AFQT to be a measure of innate ability;

[1] See also Johnson and Neal (1998) and the critique in Darity and Mason (1998) and the reply by Heckman (1998). Note, however, that if AFQT is influenced by investments, then the return to AFQT is an equilibrium price. If blacks and whites discount future income at the same rate, in equilibrium blacks and whites might well get the same return to AFQT even if for a fixed level of investment blacks get a lower return.

rather we view it as a measure of both innate and acquired personal traits. We do not attempt to explain the behavior of children and adolescents prior to the administration of the AFQT, nor do we assume such behavior takes account of the value of investment in education or human capital. But we do assume that students act as rational agents after the administration of the AFQT, who, aside from wanting to invest in their human capital, are motivated by a desire to signal.

Unfortunately, our model does not explain why blacks have earnings that are similar or somewhat lower than those of whites conditional on only AFQT unless education is a pure signal at the margin, an assumption that we find somewhat extreme. Since for a given AFQT, blacks get more education than do whites, they should also earn more than whites not somewhat less. The remaining difference could reflect either missing variables or labor market discrimination. This is an old debate that precedes NJ, and it is not one we will pretend to resolve. We do explore whether the wage differential can be explained by differences in the quality of schools attended by blacks and whites and find no evidence to support this hypothesis.

The paper is organized as follows. We begin with the principle empirical finding: that conditional on AFQT, blacks get more education than do whites. We show that this differential cannot be explained by differences in the quality of the schools attended by blacks and whites. We then present our model of statistical discrimination/educational sorting and show that it implies that blacks get more education than whites except at very low and very high levels of ability. We also develop the implications of the model for wage/education profiles. We then return to the data and test the implications of the model. Next we turn our attention to the Neal/Johnson findings and show that, as would be expected from the earlier results, a substantial black-white wage differential reemerges when we control for education as well as AFQT. In the conclusion we explore the implications of the failure of our model's prediction that blacks will earn more than whites conditional only on AFQT.

2 Educational Attainment: Empirical Findings

2.1 The Data

Although our initial focus is on differences in educational attainment not wages, later in the paper we will want to place our results in juxtaposition with those of Neal and Johnson. Therefore to a large extent, we mimic their procedures. Following NJ, we rely on data from the National Longitudinal Survey of Youth (NLSY79). Since 1979 the NLSY has followed individuals born between 1957 and 1964. Initially surveys were conducted annually. More recently, they have been administered every other year. The NLSY oversamples blacks and Hispanics as well as people from poor families and the military. We drop the military subsample and use sampling weights to generate representative results.[2]

[2] Neal and Johnson also drop the over-sample of poor whites. Since having a larger sample is helpful, we retain this group and, as noted above, use sampling weights. It will become apparent that this is not an important source of differences.

Education is given by the highest grade completed as of 2000. For those missing the 2000 variable, we used highest grade completed as of 1998 and for those missing 1998 as well, we used the 1996 variable. Where available we used the 1996 weight. For observations missing the 1996 weight, we imputed the weight from the 1998 and 2000 weights using the predicted value from regressions of the 1996 weights on the 1998 and/or 2000 weights.

We determined race and sex on the basis of the sub-sample to which the individual belongs. Thus all members of the male-Hispanic cross-section sample were deemed to be male and Hispanic regardless of how they were coded by the interviewer.

In 1980, the NLSY administered the Armed Services Vocational Aptitude Battery (ASVAB) to members of the sample. A subset of the ASVAB is used to generate the Armed Forces Qualifying Test (AFQT) score. The AFQT is generally viewed as an aptitude test comparable to other measures of general intelligence. Like other such measures, it is generally regarded as reflecting a combination of environmental and hereditary factors. The AFQT was recalibrated in 1989. The NLSY data provide the 1989 AFQT measure. Following NJ, we regressed the AFQT score on age (using the 1981 weights) and adjusted the AFQT score by subtracting age times the coefficient on age. We then renormed the adjusted AFQT to have mean zero and variance one.

In the later part of the paper, we also examine wages. Because of the difficulties in addressing differential selection into labor force participation of black and white women (Neal, 2004), we limit our estimates using wages to men. In order to minimize the problem of missing data, we used hourly earnings data from the 1996, 1998 and 2000 waves of the survey. Next we took all observations with hourly wages between $1 and $100 in all three years and calculated (unweighted) mean hourly earnings for this balanced panel. We used the average changes in hourly wages to adjust 1996 and 2000 wages to 1998 wages. Note that this adjustment includes both an economy-wide nominal wage growth factor and an effect of increased experience. We then used the adjusted 1996, 1998 and 2000 wages for the entire sample to calculate mean adjusted wages for all respondents. We limited ourselves to observation/years in which the wage was between $1 and $100. If the respondent had three valid wage observations, we used the mean of those three. If the respondent had two observations, we used the average of those two. For those with only one observation, the wage measure corresponds to that adjusted wage. There were 237 observations of men who were interviewed in at least one of the three years but who did not have a valid wage in any of the three years. In the quantile regressions, these individuals are given low imputed wages except for a five cases coded as missing for which the reported wage in at least one of the three years exceeded $100 per hour and for which there was no year with a valid reported wage.

2.2 Findings

Most labor economists are aware that average education is lower among blacks than among whites. In our sample blacks get about three-quarters of a year less education than do whites. It is less well known that conditional on AFQT, blacks get more education than whites do. This is shown in Table 1.[3] In the first and fourth columns, we show the difference in educational attainment between blacks and non-Hispanic whites among men and among women conditional on age and AFQT. Black men get about 1.2 years more education than do white men with the same AFQT. Among women the difference is about 1.3 years. There are also smaller but statistically significant differences between Hispanics and non-Hispanic whites.

Why should blacks, and to a lesser extent Hispanics, obtain more education than whites with the same measured cognitive skills? There are, of course, a large number of potential hypotheses. We will focus on two. The first is that AFQT is largely determined by schooling. The second is that statistical discrimination in the labor market leads them to over-invest in education.

The first explanation can be summarized as follows. Since blacks attend lower quality schools, on average they gain fewer cognitive skills from a given level of education. Under this view, it is not surprising that blacks have more schooling given their AFQT; they require more schooling to reach a given level of cognitive skills. When we regress education on AFQT, we are, in effect, estimating a reverse regression.

For lower school quality among blacks to explain their greater education given their AFQT, it is important that the effect of schooling on AFQT be sufficiently large. To see this, let us consider the opposite extreme. Suppose that AFQT were fully determined before age 15 (the youngest age at which members of the sample were tested) and therefore before students typically dropout. Then AFQT would be exogenous to the dropout decision. The question then would only be whether raising school quality increases or decreases educational attainment. Put differently, of two people with IQ's of 100 (or normalized AFQT's of 0), would we expect the one in a higher quality school to get more or less education than the one in the lower quality school?

Most labor economists would expect that holding other factors constant, lower school quality would lower years of education. Standard theoretical models do not offer us unambiguous results about the effect of school quality on years of schooling. In these models, the sign of the effect depends on second derivatives. The data, however, suggest a positive correlation between school quality and years of schooling (e.g. Card and Krueger 1992a&b).

To summarize, if AFQT is heavily influenced by education and if most sample members had completed their education at the time that they took the AFQT, then school quality differences would provide a plausible explanation for the higher education among blacks given their AFQT. If school quality has little effect on AFQT or if most sample members had not completed schooling, then we would expect blacks to get less education given their AFQT or given their AFQT and completed schooling at the time they took the test. Our own view is that the AFQT measures skills that are more heavily affected by preadolescent and early adolescent education so that the endogeneity of AFQT to ultimate educational attainment is not likely to be a major issue. However,

[3] See Rivkin (1995) for findings from High School and Beyond that conditional on math and reading scores, blacks are more likely to remain in high school and begin college. Cameron and Heckman (2001) also use the NLSY and find that blacks get more education than whites conditional on measures of family background and note that AFQT has a particularly strong effect on reversing the education differential.

others certainly disagree. Therefore we address the question empirically.

Our first approach is to measure the education differential conditional on measured school inputs. Because the NLSY was unable to obtain school quality information for a significant minority of respondents, the middle column of each panel of table 1 replicates the first column for the sample with school input information. The principal results do not change. The estimated black/white education gaps differ by a couple of hundredths. For Hispanic men, the estimate education gap does increase.

The third column in each panel controls for standard inputs into the education production function. Almost none of the individual coefficients is statistically significant. Among men, attending a school with more highly educated teachers is associated with greater educational attainment. Among women this variable and attending a school with more library books is associated with getting more education. In part, the paucity of individually significant factors reflects multicollinearity among the measured inputs. In both cases, the coefficients on the school inputs are jointly significant. More importantly, controlling for these factors has almost no effect on the estimated education gaps.

