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Education and Labor-Market Discrimination

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Abstract: When we compare black and white men of similar cognitive ability, as measured by their AFQT score, there is no significant difference in their earnings. However, when we control for education as well as AFQT, a black-white wage differential reemerges. This difference reflects the fact that conditional on AFQT, blacks get substantially more education than do whites. We explore and reject the hypothesis that differences in school quality between blacks and whites can explain either the wage or the education differential. We propose a model that combines statistical discrimination and educational sorting and show that it can explain many of the empirical regularities. We argue that our finding support the view that some of the black-white wage differential is not due to premarket factors but instead 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 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 wage differentials are substantially larger when we control for education as well as AFQT than when we control for AFQT alone. The reason is that conditional on AFQT, blacks get significantly more education than do whites. 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. The first is that education is a poor proxy for skills. In particular, 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 address this issue in two ways. First, we point out that as a theoretical issue, lowering school quality may increase or decrease earnings conditional on education and AFQT. Second, we control for measures of school quality as well as quantity in the wage equation and find no evidence that measured aspects of school quality account for the differential.

NJ also 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

[1] For a discussion of the Neal/Johnson see the critique in Darity and Mason (1998) and the reply by Heckman (1998).

controlling for education understates the importance of discrimination.

However, if blacks obtain *more* education because they anticipate labor market discrimination, *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,[2] 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.

We focus on men because the issues around nonparticipation of black and white women add considerable complexity to the analysis (Neal, 2002). We begin by establishing that the black-white wage differential is substantially larger when we control for education as well as AFQT than when we control for AFQT alone. Conditional on AFQT, blacks get more education than do whites, but they are not rewarded for this additional education.

Do these wage differentials reflect premarket discrimination in the form of lower quality schools or do they reflect something happening in the labor market? Our evidence suggests that the difference is not school quality. Controlling for a variety of school quality measures has little effect on the estimated differential. Moreover, our evidence indicates that blacks would respond to lower quality education by getting less education. As in most studies, we find that school quality and educational attainment are, if anything, positively correlated. There is no evidence of a negative correlation in our data.

In this paper, we suggest that the observed differences in education between blacks and whites reflect imperfect information in the labor market about skill levels. We hypothesize that blacks, particularly those with intermediate levels of skills, make greater use of education as a signal of their skills than do whites. We develop the theoretical model and show that is consistent with some additional aspects of the data. We begin by replicating the NJ result on more recent data.

2 Data

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

[2]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.

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.

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 adjusted AFQT to have mean zero and variance one.

In order to minimize the problem of missing data, we used earnings and hours data from the 1996, 1998 and 2000 waves of the survey. If a respondent reported more than 4000 hours in a year, we coded hours as 4000. We then divided annual earnings by annual hours to get an hourly wage for each year. 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 417 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 handful of 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.

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. As noted in the introduction, we limited the sample to males.

3 The Basic Result

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 and replicates their principal finding using more recent data. 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. We have not explored whether this reflects different time periods or different sample choices since the substance of the results is unchanged. The second row shows the effect of controlling for years of education completed, this reduces the black-white wage differential and largely eliminates the Hispanic-white differential. However, there remains a significant black-white wage differential. The third row adds AFQT instead of education.[3] This produces a very substantial reduction in the estimated black-white wage differential which ceases to be significant at the .05 level and turns the Hispanic-white wage differential positive albeit insignificant.

Row (3) is the basic result in NJ. Since all the variables in this row were determined before 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 reappears. The 14% wage differential implied by row (4) is both statistically and socially significant. The Hispanic-white differential remains small and insignificantly positive. 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.

Applying the omitted variable bias formula to rows (3) and (4) establishes 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.

As discussed in the introduction, the results in row (4) do not demonstrate the existence of labor market discrimination. Blacks could, on average, be less skilled than whites with the same AFQT and education. In particular, years of schooling may be less productive for blacks than for whites because of the lower quality of the schools they attend. We will explore this possibility in

[3] NJ include AFQT-squared as well as AFQT. However, since the squared term is never significant and the interpretation of the equation with only a linear term simpler, we drop the squared term.

later sections.

Restricting the sample to the younger cohorts substantially reduces the number of observations. The middle panel in table 1 explores what happens when we remove this restriction. There are no substantive differences between the top and middle panel, and none of the differences approaches statistical significance. It remains true that controlling for education largely eliminates the Hispanic-white differential but leaves a substantial black-white differential. Controlling for AFQT alone, 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 most of the remainder of this paper, we will abandon it so that we can take advantage of the larger sample size.

The bottom panel of table 1 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 in all specifications. 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 14% or again about half of the differential that remains when we control only for education.

In sum, we find consistent evidence that blacks earn substantially less than whites with the same educational attainment and AFQT. The fact that holding only AFQT constant there is a smaller black-white wage differential combined with the positive coefficient on schooling in the wage equation tells us that blacks get more education than do whites with the same AFQT.