Table 2 repeats the exercise for individuals born after 1961 (the sample used by NJ). Only about 5% of this sample had completed schooling when they took the AFQT. While their AFQT may have been influenced by their education up to this point, future education should be caused by skills acquired up to this point and not the other way around. In addition to controlling for AFQT, we now control for grade completed as of 1980. As can be seen, the coefficient on completed schooling, although statistically significant, is small. Not surprisingly therefore, the results are similar when we do not control for completed schooling as of 1980, and we therefore do not show the results.

For women, the education differences are similar to those obtained in table 1. Relative to non-Hispanic white women, black women get about 1.3 years more education and Hispanic women get about half a year more education. For men, the numbers are somewhat different from those in table 1. For blacks, the education differential is somewhat smaller than in table 1 but still quite large. For Hispanics the differential is larger and the somewhat puzzling difference between those with and without school quality data remains.

Because inputs may be a very poor proxy for school quality, in table 3 we control for measures of school composition and student behavior. These are designed to capture some of the elements that people think about when they think about struggling schools: high proportions of disadvantaged students, high dropout rates and poor attendance. The results are very similar to those we obtained in tables 1 and 2. Among all men, the estimated education differentials are similar to those obtained with all men without controls for both blacks and Hispanics. For the younger cohorts the estimated differential for blacks is somewhat larger than is obtained without controls. For women there is little difference from the results we obtain without controls both for all women and for the younger women.

Moreover, consistent with Cameron and Heckman (2002), the findings in tables 1-3 are robust to including measures of family background (not shown). Controlling for mother's and father's education, number of siblings and father's and mother's occupation (12 categories) has little or no effect on either the coefficient on black or on AFQT. Controlling for parental education does noticeably increase the Hispanic/non-Hispanic white education differential. Based on parental education, Hispanics would be predicted to get much less education than they actually obtain.

Before we move on, it is important to make it clear what we are *not* claiming. As stated in the introduction, we are not claiming that AFQT is innate or even unaffected by education and school quality. And we are not claiming that school quality is unrelated to educational attainment. To the contrary, individuals who attend higher quality schools both have higher AFQT's and get more education. It is beyond the scope of the paper to address whether these relations are causal. However, from our perspective, the simplest and most probable explanation for our results is that the effect of school quality on AFQT and the effect of school quality on educational attainment roughly cancel so that AFQT given educational attainment is roughly independent of school quality.

3 Why Blacks Get More Education than Whites: A Signaling Model

Why then do blacks get more education than do whites with the same measured ability? In this section, we argue that statistical discrimination against blacks creates incentives for them to signal ability through education. We believe that ethnographic evidence supports the view that blacks see education as a means of getting ahead. Newman (1999) finds that blacks in low-skill jobs in Harlem view education as crucial to getting a good job and that blacks with low levels of education have difficulty obtaining even jobs that we would not normally think of as requiring a high school diploma. Kirschenman and Neckerman (1991) also find that employers are particularly circumspect in their assessment of low-skill blacks, a finding consistent with our approach.

Our theoretical model merges the standard model of statistical discrimination (Aigner and Cain, 1977) with a conventional sorting model. In a sense, it stands Lundberg and Startz (1983) on its head, by dealing with observable investment in contrast with the unobservable investment in that paper. As is standard in the statistical discrimination literature, we assume that the productivity of blacks is less easily observed than the productivity of whites. However, consistent with our reading of the ethnographic literature, we make one nonstandard assumption. We assume that as education levels increase, the ability of firms to assess the productivity of black and white workers converges.

Our strategy for analyzing statistical discrimination is to develop a game-theoretic signaling model of educational attainment and apply it separately to blacks and to whites, by setting appropriate parameters for each group. Then we compare the equilibrium outcomes of the two groups. We assume that the ability of firms to observe worker productivity increases with the worker's education and that for sufficiently high levels of education, firms observe productivity precisely. The results would not change substantively if at that level there were additional uncertainty about productivity, provided that the uncertainty was orthogonal to information available to either workers or firms. Economics departments may have considerable uncertainty about the future productivity of a freshly-minted Ph.D., but their predictions are likely to be as accurate as those of the job candidate. We assume that, in contrast, without information revealed by the level of education itself, employers hiring workers with lower levels of education would not know as much about potential employees' productivity as those workers do.

The principal result is that since they have greater difficulty observing blacks' productivity, employers put more weight on the observable signal of productivity, education, when making offers to blacks than they do when making offers to whites. In response, blacks choose to get more education.

3.1 The Signaling Game

Consider a game between a continuum of workers of different ability levels a, where a is continuously distributed over some fixed interval. Each worker must choose a level of education s. Because we assume that education and ability are complementary inputs in the creation of productivity (in a sense defined below), we shall search for a separating equilibrium in which the workers' strategy profile is described by a continuous and differentiable function $S(a)$, strictly increasing in a, where $s = S(a)$ is the education obtained by a worker of ability a. Firms in our model simply follow the rules of a competitive labor market—they play no strategic role in the game. (But employers beliefs about S in equilibrium are required to be correct.)

Suppose that a worker's productivity p^*, conditional on his education level s and ability a, has the log-normal distribution given by

$$p^* = Q(s,a)\,\hat{\varepsilon}, \tag{1}$$

where $Q(s,a)$ is a deterministic function of education and ability and where $\varepsilon \equiv \ln \hat{\varepsilon}$ is a normal random variable with mean 0 and variance σ_ε^2. Letting $q(s,a) \equiv \ln Q(s,a)$ denote the mean of $\ln p^*$, we can write log productivity as

$$\ln p^* = q(s,a) + \varepsilon. \tag{2}$$

We assume that the effect of education on log-productivity is characterized by diminishing returns ($q_{ss} < 0$) but that ability complements the productivity-increasing effects of education ($q_{sa} \geq 0$).

A potential employer can observe a worker's education level s but not his true productivity p^*. However, the employer does observe a productivity signal p given by

$$\ln p = \ln p^* + u, \tag{3}$$

where u is a random error of observation. The error term u has variance $\sigma_u^2(s)$, which is common to all firms, continuous and decreasing in s. We assume that ε and u are independently distributed.

Let $\lambda(s) \in [0,1]$ be given by

$$\lambda(s) \equiv \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \sigma_u^2(s)}.$$

If $\lambda(s)$ is near 0, then $\sigma_u^2(s)$ must be large, in which case the employer's ability to observe worker productivity directly is poor. Conversely, if $\lambda(s) = 1$, then $\sigma_u^2(s) = 0$, and the employer can observe worker productivity perfectly. In the latter case, workers would have no incentive to signal their productivity to employers, and they would obtain the efficient level of education.

3.1.1 The Equilibrium Competitive Wage

In the candidate separating equilibrium described by the workers' strategy profile S, an employer can infer a worker's ability a from his knowledge of the worker's education s. If $\hat{q}(s)$ denotes the employer's equilibrium inference about the value of $q(s,a)$ conditional on s, it follows that $\hat{q}(s) \equiv q(s, A(s))$, where $A \equiv S^{-1}$.

Proposition 1 *From the point of view of an employer who has observed a worker's productivity signal p and education level s, the conditional mean and variance of the unobservable random element ε is given by*

$$E[\varepsilon \,|\, p, s] = \lambda(s)(\ln p - \hat{q}(s)) \tag{4}$$

and

$$\sigma^2[\varepsilon \,|\, p, s] = (1 - \lambda(s))\,\sigma_\varepsilon^2. \tag{5}$$

Proof. Because the values of $\ln p - \hat{q}(s)$ and s uniquely determine p, we know that any expectation conditioned on p and s will remain unchanged if conditioned on $\ln p - \hat{q}(s)$ and s instead. Therefore we can write

$$E[\varepsilon \,|\, p, s] \equiv E[\varepsilon \,|\, \ln p - \hat{q}(s)\,, s]\,. \tag{6}$$

Moreover, (2) and (3) imply that

$$\ln p - \hat{q}(s) = u + \varepsilon \tag{7}$$

in equilibrium. The proposition now follows from (6) and from standard results for the sum of independent normal random variables. ■

In a competitive labor market, an employer will offer the wage $\hat{w}(p,s) \equiv E[p^* \,|\, p, s]$ to a worker with observed characteristics p and s. We show:

Proposition 2 *The log of the equilibrium competitive wage is given by*

$$\ln \hat{w}(p,s) = \lambda(s) \ln p + (1 - \lambda(s))\big(\hat{q}(s) + .5\sigma_e^2\big)\,. \tag{8}$$

Proof. We calculate the expected values of the terms of equation (2) conditional on the observed p and s. This yields

$$E[\ln p^* \,|\, p, s] = \hat{q}(s) + E[\varepsilon \,|\, p, s]\,. \tag{9}$$

Applying Proposition 1 give us

$$E[\ln p^* \mid p, s] = \lambda(s) \ln p + (1 - \lambda(s))\,\hat{q}(s)$$

and

$$\sigma^2[\ln p^* \mid p, s] = (1 - \lambda(s))\,\sigma_\varepsilon^2.$$

A lognormally-distributed random variable x satisfies

$$\ln E[x] = E[\ln x] + \frac{1}{2}\sigma^2[\ln x],$$

which, applied to $\hat{w}(p,s) \equiv E[p^* \mid p, s]$, yields the proposition. ■

3.1.2 Workers' Equilibrium Strategies

Each worker knows his own ability a. But a worker must choose his level of education s before ε and u are realized. When other workers have the strategy profile $S(a)$, a designated worker's expectation of his wage, conditional on his own s and a, is given by $E_{\varepsilon,u}[\hat{w}(p,s)]$, where $E_{\varepsilon,u}$ integrates over ε and u.