We are thus left with two, presumably related, mysteries: Why do blacks get more education than equivalent whites? And why are blacks paid less than whites with the same education and AFQT? In the next section, we ask whether premarket discrimination is likely to account for these facts.

4 A Premarket Explanation

It is, of course, impossible to prove that there is no set of additional controls that would explain the black-white wage differential described in the previous section. We can and will, however, focus on the most plausible of the premarket explanations and the one which NJ use to justify excluding education from their principal specification: that blacks on average attend lower quality schools. In formalizing this hypothesis, it is important to remember that we need to explain two facts: that blacks get more education given their AFQT and that blacks earn less given their AFQT and educational attainment. We begin by addressing the first.

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). Since blacks, on average, undoubtedly receive lower quality schooling than do whites, we should expect them to get less education given their AFQT, not more.

It is possible to reverse this prediction if AFQT is greatly influenced by education. In this case, if school quality did not affect educational attainment, blacks would have lower AFQT given education. The higher level of educational attainment given AFQT would simply be the result of estimating the equation in the wrong direction. Given the paucity of evidence that education can explain much of the variation in AFQT, we find this explanation unlikely. However, at this point, we wish only to point out that for lower quality education to increase education conditional on AFQT requires that the effect of quality on educational attainment be small relative to its direct effect on AFQT. We will address this issue empirically shortly.

At first blush, the school quality story appears to do a better job of explaining why blacks have lower wages conditional on AFQT and educational attainment. We would expect students who attend lower quality schools to be less productive. However, recall that we are interested in the predicted effect of school quality on wages *conditional on schooling and AFQT*. Recall that lowering school quality lowers educational attainment and hence increases (innate) ability conditional on schooling. If AFQT is an imperfect measure of ability, then the unmeasured ability of individuals with a given level of education will be higher when school quality is lower. If their school quality is lower, we would therefore expect blacks to have higher unmeasured ability. Whether this latter effect outweighs the direct effect of school quality on earnings is an empirical issue.

Thus theory does not tell us whether our inability to control fully for school quality biases the coefficient on black upwards or downwards. We therefore turn to direct evidence to address this question.

4.1 AFQT, Educational Attainment and School Quality

Table 2 examines the relation between school quality as measured by inputs, on the one hand, and AFQT and educational attainment, on the other. Table 3 repeats the exercise but measures school quality by student demographics and behaviors. The first column of each table simply repeats the standard finding for the period that the black-white test score gap was about one standard deviation. The second column adds controls for school quality.

In Table 2, we observe that some measures of school quality are associated with AFQT. Students attending larger schools, holding other resources such as number of teachers constant, have lower AFQT scores. More teachers, guidance counsellors and books as well as more educated teachers are associated with higher AFQT scores. The only surprising result is that better-paid teachers are associated with lower AFQT scores. This suggests that school quality measures may be proxying for unmeasured student characteristics if teachers receive a compensating differential for less desirable student characteristics.

At first blush the results in column 2 suggest that school quality could account for the AFQT difference. However, the black-white AFQT differential is essentially unchanged from the first to the second column This shows that race is uncorrelated with those school inputs that are associated with AFQT differences.

Moreover, the school inputs that are associated with reduced (increased) AFQT are also associated with reduced (increased) educational attainment. Thus, as discussed in the previous section, any direct effect of school quality on AFQT is offset by the fact that, for a given AFQT, students get more education when school quality is higher. While there is no precise way to find the effect of exogenous differences in AFQT on educational attainment, a reasonable estimate is that average AFQT increases by .3 standard deviations with each year of education[4] and that most of this relation runs from AFQT to education and not vice versa. Using this value, the full effect of a change in school quality on AFQT given school quality is the coefficient of school quality on AFQT minus .3 times the coefficient on education. Given a relation of this magnitude, Table 2 suggests no effect of school quality on AFQT given education.[5]

Table 3 repeats the exercise in table 2 using student composition and behavior to measure school quality. The proportion disadvantaged and the proportion dropping out as well as the proportion of students who are black are associated with lower individual AFQT scores. Of course, this may reflect the fact that students who attend schools with high proportions of disadvantaged students and dropouts are, themselves, more likely to be disadvantaged and to drop-out. In contrast with controlling for inputs, controlling for these characteristics does somewhat reduce the black-white test score differential.

However, just as in table 2, those factors that are associated with a reduction in AFQT scores are also associated with lower educational attainment. Thus these two effects offset each other. Again, it does not appear likely that school quality changes the equilibrium relation between AFQT and educational attainment.

[4] The mean AFQT of a high school dropout with 10 or 11 years of completed education is about 1.1 standard deviations below the mean while for those with 16 years of education, mean AFQT is a little over .8 standard deviations above the mean.

[5] To clarify this point, consider taking someone who would have obtained 13 years of education and getting them to take 14 years of education. The AFQT difference between individuals with those two levels of education is on average about .3 standard deviations. If there were no other effects, conditional on having 14 years of education, those affected by the intervention would have an AFQT that is .3 standard deviations below that of those not affected by the intervention. The direct effect of the intervention on AFQT (through both the quality and quantity of education) is given in the middle column of table 2. If the direct effect were to raise AFQT by .3 standard deviations, there would be no net effect of school quality on AFQT given education.

4.2 Education Quality, Wages and Years of Education: Direct Evidence

We now ask more directly whether controlling for school quality can explain the greater education of blacks conditional on AFQT. The left-side of table 4 shows the results of regressing educational attainment on AFQT and adding controls for school inputs. In the absence of controls (not shown), depending on the sample used, blacks obtain, on average, 1.1 - 1.2 more years of education than whites with the same AFQT score.

The left side of table 4 shows the effect of adding input measures to control for school quality. In this case all of the coefficients have the expected sign except for the number of library books which has a trivial and insignificant negative coefficient. However, the only statistically significant and large effects are from class size (log enrollment and log teachers) and teacher education. A higher teacher/pupil ratio is associated with students obtaining more education as is a more educated faculty.[6] However, we find no effect on the education differential. The higher level of educational attainment among blacks is not explained by differences in school inputs.

The right side of table 4 controls for student composition and behavior. As we would expect, students who attend schools where more students are disadvantaged, the average daily attendance is lower and the dropout rate is higher get less education although the coefficient on daily attendance falls short of statistical significance. The fraction of students who are black shows no relation to educational attainment. Again, although the measures of school quality have some predictive power for educational attainment, they do not affect the estimated black-white education differential. Conditional on AFQT and school quality, blacks obtain about 1.2 years more education than do whites.

Finally, we ask directly whether school quality can explain the black-white wage differential we find when we control simultaneously for educational attainment and AFQT. In table 5, we add the school quality variables to the principal equation in table 1 (row 8). Most of the coefficients have the anticipated sign. Holding other resources constant, larger schools are associated with lower wages although the coefficient falls well short of significance. Holding enrollment constant, schools with more guidance counsellors and library books are associated with higher wages although the latter is significant at only the .1 level. Having more educated teachers and higher paid teachers is associated with higher student earnings while teacher turnover has an insignificantly negative effect. The one coefficient that has the "wrong" sign is the number of teachers which is small and

[6] If ability is imperfectly observed by the econometrician and/or the market, the positive relation between the teacher/pupil ratio and educational attainment can explain the frequency of anomalous results regarding the effect of the teacher/pupil ratio on earnings. Lowering the pupil/teacher ratio will have two effects. If students do not respond by getting more education, then they should have higher wages at each level of education. However, because the level of educational attainment associated with each level of unobserved ability rises, the unobserved ability associated with each level of education falls, lowering the wage associated with each level of education. If the latter effect dominates, lowering the pupil/teacher ratio will appear to lower wages conditional on education (Lang, 1993). We will make a similar argument regarding the relation between blacks' higher educational attainment and wages conditional on that educational attainment.

insignificantly negative. The six measures of school inputs with the correct sign are jointly highly significant (F(6,2032)=5.51). Thus, the school input measures do predict wages.

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 -0.16. At least as measured by inputs, differences in school quality do not account for the black-white wage differential.

The right-side of table 5 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 a higher fraction of disadvantaged students and dropouts are associated with lower wages, average daily attendance and the fraction of students who are black are not. The results are again quite similar to those obtained without controls for school quality. There is no indication that differences in school quality can account for the black-white wage differential.

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.

5 Statistical Discrimination and Sorting

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.

For technical simplicity, 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. However, this is not what drives the results. Moreover, we recognize that even at high levels of education, there is uncertainty about how productive a worker will be. What the assumption really captures is the view that firms are as informed about a highly-educated worker's productivity as that worker is himself. Economics departments may have considerable uncertainty about the future productivity of a freshly-minted PhD, but their predictions may be as accurate as those of the job candidate. We assume that, in contrast, absent revealing information from the level of education itself, employers at lower levels of education would not know as much about potential employees' productivity as those workers do.

We find this assumption to be a natural way of generating convergence in the observability of blacks' and whites' productivities. However, the results would not change substantively if observability of productivity for whites were, say, constant with respect to education while observability increased with education for blacks until converging with that of whites.

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 wage offers to blacks than they do when making offers to whites. In response, blacks choose to get more education.