As a first step in deriving the best response of a worker with characteristics (s,a) to the profile $S(a)$, we compute the value of $\ln E_{\varepsilon,u}[\hat{w}(p,s)]$. From (8), (2) and (3), we see that

$$\ln \hat{w}(p,s) = \lambda(s)(q(s,a) + u + \varepsilon) + (1-\lambda(s))\big(\hat{q}(s) + .5\sigma_e^2\big),$$

which is a normally distributed random variable with mean

$$E_{\varepsilon,u}[\ln \hat{w}(p,s)] = \lambda(s)\, q(s,a) + (1-\lambda(s))\big(\hat{q}(s) + .5\sigma_e^2\big)$$

and variance

$$\sigma^2[\ln \hat{w}(p,s)] = \lambda(s)^2\big(\sigma_e^2 + \sigma_u^2(s)\big) = \lambda(s)\,\sigma_e^2.$$

Again, from the standard properties of log-normal random variables, we have

$$\ln E_{\varepsilon,u}[\hat{w}(p,s)] = E_{\varepsilon,u}[\ln \hat{w}(p,s)] + \frac{1}{2}\sigma^2[\ln \hat{w}(p,s)],$$

so that

$$\ln E_{\varepsilon,u}[\hat{w}(p,s)] = \lambda(s)\, q(s,a) + (1-\lambda(s))\,\hat{q}(s) + .5\sigma_e^2. \tag{10}$$

This confirms the intuition that a designated worker's expected wage depends both on his actual ability and the ability level inferred by the employer, which in turn depends on $S(a)$.

Workers maximize expected discounted net income. Assume that the only cost of education is its opportunity cost in terms of lost income while in school. If r is the worker's discount rate, the expected present value at time $t = 0$ of the future income of a worker with characteristics (s,a) is given by

$$v(s,a) \equiv \int_s^{\infty} e^{-rt} E_{\varepsilon,u}[\hat{w}(p,s)]\,dt \equiv \frac{1}{r}e^{-rs}E_{\varepsilon,u}[\hat{w}(p,s)]$$

or

$$\ln v(s,a) \equiv -r - rs + \ln E_{\varepsilon,u}[\hat{w}(p,s)].$$

The first-order condition for maximizing $v(s,a)$ with respect to s is

$$\frac{\partial}{\partial s}\ln E_{\varepsilon,u}[\hat{w}(p,s)] = r. \tag{11}$$

This restates the well-known proposition that when the only cost of schooling is the student's opportunity cost, the worker will continue to obtain information so long as rate of return to additional education exceeds the discount rate r. We restrict the class of equilibria we consider to those for which (11) has a unique solution.

We are now in a position to describe a separating equilibrium of the wage/education game among the class of strategy profiles that are "well behaved" (continuous, differentiable, monitonically increasing and specify a unique best response for every worker type).

Proposition 3 *If the support of worker abilities is the interval* $[a_0,\ a_1]$*, then any well-behaved separating equilibrium* S *has the property that the education level* $S(a_0)$ *of the lowest-type worker must be efficient and not influenced by signaling.*

Proof. In an equilibrium with $S(a)$ strictly increasing in a, the employer would infer that a worker with education $S(a_0)$ has ability a_0, the lowest level in the support. If $S(a_0)$were inefficiently high, the worker of ability a_0 could safely deviate to the lower efficient level of education without lowering the employer's inference of his ability, and so raise his payoff. If $S(a_0)$ were inefficiently low, the worker of ability a_0 would deviate to $s > S(a_0)$ even without consideration of the positive payoff from signaling. ■

We can now provide a complete description of any well-behaved equilibrium.

Proposition 4 *Suppose* $[a_0,\ a_1]$ *is the support of worker abilities. If a workers' equilibrium strategy profile* $S(a)$ *is well behaved, then its inverse* $A(s)$ *must satisfy the differential equation*

$$q_s + (1-\lambda)\, q_a A' = r. \tag{12}$$

For $0 \le \lambda < 1$ *, this equation is equivalent to*

$$S' = \frac{(1-\lambda)\, q_a}{r - q_s}. \tag{13}$$

For $\lambda = 1$*, the equilibrium condition is given by the solution for* s *of the equation*

$$q_s(s, a) = r. \tag{14}$$

This solution of (14) defines the efficient level of education, which we denote by $S^*(a)$*. Furthermore, we have* $S(a_0) = S^*(a_0)$ *for any function* $\lambda(s)$*. Therefore each* $\lambda(s)$ *corresponds to exactly one well-behaved equilibrium.*

Proof. Substituting (10) into (11) yields the differential equation

$$\frac{\partial}{\partial s}\big(\lambda(s)\, q(s,a) + (1-\lambda(s))\, \hat{q}(s) + .5\sigma_e^2\big) = r,$$

or

$$\lambda'(s)\, q(s,a) + \lambda(s)\, q_s(s,a) - \lambda'(s)\, \hat{q}(s) + (1-\lambda(s))\big(q_s(s, A(s)) + q_a(s, A(s))\, A'(s)\big) = r. \tag{15}$$

This equation implicitly defines the best response s of a worker with ability a to the strategy profile S. Consequently, $a = A(s)$ and $q(s,a) = \hat{q}(s)$ in equilibrium, and (15) reduces to (12).

Equation (13) follows from the fact that the derivative of S is the reciprocal of the derivative of A. Proposition 3 implies that $S(a_0) = S^*(a_0)$. ■

The left-hand side of equation (12) represents the worker's rate of return to a marginal unit of education, which, given appropriate concavity conditions and the strategy-profile-inverse A, must be equated to r. This rate of return arises from the direct and indirect effects of education.

First, consider the direct effect of additional education on the employer's inference of productivity when inferred ability is held constant. The direct effect works through two channels. For any given productivity signal p, additional education leads the employer to infer higher productivity, which increases the return to education by $(1-\lambda)\,q_s$. But additional education also increases the expected value of the p signal, and the increase in p causes the expected return to education to increase by λq_s. These effects sum to q_s, the first term of (12).

Second, in equilibrium, an increase in education causes the employer to increase inferred ability. The rate of increase of inferred ability with respect to education is A', the effect of increased ability on expected log productivity is q_a and the weight that the employer puts on this inference (as opposed to his signal) is $1-\lambda$. The second term, $(1-\lambda)\,q_a A'$, is the product of these effects.