To fix ideas we begin with the case where productivity is full observable. Potential employers can observe a worker's productivity, p^*, and education, s, but not innate ability, i. We assumed that i is distributed continuously on $[i_0, i_1]$. We let $\ln p^* = q(s,i)$, with q increasing in both of its arguments but at a decreasing rate and $q_{is} > 0$. Labor and product markets are perfectly competitive, so that in equilibrium a worker's wage is given by $w = p^*$. 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 present value of the future income of a worker with characteristics s, i is given by

$$v(s,i) = \int_s^\infty e^{-rt} w dt = \frac{we^{-rs}}{r} = \frac{1}{r} e^{q(s,i)-rs}.$$

The worker chooses the level of education that maximizes $v(s,i)$, so that $s(i)$, the education choice of a worker with ability i, is the solution of $q_s(s,i) = r$. That is, the rate of return on a marginal unit of education (the derivative of log-productivity with respect to education) must equal the discount rate. If returns to education, q_s, are decreasing in the level of education ($q_{ss} < 0$) but increasing in ability ($q_{si} > 0$) then s is a sufficient statistic not only for productivity, which is observable, but also for unobservable ability. Of course in this initial expository case, the information about ability conveyed by the education level is redundant from the firm's point of view; the firm need observe productivity and nothing more. In any event, the labor market would operate efficiently: workers would be paid their marginal product, and they would obtain the level of education appropriate to their ability.

Now let us introduce two potential sources of randomness into the model. First, we will allow actual productivity p^* to depend in part on a random element uncorrelated with education and ability. We let $\ln p^* = q(s,i) + e$, where e is a normally distributed error term with mean zero and variance σ_e^2. Second, we assume that p^* cannot be observed precisely; rather, employers observe p, where $\ln p = \ln p^* + u$, and u is normally distributed with mean 0 and variance $\sigma_u^2(s)$, is common to all firms, continuous and decreasing in s and uncorrelated with e. Neither e nor u can be observed by the worker. We show below that, as does the deterministic model, an appropriately structured game-theoretic model with random elements supports separating equilibria, in which workers of differing abilities choose different levels of education. We first derive the wage/schooling relation if there is a separating equilibrium in which schooling is an increasing function of ability. To complete the proof, we then show that given this relation, schooling is an increasing function of ability provided that σ_u^2 does not decreasing too rapidly as s increases.

Lemma 1 *Suppose that $s = s(i)$ is a continuous monotonically increasing function, then firms wage offers will be*

$$\ln w(s,p) = \ln E(p^*|s,p) = \lambda \ln p + (1-\lambda)\widetilde{q}(s) + .5(1-\lambda)\sigma_e^2 \tag{1}$$

where

$$\begin{aligned} \lambda(s) &= \frac{\sigma_e^2}{\sigma_e^2 + \sigma_u^2(s)} \\ \widetilde{q}(s) &= q(s, i(s)) \end{aligned}$$

Proof. *From standard results for independent normally distributed variables*

$$E(\ln p^*|s,p) = \lambda \ln p + (1-\lambda)\widetilde{q}(s)$$

and thus

$$\ln p^* - E(\ln p^*|s,p) = -\lambda u + (1-\lambda)e$$

and

$$(\ln p^*|s,p)\,\tilde{}\,N(\lambda \ln p + (1-\lambda)\widetilde{q}(s), (1-\lambda)\sigma_e^2)$$

so that

$$E(e^{p^*}|s,p) = e^{\lambda \ln p + (1-\lambda)\widetilde{q}(s) + .5(1-\lambda)\sigma_e^2}.$$

Taking logs gives (1). ■

Lemma 2 *If the wage is given by (1) then i is a continuous increasing function of s.*

Proof. *Using standard results in the literature (e.g. Lang and Ruud, 1986), workers choose s to satisfy the first order condition*

$$\frac{d \ln E(w)}{ds} = r.$$

Using (1), we have

$$w = e^{\lambda q + (1-\lambda)\widetilde{q}(s) + .5(1-\lambda)\sigma_e^2 + \lambda(e+u)}$$

which using the properties of log-normal random variables gives

$$E(w) = e^{\lambda q + (1-\lambda)\widetilde{q}(s) + .5\sigma_e^2}$$

or

$$\ln(E(w)) = \lambda q + (1-\lambda)\widetilde{q}(s) + .5\sigma_e^2.$$

Using the first order condition, we have

$$\lambda q_s + (1-\lambda)\widetilde{q}_s + \lambda_s(q - \widetilde{q}) = \lambda q_s + (1-\lambda)\widetilde{q}_s = r. \tag{2}$$

Applying the implicit function theorem, we have

$$\frac{ds}{di} = -\frac{\lambda q_{is}}{A} > 0$$

where $A = \frac{d^2 \ln w}{ds^2} < 0$ by the second order conditions. ■

We have thus far established that if there is a separating equilibrium, firms will offer wages that are a (geometric) weighted average of the mean productivity of workers with that productivity and the worker's observed productivity and that if firms use that weighted average, workers will sort themselves into different education groups on the basis of ability. The existence of a separating equilibrium follows immediately.