In (12), the term $(1-\lambda)\,q_a A'$ is always nonnegative so that for any equilibrium $S(a)$, we have $q_s(S(a)\,,a) \leq r$. Because we have assumed that q_{ss} is negative, and because the efficient level of education $S^*(a)$ is defined by $q_s(S^*(a)\,,a) = r$, the following proposition holds:

Proposition 5 *Let $S(a)$ describe any separating equilibrium of the workers' signaling game. Then for all $a \in [a_0,\ a_1]$, $S(a) \geq S^*(a)$*

Because an equilibrium strategy profile satisfies $q_s(s,a) = r$ whenever $\lambda(s) = 1$ (see Proposition 4), and because that equation characterizes full-information level of education, we have:

Proposition 6 *Let s^* be the lowest value of s such that $\lambda(s) = 1$ for all $s \geq s^*$, and let $a^* = A(s^*)$. Then for $a \geq a^*$, $S(a)$ is the same as in the case where information about productivity is perfect at all levels of education.*

3.1.3 Example: Ability as the capacity to be educated

We now analyze a special case of this model in which ability is viewed as the capacity to be educated. Let productivity p^* be given by

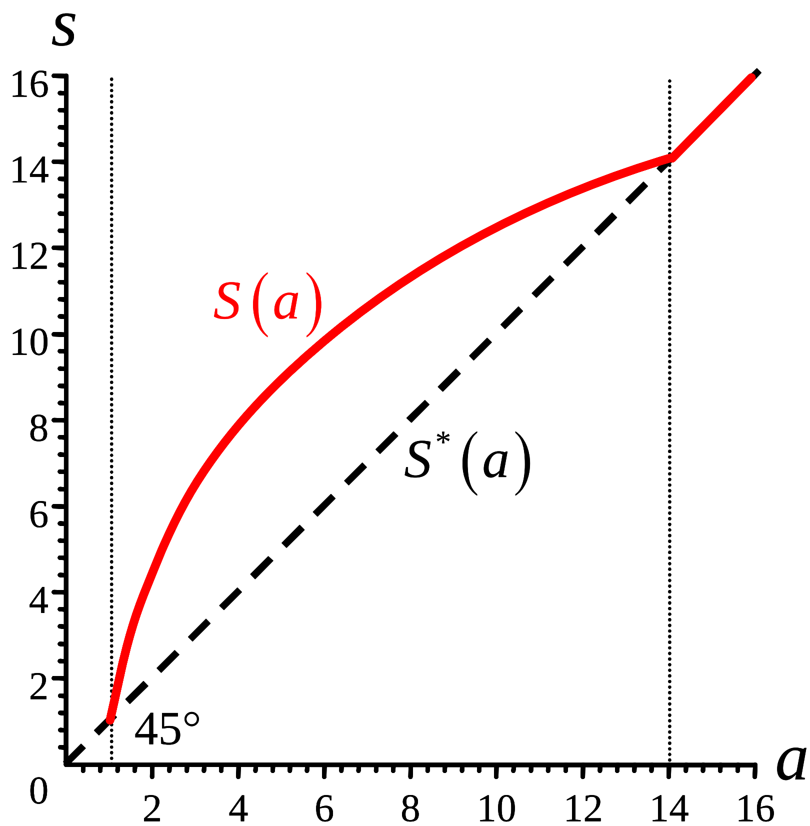
$$p^* = \min\{s,a\}\,\hat{\varepsilon},$$

where $\hat{\varepsilon} = \exp(\varepsilon)$ is a lognormal random variable. This yields a special case of (2) in which $q(s,a)$ is defined by

$$q(s,a) = \min\{\ln s, \ln a\}\,. \tag{16}$$

In this example, additional education is productive only when $s < a$. But when $s < a$, additional ability is not productive, so that the worker has no incentive to use additional education to signal ability. When $s > a$, additional ability is productive but additional education is not, so if the worker obtains additional education, signaling can be his only purpose. Therefore, in this example, we have decoupled the productivity and signaling effects of added education.

Figure 1.



We now find the efficient level of education in this framework. From (16) we have

$$q_s(s,a) = \begin{cases} 1/s & \text{for} \quad s < a \\ 0 & \text{for} \quad s > a \end{cases},$$

which defines the social rate of return to education. Additional education is efficient so long as $q_s(s,a) > r$. This means that the efficient level is given by

$$S^*(a) = \min\left\{\frac{1}{r}, a\right\}. \tag{17}$$

This is the equilibrium level of education when information is perfect ($\lambda = 1$).

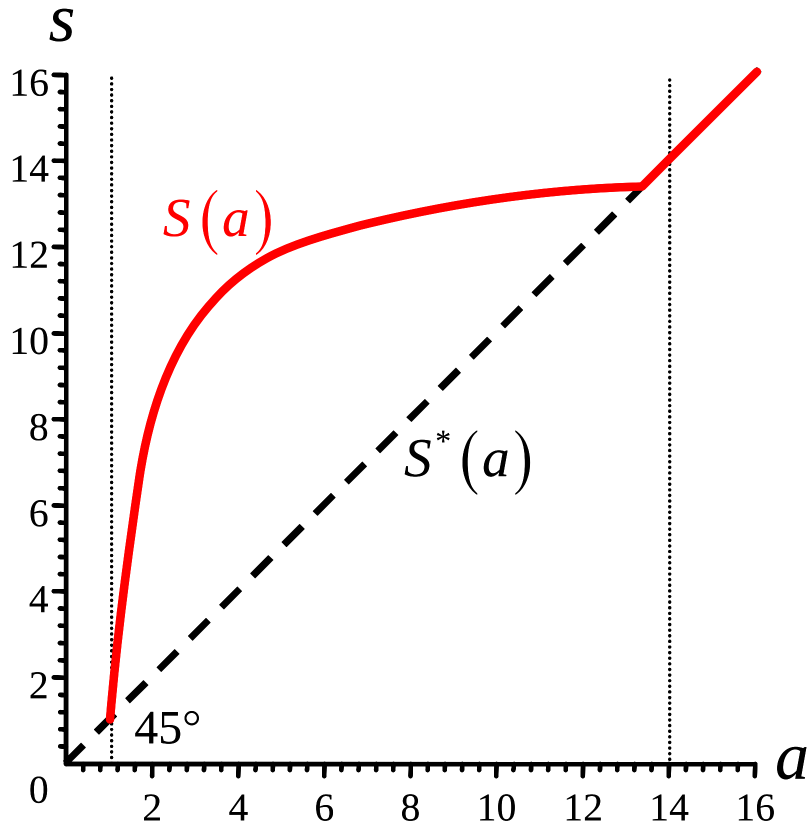
For $\lambda(s) < 1$ and $s > a$, equation (13) yields the equilibrium condition

$$S'(a) = \frac{1 - \lambda(s)}{r}\frac{1}{a}. \tag{18}$$

Let $\tilde{S}(a)$ be a solution of (18) From (17) we see that the efficient level of education $S^*(a)$ increases along the 45-degree line until $s = 16$ and is constant at 16 thereafter. From Proposition 5, it follows that for $a \leq 16$, $S(a) = \tilde{S}(a)$ whenever $\tilde{S}(a) > a$ and $S(a) = a$ otherwise.

For Figure 1 we specify $r = .0625$ ($1/r = 16$), and we normalize a so that the lowest level of ability is given by $a_0 = 1$. Proposition 4 tells us that $S(1) = S^*(1) = 1$, the efficient level of

Figure 2.



education for $a = 1$. For constant $\lambda(s) = \lambda_0$, the solution of (18)is

$$\tilde{S}(a) = \frac{1 - \lambda_0}{r} \ln a + 1, \tag{19}$$

which describes the equilibrium in the region $s > a$ (above the 45-degree line). The function $S(a)$ is graphed in Figure 1 with λ constant at $\lambda_0 = .692$, a value calibrated to cross the diagonal at $s = 14$.

In Figure 2, we illustrate the situation in which $\lambda(s) = s/b$ (λ increases linearly in s and reaches 1 at $s = b$). In that case, the differential equation for an equilibrium in the region $s > a$ becomes

$$S'(a) = \frac{b - s}{br} \frac{1}{a},$$

and if we require $S(1) = 1$, its unique solution is

$$\tilde{S}(a) = b + (1 - b)\, a^{-\frac{1}{br}}$$

Again, for $a \leq 16$, $S(a) = \tilde{S}(a)$ whenever $\tilde{S}(a) > a$ and $S(a) = a$ otherwise. This is graphed in Figure 2 for $b = 14$. Note that $S(a)$ becomes equal to $S^*(a)$ before $s = 14$ when perfect information is obtained.

3.2 Statistical Discrimination

We are now in a position to model statistical discrimination. The literature on statistical discrimination suggests that firms observe the productivity of blacks less accurately than that of whites. This is almost a convention in the literature, but it can be justified on the grounds that blacks have poorer networks than do otherwise comparable whites or on the basis of language differences. Considerable research shows that blacks and whites use different nonverbal listening and speaking cues and that this can lead to miscommunication (Lang, 1986).

Given that firms can observe the race of applicants, differences in the accuracy of productivity observations induce firms to put a relatively higher weight on education and a lower weight on observed productivity for black workers as compared with white workers. Therefore, education is a more valuable signal of ability for blacks than it is for whites, which leads us to expect blacks to obtain more education than whites of equal ability. This means that at any level of education, blacks will be of lower ability and have lower wages. However, at any level of ability, since blacks get more education, they should have higher wages if we do not hold education constant. We derive these results formally below.

Let the subscript b denote black workers and w white workers. If black productivity is observed less accurately than white productivity for $s < s^*$, then $\lambda_b(s) < \lambda_w(s)$ there. The following proposition shows that under these circumstances, blacks will get more education than whites of equal ability for all intermediate ability levels.

Proposition 7 *Given $\lambda_b(s) < \lambda_w(s)$ for all $s < s^*$, we have $S_b(a) > S_w(a)$ for all $a \in (a_0,\ a^*)$ in equilibrium.*

Proof. >From (13) we know that for $\lambda_i(s) < 1$, the equilibrium S_b and S_w are characterized by

$$S_i'(a) = \frac{(1 - \lambda_i(s))\, q_a(s, a)}{r - q_s(s, a)}, \tag{20}$$

where i is either b or w. If for $s < s^*$ blacks and whites have the same values of a and s, then from $\lambda_b(s) < \lambda_w(s)$ we know that $S_b'(a) > S_w'(a)$. By the continuity of S_b and S_w and the fact that $S_b(a_0) = S_w(a_0)$, we can infer that $S_b(a) > S_w(a)$ in a neighborhood of a_0. If $\hat{a}$ is the smallest value of a greater a_0 at which $S_b(a) = S_w(a)$, it must be true that $S_b'(\hat{a}) \leq S_w'(\hat{a})$, because $S_b(a)$ is converging to $S_w(a)$ from above. But by (20), this is possible only if $\lambda_b(s) = \lambda_w(s)$, which implies that $\hat{a} = a^*$. The proposition follows. ■

We can now show that at any education level (except the lowest) at which black productivity is observed less accurately than white productivity, the expected equilibrium earnings of blacks is less than that of whites with the same level of education.

Proposition 8 *In equilibrium, for $s \in (s_0, s^*)$, $E_{\varepsilon,u}[\hat{w}_b(p, s)] < E_{\varepsilon,u}[\hat{w}_w(p, s)]$.*

Proof. Equation (10) implies that in equilibrium we have

$$\ln E_{\varepsilon,u}[\hat{w}_i(p, s)] = \lambda_i(s)\, q(s, A_i(s)) + (1 - \lambda_i(s))\, \hat{q}_i(s) + .5\sigma_e^2, \tag{21}$$

which reduces to

$$\ln E_{\varepsilon,u}[\hat{w}_i(p,s)] = \hat{q}_i(s) + .5\sigma_e^2, \tag{22}$$

because $\hat{q}_i(s) \equiv q(s, A_i(s))$. From the previous proposition, we know that $\hat{q}_b(s) < \hat{q}_w(s)$ for $s \in (s_0, s^*)$ and the theorem follows. ■

3.3 Empirical Implications of the Model

Let us suppose that the productivity of black workers with low and intermediate levels of education and ability cannot be observed as accurately as the productivity of white workers with the same levels education and ability, whereas observations of the productivity of workers with high levels of education and ability are equally accurate for both races.

The primary implication of our model is that under these circumstances, black workers with low or intermediate levels of ability will obtain more education than their white counterparts, but black workers of high ability will obtain the same levels of educations as high-ability whites.

The model also has implications about the measured return to education. If we measure the return to education by comparing wages at an intermediate level of education with wages at the lowest level of education, our model predicts that the measured return to education should be lower for blacks than for whites. However, if we measure the return to education by comparing wages at an intermediate education level with wages at high levels of education, the measured return to education should be higher for blacks than it is for whites. This suggests that as the level of education increases, the measured return to education, not controlling for ability, should initially be lower for blacks than for whites and then become higher for blacks than for whites. Of course, this conclusion refers to the measured return. The actual private return to education is the common interest rate, r, for all workers.

Since, relative to whites with the same ability, blacks with intermediate levels of ability get more education, our model predicts that at these ability levels, blacks should earn more than whites do. At low and high ability levels, blacks and whites should have similar earnings. Put differently, the return to ability (not controlling for education) should be higher for blacks than for whites at relatively low levels of ability and lower for blacks than for whites at somewhat higher ability levels.

We note that the "*ability to learn*" example above demonstrates that our results apply more generally than simply to the case in which there is no asymmetric information beyond some level of education. In the case graphed in Figure 1, with imperfect information, the wage paid to workers with a given level of education is lower than it is with perfect information whenever the two education levels diverge. Relative to the case of perfect information, with imperfect information, the estimated return to education would be lower at low levels of education and higher at high levels of education.

4 Evidence

We begin with the prediction about the relation between educational attainment and ability. We have already seen that conditional on AFQT, blacks get more education relative to whites. Our model suggests that this should be true at intermediate levels of ability but not at very low or very high levels of ability.

Table 4 shows the relation between education and AFQT, separately for men and women. Within each sex the younger cohorts, who had not completed school at the time that they took the AFQT, are shown separately, both with and without a control for their completed education at the time they took the test. In every specification, the interaction of race and the AFQT-squared term has its predicted negative sign. This is true for Hispanics as well as for blacks.

Although the individual interaction terms are generally not statistically significant when we limit the sample to the younger cohorts, in no case are the differences between the young and older cohorts in the three black interaction terms, the three Hispanic interaction terms or the six interaction terms statistically significant.[4] Thus the results are not driven by the causal impact of education on AFQT.

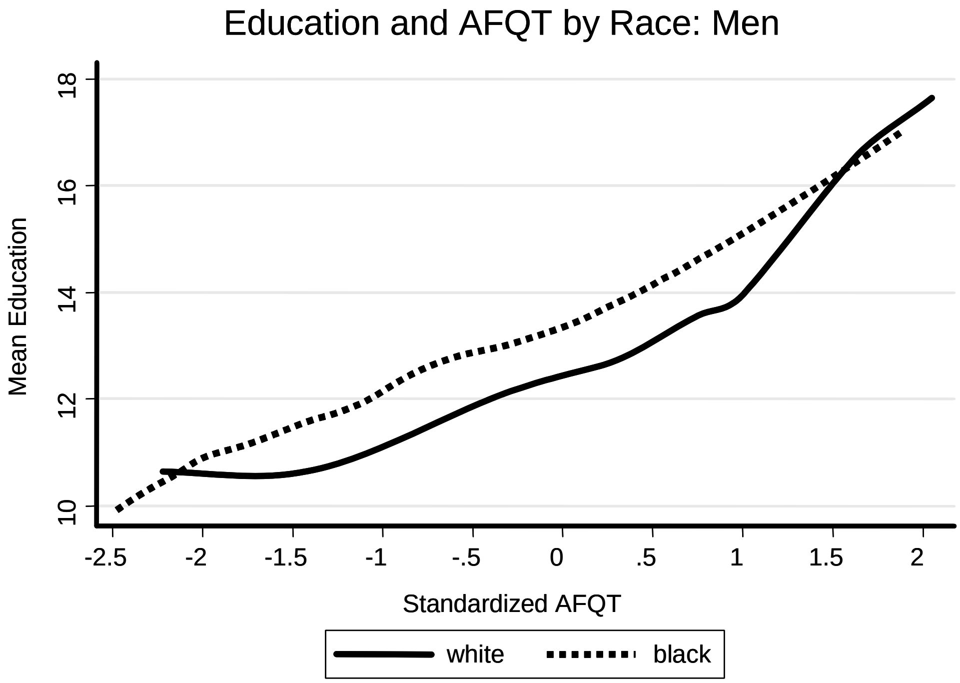
For men, the black-white education differential is maximized at an AFQT about one-sixth standard deviation below the mean where it is about 1.3 years. Educational attainment is equal for blacks and whites at almost two standard deviations below the mean and at one and two-thirds standard deviations above the mean. For women, the black-white education differential is maximized just about at the mean AFQT where it is about 1.4 years. The education levels of blacks and whites are estimated to be equalized pretty much at the extremes of the AFQT distribution.

Figure 3 shows the smoothed relation between education and AFQT for men. The nonparametric approach (which ignores the relation between age and education) confirms the parametric approach. Education levels for blacks and whites converge around a standardized AFQT of -2 and a little above 1.5. Figure 4, for women, is less consistent with the parametric estimates. It shows that education levels converge at a standardized AFQT between -2 and -2.5. However, education levels for black women remain higher than for white women even at very high AFQT levels. One potential explanation for this difference is the very high rate of labor force participation of high-skill black women relative to white women discussed in Neal (2004).

Because of the complications associated with differences in the selection of black and white women into the labor force, our discussion of the wage predictions is restricted to men. Our model implies that the wages of blacks and whites will be similar at low levels of education and at high levels but that blacks will have lower wages at intermediate levels of education. To test this prediction, we regress the log wage on education and its square and interactions with race and ethnicity as well as direct effects of age, race and ethnicity. Table 5 shows the results. As predicted,

[4] The interaction between Hispanic and $AFQT^2$ does differ at the .05 level for men. However, given that we are testing multiple equalities as well as some combinations, it is not surprising that we would find one "significant" test statistic.