Theorem 1 *There is a continuum of equilibria solving the differential equation*

$$q_s + (1-\lambda) q_i \frac{di}{ds} = r. \tag{3}$$

Proof. *Substitute*

$$\widetilde{q}_s = q_s + q_i \frac{di}{ds}$$

in (2).

Theorem 2 *Let s^* be the lowest value of s s.t $\lambda(s^*) = 1$ and let $i^* = i(s^*)$ where $i(s^*)$ is the inverse function of the equilibrium relation $s(i)$. Then for $i \geq i^*$, $s(i)$ is the same as in the case where information about productivity is perfect at all levels of education.*

Proof. *Set $\lambda = 1$, then we have the first order condition*

$$q_s = r$$

which is the first order condition when information is perfect. ■

■

This theorem is not very surprising. If in the presence of perfect information, workers choose a level of education at which information is perfect, the presence of imperfect information at lower levels of education does not change their education choice.

In problems of this type, any refinement that selects a unique equilibrium will select the equilibrium in which the lowest ability type gets the same level of education as s/he would obtain in the presence of perfect information. If no type is obtaining that level of education, provided that firms cannot believe that a worker is worse than the worst type, the lowest ability type must be better off by getting that level of education since type has been revealed and s/he cannot be construed as having a lower type than already revealed. If another type is getting that level of education, then the lowest type will do at least as well by getting that level of education.

Rather than choosing a refinement (e.g. Banks and Sobel, 1987), we assume directly that the equilibrium is the solution to (3) in which the lowest ability type chooses the level of education that solves

$$q_s(s, i_0) = r.$$

Theorem 3 *All individuals with $i_0 < i < i^*$ obtain more education when information is perfect than when it is imperfect. The difference is initially increasing in i and then decreasing.*

Proof. Education levels are equal at i_o and i^* and are continuous in i in both models. At values of i between these levels, the return to education when information is imperfect exceeds the return when it is imperfect by

$$(1-\lambda) q_i \frac{di}{ds} > 0$$

and thus such individuals choose more education. ■

We are now in a position to examine 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). In our model, we model lower accuracy in the observation of black productivity as $(1-\lambda_b) = \gamma(1-\lambda_w)$, $\gamma > 1$ which implies that $1-\lambda(s)$ is greater for blacks than it is for whites for all $s < s^*$.

Given that firms can observe the race of applicants, this implies that firms will 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.

Empirical Implications. Intuitively, since when making wage offers to blacks, firms put more weight on education and less on measured productivity, blacks will get more education. 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.

Theorem 4 $s_b(i) > s_w(i), \forall i^* > i > i_0$ *where* b *and* w *denote black and white.*

Proof. *Suppose that*

$$s_b(i) \leq s_w(i)$$

for some $\widetilde{i} \neq i_0$*. Then*

$$q_s(s_w(\widetilde{i}), \widetilde{i}) + (1-\lambda_w) q_i(s_w(\widetilde{i}), \widetilde{i}) \frac{di}{ds}_{|w} \geq q_s(s_w(\widetilde{i}), \widetilde{i}) + (1-\lambda_b) q_i(s_w(\widetilde{i}), \widetilde{i}) \frac{di}{ds}_{|b} \quad (4)$$

which implies

$$\frac{di}{ds}_{|w} > \frac{di}{ds}_{|b}$$

or

$$\frac{ds}{di}_{|w} < \frac{ds}{di}_{|b}.$$

Since $s_b(i_o) = s_w(i_0)$ *by assumption and since any time* $s_b(i) = s_w(i)$, $\frac{ds}{di}_{|w} < \frac{ds}{di}_{|b}$, $s_b(i) > s_w(i)$ *whenever* $i^* > i > i_0$. ■

Corollary 1

$$\widetilde{q}_b(s) < \widetilde{q}_w(s), \forall s(i^*) > s > s(i_0).$$

Thus, at all education levels at which information is imperfect, except the lowest, blacks earn less than do whites (not holding ability constant). It follows that the return to education measured by comparing wages at any level of education at which information is imperfect with wages at the lowest level of education should be lower for blacks than for whites. Conversely, if we measure the return to education by comparing wages in the range where information is imperfect with wages in the range where it is perfect, the measured return to education should be higher for blacks. This suggests that the measured return to education, not controlling for ability, should initially be lower for blacks than for whites and become higher than the return for whites over some range.

It is important to note that this conclusion refers to the measured return. The actual private return to education is the common interest rate, r, for all workers.