Figure 3.



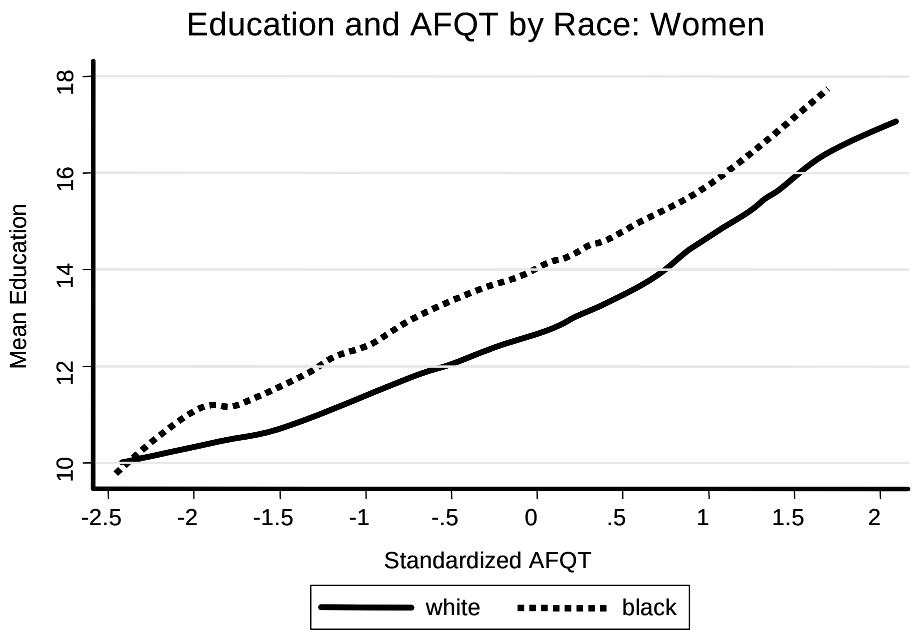
the return to education is initially lower for blacks than for whites and then turns more positive. Wages for blacks and whites are estimated to be equal for those with a fifth grade education and those with nineteen years of completed education although these points of equality are imprecisely estimated. The results of the comparison of Hispanics with white non-Hispanics are similar. If we control for school quality, the coefficients (not shown) are similar but more imprecisely estimated. With either set of school quality measures, wages for blacks and whites converge at nineteen years of education and at either six or seven years of education.

Figure 5 shows this nonparametrically. It plots average wages (on a log scale) for men by education and race. There are very few individuals without any high school education and very few blacks with more than eighteen years of education. The estimates suggest that, as predicted by the model, wages are very similar for blacks and whites at low and high levels of education

To the extent that AFQT is a good proxy for ability, the one prediction of our model that does not hold is that blacks should receive higher wages than whites with the same ability except at very low and very high levels of ability. Like NJ we find that conditional on AFQT, blacks earn less than whites although the difference is generally small and often insignificant depending on the specification.[5]

[5] The model also implies that at low levels of education, the variance of earnings will be lower for blacks than for whites but that this difference will disappear at higher levels of education. When we regress the squared residual from the regression of the lwage on education, education squared, age and race/ethnicity on race/ethnicity and interactions with education, the point estimates confirm the hypothesis but are so imprecisely estimated as to not be meaningful.

Figure 4.



5 Neal and Johnson Revisited

Table 6 replicates the results in NJ with our data. Many of the results can be anticipated on the basis of our discussion so far, but we believe it is helpful to present them in the same form as in the original NJ paper. In order to ensure that the AFQT score is not affected by labor market experience, NJ limited their sample to younger cohorts who would, for the most part, still have been in school when they took the AFQT. The first panel of table 1 limits the sample in the same way. In the absence of any controls (row 1), there are large differences in the average log wages of blacks, Hispanics and whites. In fact, the differences reported here are somewhat larger than those reported in NJ.[6]

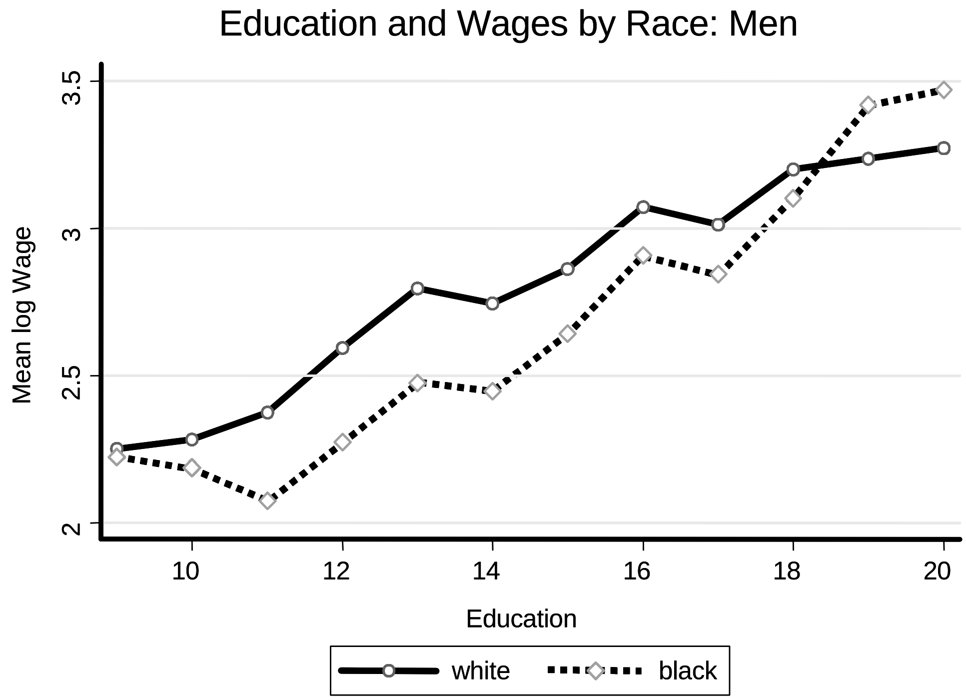
The second row shows the effect of controlling for years of education completed, this reduces both the black-white and Hispanic-white wage differentials. However, the differentials remain significant. The third row adds AFQT instead of education.[7] This produces a very substantial reduction in the estimated black-white wage differential and turns the Hispanic-white wage differential insignificant.

Row (3) is the basic result in NJ. Since all the variables in this row were determined before

[6]Derek Neal was very helpful, supplying us with the code to replicate his and William Johnson's results. The modest difference in our results derives from a number of differences including our decision to use the low-income white sample, NJ's use of the "class of worker" variable and our use of a later time period. Carneiro, Heckman and Mastrov (2004) explores the issue of time variation in the black-white wage differential using various specifications including those used by NJ. See also the discussion of this issue in Haider and Solon (2004).

[7]NJ include AFQT-squared as well as AFQT. However, since the squared term is generally not significant and the interpretation of the equation with only a linear term simpler, we drop the squared term.

Figure 5.



individuals entered the labor market, this result seems to create a strong prima facie case that the black-white wage differential is largely due to premarket factors that lower the AFQT of blacks relative to whites.

Row (4) presents the principal result of this paper. If we control for AFQT *and* education, the black-white wage differential increases again. The 15% wage differential implied by row (4) is both statistically and socially significant. The Hispanic-white differential remains small and insignificant. Put differently, after controlling for education, accounting for AFQT differences explains slightly less than half of the black-white wage differential While the premarket factors captured by AFQT are an important component of the black-white wage differential, there remains a substantial differential that could be attributable to labor market discrimination.

The difference between rows (3) and (4) is a simple application of the omitted variables bias formula since we have established that blacks get about one year more education than do whites with the same AFQT. Yet blacks earn about the same as whites with the same AFQT. Blacks do not appear to be rewarded for their additional year of education relative to whites, or, equivalently, must spend an extra year in school to attain the same level of compensation.[8]

Restricting the sample to the younger cohorts substantially reduces the number of observations. The middle panel in table 6 explores what happens when we remove this restriction. There are few substantive differences between the top and middle panel It remains true that controlling for education significantly reduces the Hispanic-white differential but leaves a substantial black-white

[8] Carneiro et al (2004) use a specification similar to that in row (4) but adjust AFQT for schooling completed at the time the respondent took the AFQT. They find much larger wage differentials.

differential. Controlling for AFQT alone, reduces or eliminates both differentials. Controlling for both variables simultaneously eliminates the Hispanic-white differential but leaves a black-white wage differential equal to roughly half that observed when we control for education and not AFQT. Because the results are unaffected by cohort restriction, for the remainder of this paper, we focus on the full sample.

The bottom panel of table 6 addresses the problem of nonparticipation. We treat nonparticipants as having a low wage and estimate the wage equation by least absolute deviations. Not surprisingly since nonparticipation is greater among blacks than among whites, this increases the estimated black-white wage differential. However, in the final specification, the effect is modest. Controlling for both educational attainment and AFQT, we find a residual black-white wage differential of about 16% or again about half of the differential that remains when we control only for education.

If, as is generally accepted among labor economists, education is rewarded in the labor market, then in the absence of labor market discrimination, blacks should earn more than whites with the same AFQT. Given the education differential, the absence of a wage differential favoring blacks when we control only for AFQT suggests that blacks are not rewarded fully for their skills.

Although NJ explore the effect of also controlling for education to some extent, they explicitly reject including education in their main estimating equation. They provide two arguments for their position. First, they maintain that we should examine black-white wage differentials without conditioning on education because education is endogenous. Their argument would be much more compelling if blacks obtained less education than equivalent whites. In that case, we might argue that blacks get less education because they expect to face discrimination in the labor market, and therefore controlling for education understates the importance of discrimination.

However, if blacks obtain *more* education because they anticipate labor market discrimination as we argue in this paper, *failing to control* for education understates the impact of discrimination. Consider the following example. Suppose that the market discriminates against blacks by paying them exactly what it would pay otherwise equivalent whites with exactly one less year of education. Then, to a first approximation,[9] all blacks will get one year more education than otherwise equivalent whites. Controlling only for ability, we find that blacks and whites will have the same earnings, but controlling for education as well as ability, we see that blacks earn less than whites by an amount equal to the return to one year of education.

Note that even if the higher educational attainment among blacks reflects premarket factors, it may still be appropriate to control for education when measuring discrimination in the labor market. After all, we would still anticipate that the labor market would compensate blacks for their additional education regardless of their reason for getting more education.

The second argument that NJ make is that education is a poor proxy for skills. In particular,

[9] This statement is precise if all workers maximize the present discounted value of lifetime earnings, lifetimes are infinite, there are no direct costs of education and the return to experience is zero.

on average, blacks attend lower quality schools than do whites. Whites will have more effective education than do blacks with the same nominal years of completed education. We have already noted that students who attend lower quality schools tend to get less education. Therefore if blacks attend lower quality schools, for any given level of education, they will have higher unmeasured ability. Differential school quality could lead to a spurious positive or negative coefficient on race.

We address this question directly in table 7 by controlling for measures of school quality in the wage equation. Most of the coefficients have the anticipated sign. Holding other resources constant, larger schools are associated with lower wages. Holding enrollment constant, having more guidance counsellors, more teachers and more library books are associated with higher wages. Having more educated teachers and higher paid teachers is associated with higher student earnings while teacher turnover has a negative effect.

Yet, controlling for inputs indicates that there is almost no effect on the measured black-white wage differential. The difference between the coefficients with and without school quality controls reflects differences in the sample rather than the effect of adding the controls. The coefficient on black using the observations for which we have school input measures is -0.14. At least as measured by inputs, differences in school quality do not account for the black-white wage differential.

The right-side of table 7 controls for measures of student composition and behavior. Perhaps surprisingly, this effort is in some ways less successful than the estimation using school inputs. While higher fractions of disadvantaged students and dropouts are associated with lower wages, average absenteeism and the fraction of students who are black are not. The results are again quite similar to those obtained without controls for school quality.

Thus we find no evidence that the wage and education differentials are driven by differences in school quality. It is important to note that the absence of evidence for the role of these premarket factors does not depend on a causal interpretation of the relation between education quality and outcomes. It is entirely possible that attending a school with a higher dropout rate does not make any individual more likely to dropout. Students who attend schools with high dropout rates may have characteristics that make them more likely to dropout. Even if the dropout rate were merely a proxy for these unmeasured characteristics, we would expect including the dropout rate to lower the black-white education differential. The fact that it does not, supports the view that such premarket differences do not explain the wage and education differentials.

We have reproduced all of the estimates in the tables adding controls for father's and mother's education and number of siblings. Although in many cases the parameter estimates are more imprecise, the principal results are unchanged. The major effect of adding these controls is that the estimated black-white wage differential typically falls by about three percentage points and falls short of significance in the specifications controlling for AFQT but not education. However, it is not obvious how to interpret specification which control for these factors, and since controlling for them does not change the substance of the results, we focus on the estimates without these additional controls.

6 Discussion and Conclusion

While some of the principal predictions of the theory we presented are consistent with the data, it is important to recognize that the combination of statistical discrimination and educational sorting that we discuss cannot fully explain the data. Our model implies that, conditional on ability, relative to whites, blacks get more education. This, in turn, implies that conditional on AFQT, blacks should earn more than whites. But neither our results nor those of Neal and Johnson support that conclusion for men.

One potential explanation is that education is a pure signal at the margin. This is the case in our "ability to learn" example. In that example, while education is productive up to some point that depends on the worker's ability, it is unproductive beyond that point. In order to signal their ability, most workers invest in education beyond the point at which it increases their productivity. However, we view this model as extreme.

Our model and the supporting empirical evidence identifies statistical discrimination as one source of differences in outcomes for blacks and whites. Altonji and Pierret (2001) also provide evidence of its importance. We have focused our attention on only one effect, increased investment in the observed signal. Blacks may also invest less in unobservable skills as in Lundberg and Startz which would lead to them have lower wages even conditional on AFQT. In addition, the work of Bertrand et al (2004) on names and job applications suggests to us that statistical discrimination is of particular importance in the presence of search frictions. They find that applicants with African American names are less likely to receive calls for interviews than are similar applicants with names common among whites. If evaluating workers is costly, statistical discrimination may prevent large numbers of African American workers from consideration for many jobs. We expect that in this setting our principal results would hold: African Americans would have greater incentives to signal their productivity and would earn less conditional on their education. However, it is also likely that they would earn less conditional on their ability.

Thus the results in this paper cast doubt on an emerging consensus that the origins of the black-white wage differential lie in premarket rather than labor market factors. Blacks earn noticeably less than whites with the same education and cognitive score. The evidence is not consistent with the view that the unexplained differential reflects differences in school quality, the principal premarket explanation. Thus, there are good grounds for believing that at least some of the black-white wage differential reflects differential treatment in the labor market.

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TABLE 1
DETERMINANTS OF EDUCATIONAL ATTAINMENT
USING CONTROLS FOR SCHOOL INPUTS
(ALL COHORTS)

	Men			Women		
Black	1.17 (0.10)	1.19 (0.14)	1.15 (0.14)	1.30 (0.09)	1.28 (0.13)	1.25 (0.14)
Hispanic	0.28 (0.13)	0.54 (0.18)	0.53 (0.18)	0.49 (0.12)	0.54 (0.19)	0.52 (0.19)
Age/10	-0.01 (0.13)	0.11 (0.17)	0.08 (0.17)	0.31 (0.13)	0.47 (0.18)	0.45 (0.18)
AFQT	1.83 (0.03)	1.85 (0.04)	1.83 (0.04)	1.81 (0.03)	1.80 (0.05)	1.78 (0.05)
Log(Enrollment)			-0.19 (0.15)			0.10 (0.17)
Log(Teachers)			0.16 (0.20)			0.05 (0.22)
Log(Guidance)			0.08 (0.16)			-0.14 (0.18)
Log (Library books)			-0.01 (0.05)			0.15 (0.07)
Proportion Teachers MA/PhD			0.76 (0.19)			0.05 (0.19)
Teacher Salary $0,000s			0.26 (0.37)			-0.34 (0.35)
Teachers who left/100			0.15 (0.53)			0.05 (0.48)
N	4060	2302	2302	4337	2326	2326

Standard errors are in parentheses. Weights for education results are described in text.