Corollary 2 *There is some* i' *such that* $i_0 < i' < i^*$ *such that for all* $i < i'$ *the return to ability for blacks is higher than the return to ability for whites and for* $i > i'$ *the return to ability for blacks is no higher than the return to for blacks and strictly lower if* $i < i^*$ *(not holding education constant).*

Example 1 *Let*

$$q = is^{.5}$$

where i *is distributed continuously on* $[.3, 0.447\,21]$. *The lower bound is chosen so that the least able individual would choose* $s = 9$ *with perfect information while at the upper bound, the most able person would choose* $s = 20$. *We consider the case of perfect information* $(\lambda = 1)$ *and two cases of imperfect information,*

$$\lambda = .5 + .025s$$

and

$$\lambda = .75 + .0125s.$$

In both cases information becomes perfect at $s = 20$.

Figure 1 shows the relation between education and ability for these cases. The highest line is the one with the most imperfect information. The lowest is the case of perfect information. In all three cases, the level of education at the lowest ability level is the same (by assumption). Education then initially increases more rapidly with ability when education is imperfect but as information becomes more perfect, the education levels converge.

Figure 2 shows the relation between ln wages and schooling for the case of perfect information and for the case of $\lambda = .5 + .025s$. *The higher (straight) line represents the case of perfect information. As expected, except at the highest and lowest levels of education, wages are lower in the case of imperfect information. The return to education appears at first to be lower when information is imperfect and then appears to be higher at higher levels of education.*

6 Evidence

We consider three predictions:

1. For very low and very high ability levels, educational attainment should be similar for blacks and whites. At intermediate levels blacks should get more education than do similar whites.

2. The measured return to education should be lower for blacks at low levels of education but should be greater for blacks than for whites at higher levels of education.

3. The measured return to ability should be higher for blacks at lower levels of ability but should be lower at higher levels of ability.

We test these in turn.

Table 6 presents the results of regressing educational attainment on a constant, AFQT and AFQT^2 as well as interactions of these terms with black and Hispanic. Only the effect of age is constrained to be the same across groups. Since the effect of age on educational attainment is essentially zero for this sample, the model is approximately fully saturated.

The results support the first prediction. The point estimates imply that blacks whose AFQT scores fall between 2.4 standard deviations below the mean and 1.4 above, get more education than whites with the same AFQT. The corresponding range for Hispanics is from -1.5 to 1 standard deviations. Although AFQT is designed to have mean zero and variance one, it is not normally distributed. Somewhat less than 1% and somewhat more than 5% of the sample fall below and above the cutoffs for blacks while for the Hispanic cutoffs the corresponding figures are somewhat more than 10% and somewhat less than 20%. The maximum education differential between blacks and whites is about 1.3 years and occurs at about one half standard deviation below mean AFQT. For Hispanics the maximum difference is about .7 years at about one-quarter standard deviation below the mean. We can easily reject the hypotheses that each of these differences as well as the hypothesis that the two maximum heights are equal.

Table 7 examines the relation between earnings and a quadratic in education for all three groups. Again, the effect of age is constrained to be the same for all three groups. Even for this age group, there is a roughly 2% increase in earnings with age or experience.

As predicted, the difference in earnings between each of the minority groups and whites is quadratic in education. For workers with no high school education, the wage is independent of race and ethnicity and for those with more than a college degree, there is also no difference. These points are estimated quite precisely although of course that precision may be driven by the fact that we have imposed a quadratic structure. The maximum wage differential occurs at roughly twelve years of education for blacks and thirteen for Hispanics. However, the confidence interval around these points is large and very asymmetric. Thus for blacks the 95% confidence interval runs from about seven to thirteen years of education. The peak wage differential is estimated to be about 23% for blacks and about 11% for Hispanics. These estimates are statistically different at conventional levels.

At low levels of education, the majority of black respondents do not report a wage. As a result, the quantile regressions which are intended to address the problem of nonparticipation are not robust to the choice of a wage for nonparticipants when we use a quadratic in education . We can get around this problem by dropping all respondents who did not complete at least some high school.[7]

The results are shown in the lower panel of table 7. The results are imprecise, but for blacks, confirm those in the upper panel. The return to education is lower for blacks at low levels of education and higher at high levels of education. The maximum wage differential comes at about

[7] In the linear specification, dropping individuals without some high school education has no effect on the results for blacks but does change the results for Hispanics. The results become more intermediate between those for whites and those for blacks.

ten years of education, and we can reject that it occurs at more than about twelve years. Blacks with more than a college degree earn as much as whites. Except at this very high level of education or at very low levels of education, blacks earn less than whites with the same education.

Finally, we attempted to test the third prediction by replacing education and its square with AFQT and its square in table 7 (not shown). While the coefficients on black times AFQT and black times AFQT squared have the predicted signs in both the OLS and quantile regression estimates, they are too imprecise to provide a useful test of the hypothesis.

7 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.[8]

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 (2002) 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 principle 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.

[8] This is true for women but for women, we must concern oursleves with the differential selection into the labor market of black and white women.

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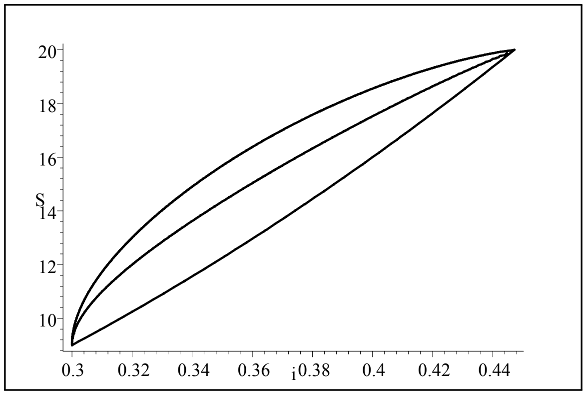
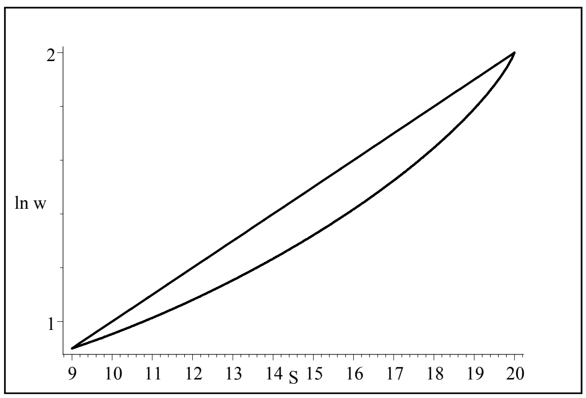


Relation Between Education and Ability



Wage as Function of Education

TABLE 1 DETERMINANTS OF LOG HOURLY WAGES					
	Black	**Hispanic**	**Age/10**	**Education**	**AFQT**
	OLS (Younger Cohorts)				
(1)	-0.35 (.04)	-0.15 (0.06)	0.29 (0.17)	-	-
(2)	-0.27 (0.04)	-0.06 (0.05)	0.30 (0.15)	0.10 (0.01)	-
(3)	-0.08 (0.04)	0.03 (0.06)	0.13 (0.15)	-	0.26 (0.01)
(4)	-0.15 (0.04)	0.01 (0.05)	0.21 (0.15)	0.07 (0.01)	0.15 (0.02)
	OLS (Full Sample)				
(5)	-0.34 (0.03)	-0.18 (0.04)	0.24 (0.04)	-	-
(6)	-0.26 (0.03)	-0.07 (0.04)	0.22 (0.04)	0.10 (0.004)	-
(7)	-0.04 (0.03)	0.03 (0.04)	0.20 (0.04)	-	0.26 (0.01)
(8)	-0.13 (0.03)	0.00 (0.04)	0.21 (0.04)	0.07 (0.00)	0.14 (0.01)
	Quantile Regression (selection adjusted)				
(9)	-0.41 (0.03)	-0.18 (0.03)	0.20 (0.06)	-	-
(10)	-0.34 (0.02)	-0.10 (0.03)	0.24 (0.05)	0.10 (0.004)	-
(11)	-0.08 (0.03)	0.04 (0.03)	0.28 (0.12)	-	0.28 (0.01)
(12)	-0.15 (0.03)	0.01 (0.03)	0.18 (0.05)	0.06 (0.01)	0.18 (0.02)

TABLE 2
DETERMINANTS OF AFQT AND EDUCATION
USING CONTROLS FOR SCHOOL QUALITY (INPUTS)

	AFQT	**AFQT**	**EDUCATION**
Black	-1.21 (0.06)	-1.18 (0.06)	-0.79 (0.16)
Hispanic	-0.591 (0.09)	-0.58 (0.09)	-0.48 (0.24)
Age/10	0.13 (0.08)	0.08 (0.08)	0.14 (0.23)
Log(Enrollment)		-0.30 (0.08)	-0.93 (0.22)
Log(Teachers)		0.15 (0.10)	0.52 (0.27)
Log(Guidance)		0.27 (0.07)	0.63 (0.20)
Log(Library Books)		0.13 (0.03)	0.26 (0.07)
Proportion Teachers MA/PhD		0.35 (0.09)	1.49 (0.25)
Teacher Salary $'0,000s		-0.44 (0.17)	-0.72 (0.49)
Teachers Who Left/100		-0.03 (0.22)	-0.19 (0.66)
N	2683	2683	2307

Standard errors are in parentheses. AFQT estimates use 1980 sampling weights. Weights for education results are described in text.