TABLE 2
DETERMINANTS OF EDUCATIONAL ATTAINMENT
USING CONTROLS FOR SCHOOL INPUTS
(YOUNG COHORTS ONLY)

	Men			**Women**		
Black	0.92 (0.14)	0.88 (0.21)	0.86 (0.21)	1.22 (0.15)	1.28 (0.23)	1.27 (0.23)
Hispanic	0.24 (0.19)	0.65 (0.28)	0.66 (0.28)	0.56 (0.20)	0.52 (0.31)	0.50 (0.31)
Age/10	-3.30 (0.72)	-1.44 (0.98)	-1.44 (0.99)	-3.24 (0.72)	-2.13 (1.12)	-1.85 (1.012)
AFQT	1.65 (0.06)	1.72 (0.07)	1.69 (0.07)	1.69 (0.06)	1.76 (0.09)	1.73 (0.09)
Grade completed 1980	0.30 (0.07)	0.15 (0.09)	0.14 (0.09)	0.43 (0.06)	0.33 (0.10)	0.29 (0.09)
Log(Enrollment)			-0.58 (0.29)			0.02 (0.30)
Log(Teachers)			0.71 (0.36)			-0.04 (0.39)
Log(Guidance)			0.02 (0.26)			-0.08 (0.33)
Log (Library books)			0.04 (0.10)			0.29 (0.11)
Proportion Teachers MA/PhD			0.11 (0.29)			0.44 (0.33)
Teacher Salary $0,000s			0.26 (0.62)			-1.15 (0.63)
Teachers who left/100			0.52 (0.83)			-0.43 (0.86)
N	1719	913	913	1665	862	862

Standard errors are in parentheses. Weights for education results are described in text.

TABLE 3 DETERMINANTS OF EDUCATIONAL ATTAINMENT USING CONTROLS FOR SCHOOL COMPOSITION/BEHAVIOR				
	Men		Women	
	All Cohorts	Young Cohorts	All Cohorts	Young Cohorts
Black	1.11 (0.16)	1.04 (0.25)	1.29 (0.16)	1.28 (0.26)
Hispanic	0.25 (0.22)	0.46 (0.34)	0.56 (0.21)	0.56 (0.35)
Age/10	0.06 (0.17)	-1.72 (0.98)	0.25 (0.18)	-2.26 (1.08)
AFQT	1.75 (0.04)	1.60 (0.07)	1.78 (0.05)	1.72 (0.09)
Grade completed 1980		0.05 (0.09)		0.31 (0.10)
Proportion Disadvantaged	-0.49 (0.22)	-0.51 (0.35)	-0.32 (0.23)	-0.18 (0.39)
Proportion Daily Attendance	0.14 (0.27)	0.31 (0.47)	-0.39 (0.27)	-0.38 (0.42)
Proportion Dropout	-0.49 (0.20)	-0.55 (0.28)	-0.20 (0.20)	0.01 (0.28)
Proportion Students Asian	4.71 (1.67)	-0.27 (2.61)	0.69 (1.44)	-0.75 (2.08)
Proportion Students Hispanic	0.52 (0.39)	0.15 (0.61)	0.18 (0.35)	-0.44 (0.57)
Proportion Students Blacks	0.10 (0.25)	-0.38 (0.40)	0.01 (0.23)	-0.23 (0.39)
N	2336	914	2385	889

Standard errors are in parentheses. Weights for education results are described in text.

TABLE 4
AFQT AND EDUCATIONAL ATTAINMENT BY RACE AND SEX

	Men			Women		
	All	Young Cohorts		All	Young Cohorts	
Constant	12.12 (0.23)	13.82 (0.78)	14.62 (0.79)	12.05 (0.23)	12.47 (0.81)	13.41 (0.81)
AFQT	1.64 (0.04)	1.61 (0.06)	1.43 (0.07)	1.67 (0.04)	1.70 (0.08)	1.43 (0.09)
$AFQT^2$	0.57 (0.04)	0.43 (0.06)	0.48 (0.06)	0.32 (0.04)	0.24 (0.07)	0.37 (0.07)
Black Interactions						
Constant	1.28 (0.13)	1.02 (0.19)	0.96 (0.19)	1.40 (0.12)	1.32 (0.20)	1.20 (0.19)
AFQT	-0.13 (0.12)	-0.18 (0.19)	-0.15 (0.19)	-0.01 (0.13)	0.03 (0.21)	0.13 (0.21)
$AFQT^2$	-0.41 (0.10)	-0.27 (0.16)	-0.29 (0.16)	-0.29 (0.11)	-0.17 (0.20)	-0.14 (0.20)
Interaction Equals 0	-1.94 1.63	-2.30 1.64	-2.09 1.57	-2.21 2.18	-2.67 2.91	-2.47 3.36
Hispanic Interactions						
Constant	0.68 (0.17)	0.29 (0.26)	0.30 (0.26)	0.99 (0.15)	0.73 (0.25)	0.78 (0.25)
AFQT	0.09 (0.13)	0.03 (0.21)	0.04 (0.21)	0.02 (0.16)	-0.07 (0.25)	-0.05 (0.25)
$AFQT^2$	-0.48 (0.12)	-0.06 (0.21)	-0.09 (0.21)	-0.66 (0.12)	-0.38 (0.22)	-0.46 (0.23)
Interaction Equals 0	-1.10 1.28	-1.97 2.40	-1.59 2.03	-1.21 1.24	-1.47 1.29	-1.35 1.24
Other controls	Age	Age	Age, Education in 1980	Age	Age	Age, Education in 1980
N	4060	1737	1719	4337	1683	1665

Standard errors are in parentheses. Weights for education results are described in text.

TABLE 5 WAGES AND EDUCATIONAL ATTAINMENT (BY RACE/ETHNICITY). N&J Wages			
	Main Effect	**Black Interaction**	**Hispanic Interaction**
OLS (N=4041)			
Constant	5.78 (0.20)	0.53 (0.49)	0.94 (0.36)
Education	0.09 (0.03)	-0.14 (0.07)	-0.16 (0.06)
Education squared/100	0.01 (0.10)	0.60 (0.26)	0.58 (0.22)
Grades at Which Total Interactions=0		5, 19	8,.19

All estimates also control for age. Standard errors are in parentheses. Weights are described in text.

TABLE 6
DETERMINANTS OF LOG HOURLY WAGES. N&J Wages

	Black	Hispanic	Age/10	Education	AFQT
OLS (Younger Cohorts)					
(1)	-0.36 (0.04)	-0.20 (0.05)	0.19 (0.14)	-	-
(2)	-0.29 (0.03)	-0.11 (0.05)	0.18 (0.13)	0.10 (0.00)	-
(3)	-0.11 (0.03)	-0.03 (0.05)	0.09 (0.13)	-	0.26 (0.01)
(4)	-0.16 (0.03)	-0.04 (0.04)	0.15 (0.12)	0.06 (0.01)	0.15 (0.02)
OLS (Full Sample)					
(5)	-0.36 (0.03)	-0.22 (0.04)	0.18 (0.04)	-	-
(6)	-0.29 (0.02)	-0.11 (0.03)	0.18 (0.03)	0.10 (0.00)	-
(7)	-0.07 (0.03)	-0.01 (0.03)	0.16 (0.03)	-	0.27 (0.01)
(8)	-0.15 (0.02)	-0.03 (0.03)	0.16 (0.03)	0.06 (0.00)	0.15 (0.01)
Quantile Regression (selection adjusted)					
(9)	-0.43 (0.03)	-0.25 (0.03)	0.12 (0.06)	-	-
(10)	-0.36 (0.02)	-0.13 (0.03)	0.17 (0.05)	0.10 (0.00)	-
(11)	-0.07 (0.03)	0.01 (0.03)	0.11 (0.06)	-	0.29 (0.01)
(12)	-0.17 (0.03)	-0.02 (0.03)	0.13 (0.05)	0.06 (0.01)	0.18 (0.02)

TABLE 7
DETERMINANTS OF LOG WAGES
USING CONTROLS FOR SCHOOL QUALITY. N&J Wages

Inputs		**Student Composition/Behavior**	
Black	-0.14 (0.04)	-0.14 (0.04)	Black
Hispanic	-0.03 (0.05)	-0.01 (0.06)	Hispanic
Age/10	0.13 (0.04)	0.14 (0.04)	Age/10
Education	0.06 (0.01)	0.06 (0.01)	Education
AFQT	0.14 (0.01)	0.15 (0.01)	AFQT
Log(Enrollment)	-0.08 (0.04)	-0.08 (0.06)	Proportion Disadvantage
Log(Teachers)	0.03 (0.05)	-0.05 (0.07)	Proportion Daily Attendance
Log(Guidance)	0.10 (0.04)	-0.10 (0.05)	Proportion Dropout
Log(Library books)	0.01 (0.01)	0.08 (0.06)	Proportion Students Black
Proportion Teachers MA/PhD	0.17 (0.05)	-0.08 (0.10)	Proportion Students Hispanic
Teacher Salary $0,000s	0.18 (0.09)	0.81 (0.43)	Proportion Students Asian
Teachers who left/100	-0.30 (0.13)		
N	2194	2223	N

Standard errors are in parenthesis. Weights were the same as the education results in Table 3 and 4