TABLE 3
DETERMINANTS OF AFQT AND EDUCATION
USING CONTROLS FOR SCHOOL QUALITY (COMPOSITION & BEHAVIOR)

	AFQT	**AFQT**	**EDUCATION**
Black	-1.16 (0.05)	-0.90 (0.07)	-0.29 (0.20)
Hispanic	-0.67 (0.08)	-0.32 (0.16)	-0.58 (0.28)
Age/10	0.19 (0.08)	0.09 (0.08)	0.07 (0.28)
Proportion Disadvantaged		-0.45 (0.10)	-1.30 (0.27)
Proportion Daily Attendance		-0.09 (0.09)	0.14 (0.26)
Proportion Dropout		-0.65 (0.09)	-1.53 (0.25)
Proportion Students Black		-0.34 (0.11)	-0.39 (0.32)
Proportion Students Hispanic		-0.05 (0.18)	0.14 (0.50)
Proportion Students Asian		1.74 (0.70)	8.00 (2.17)
N	2830	2830	2403

Standard errors are in parentheses. AFQT estimates use 1980 sampling weights. Weights for education results are described in text.

TABLE 4
DETERMINANTS OF EDUCATIONAL ATTAINMENT
USING CONTROLS FOR SCHOOL QUALITY

Inputs		**Student Composition/Behavior**	
Black	1.16 (0.14)	1.16 (0.16)	Black
Hispanic	0.51 (0.19)	0.23 (0.22)	Hispanic
Age/10	0.08 (0.18)	0.04 (0.17)	Age/10
AFQT	1.71 (0.04)	1.66 (0.04)	AFQT
Log(Enrollment)	-0.51 (0.18)	-0.42 (0.22)	Disadvantaged
Log(Teachers)	0.47 (0.21)	0.28 (0.21)	Daily Attendance
Log(Guidance)	0.14 (0.16)	-0.53 (0.20)	Dropout
Log(Library Books)	-0.01 (0.06)	-0.01 (0.24)	Students Black
Teachers MA/PhD	0.74 (0.19)	0.47 (0.39)	Students Hispanic
Teacher Salary $’0,000s	0.01 (0.38)	0.52 (0.17)	Students Asian
Teachers Who Left	0.01 (0.53)		
N	2205	2296	N

TABLE 5
DETERMINANTS OF LOG WAGES
USING CONTROLS FOR SCHOOL QUALITY

Inputs		**Student Composition/Behavior**	
Black	-0.17 (0.04)	-0.14 (0.05)	Black
Hispanic	-0.01 (0.06)	-0.03 (0.07)	Hispanic
Age/10	0.21 (0.05)	0.20 (0.05)	Age/10
Education	0.07 (0.01)	0.07 (0.01)	Education
AFQT	0.12 (0.02)	0.14 (0.02)	AFQT
Log(Enrollment)	-0.05 (0.05)	-0.14 (0.07)	Disadvantaged
Log(Teachers)	-0.02 (0.05)	-0.05 (0.06)	Daily Attendance
Log(Guidance)	0.13 (0.05)	-0.12 (0.06)	Dropout
Log(Library Books)	0.03 (0.02)	0.10 (0.08)	Students Black
Teachers MA/PhD	0.14 (0.06)	0.06 (0.12)	Students Hispanic
Teacher Salary $',000s	0.03 (0.01)	1.39 (0.53)	Students Asian
Teachers Who Left	-0.19 (0.16)		
N	2045	2114	N

TABLE 6
DETERMINANTS OF EDUCATIONAL ATTAINMENT
(BY RACE/ETHNICITY)

	Main Effect	**Black Interaction**	**Hispanic Interaction**
Constant	12.68 (0.23)	1.21 (0.13)	0.66 (0.17)
AFQT	1.87 (0.03)	-0.35 (0.15)	-0.19 (0.16)
AFQT squared/100	0.50 (0.03)	-0.36 (0.09)	-0.43 (0.11)
Total Interaction = 0		-2.38 1.41	-1.48 1.04

Standard errors are in parentheses. Estimates also control for age. N = 4060

TABLE 7 DETERMINANTS OF LOG WAGE (BY RACE/ETHNICITY)			
	Main Effect	**Black Interaction**	**Hispanic Interaction**
		OLS (N=4060)	
Constant	0.70 (0.23)	1.00 (0.72)	0.73 (0.43)
Education	0.15 (0.03)	-0.21 (0.11)	-0.13 (0.07)
Education squared/100	-0.16 (0.11)	0.87 (0.38)	0.50 (0.25)
Total Interaction = 0		7,18	8,18
		Quantile Regression (N=4143)	
Constant	0.04 (0.41)	0.44 (0.73)	-1.56 (0.70)
Education	0.24 (0.06)	-0.16 (0.11)	0.19 (0.10)
Education squared/100	-0.47 (0.19)	0.74 (0.37)	-0.61 (0.35)
Total Interaction = 0		3,18	-

Standard errors are in parentheses. Estimates also control for age.