Journal of Economic Perspectives—Volume 9, Number 4—Fall 1995—Pages 133–154

Human Capital vs. Signalling Explanations of Wages

Andrew Weiss

Workers with higher levels of education and more work experience tend to have higher wages. For some years, the most common explanation for these correlations has been that time spent in school or on the job increases wages by directly increasing the worker's productivity. This learning explanation is usually associated with human capital theory.

However, it seems unlikely that learning explains all the wage differences associated with schooling and work history. Better-educated workers are not a random sample of workers: they have lower propensities to quit or to be absent, are less likely to smoke, drink or use illicit drugs, and are generally healthier. It is unlikely that employers make full use of differences in propensities to quit or to be absent or sick when hiring workers. These characteristics are often not directly observed, and the Americans with Disabilities Act precludes firms from using either poor health or the likelihood of future sickness as a hiring criterion unless it is directly related to job performance.[1] However, if low levels of education are associated with these unfavorable employee characteristics, and employers are allowed to take education into account when hiring workers, we would expect employers to favor better-educated workers as a means of reducing their costs of sickness and job turnover. In turn, students will take these hiring criteria into account when deciding how long to stay in school. Students will choose a length of schooling to "signal" their ability to employers, and employers will demand a minimum level of schooling

[1] The American Lung Association has found that a smoker costs his employer up to $5000 more in annual health insurance costs. However, in 29 states it is illegal to refuse to hire smokers (*New York Times,* May 8, 1994, p. E5).

■ *Andrew Weiss is Professor of Economics, Boston University, Boston, Massachusetts.*

from applicants in order to "screen" their workers. Both signalling and screening serve to "sort" workers according to their unobserved abilities. This paper will use the term "sorting" to refer to both signalling and screening of workers.[2] We shall focus on the way in which individuals are sorted according to a measure of ability that improves productivity across all jobs.

"Sorting models" of education can best be viewed as extensions of human capital models. However, while human capital theory is concerned with the role of learning in determining the return to schooling, sorting models, while allowing for learning, focus on the ways in which schooling serves as either a signal or filter for productivity differences that firms cannot reward directly. Sorting models extend human capital theory models by allowing for some productivity differences that firms do not observe to be correlated with the costs or benefits of schooling.[3] (Sorting models can also include ability differences that are observed by firms but which the firms cannot use in making employment decisions. Both these extensions of human capital theory have the same qualitative implications.) In sorting models, schooling is correlated with differences among workers that were present before the schooling choices were made; firms make inferences about these productivity differences from schooling choices, and students respond to this inference process by going to school longer.

If the sorting extensions of human capital theory are important, the marginal benefits from schooling or work experience for an individual could greatly exceed the expected value of the effects of those activities on productivity, even ignoring taxes, subsidies and externalities. An accurate measure of the change in wages for a person who goes to school for 12 years instead of 11 would not measure the effect of that year of education on his productivity, but rather the combined effect of one additional year of learning and the effect of being identified as the type of person who has 12 rather than 11 years of schooling. Because individuals will react to their private wage gains, rather than to the social gains from greater productivity, schooling and employment decisions will be distorted.

The remainder of this paper discusses whether various empirical regularities are better explained by learning or sorting considerations. It first examines the positive correlation between wages and education and then turns to the relationship between wages and job tenure. The bottom line is that labor economists should take into account the distortions induced by signalling or screening when estimating social rates of return to schooling and job experience. Meanwhile, policymakers

[2] In signalling models the informed (students) move first. In screening models the uninformed (firms) move first. Signalling models often have multiple equilibria; screening models suffer from the opposite problem of nonexistence of equilibrium. Realistic dynamic models combining signalling and screening have not been well studied.

[3] The relationship between wages and education could be the outcome of either students choosing an education program to signal their ability, or students choosing education levels in response to the relative wage offers of firms, in which case wages would serve to screen workers.

should be cautious about using "consensus" estimates of rates of return to schooling in considering policies designed to reduce dropout rates or when allocating resources across primary, secondary, and postsecondary schools.

Explaining the Connection Between Education and Wages

Interpreting the Coefficient on Education in a Wage Equation

There have been literally thousands of published estimates of rates of return to education. The estimates are generally derived using least squares regression, where the dependent variable is the logarithm of wages or earnings, and the independent explanatory variables include a constant, observed demographic characteristics such as schooling, race, sex, and experience, and other observed variables that are deemed relevant by the researcher. This method of explaining wages is often known as a Mincerian earnings equation, after Jacob Mincer. Since the coefficient that appears in front of the schooling term describes the percentage change in wages associated with each additional year of schooling, it has been interpreted as the private rate of return to schooling. This interpretation is accurate as long as there are no ability differences that are not included in the wage equation, but that are observed by the firm. If such ability differences did exist, an individual who graduated from high school but who did not look like a typical high school graduate would not get the wages of a high school graduate, and so that individual's return to schooling would differ from the estimated regression coefficient.

With less justification, the coefficient on education in the log wage regression has also been interpreted as an estimate of the productivity-enhancing effects of education. The assumptions needed for that interpretation are far stronger. Not only must wages be proportionate to productivity, but also all attributes that are not observed by firms and that affect productivity must be uncorrelated with schooling, or else firms must be irrational.

One frequent test of the extent to which education is directly affecting individual productivity is to measure the effect on the education coefficient when additional right-hand variables intended to capture ability differences—such as IQ—are included in the wage equation. The usual finding is that the coefficient on education is not strongly affected by the inclusion of additional right-hand variables. These results have been (mis)interpreted as suggesting that unobserved ability differences do not have important effects on productivity.

However, in sorting models, firms do not directly observe the attributes that are omitted from a standard wage equation and that affect worker productivity. Rather, firms use education choices to draw inferences about unobserved attributes. The coefficient on education is fully capturing the effects of that inference process and would not be affected by the inclusion of additional explanatory variables that are not observed by the firm. Even if the researcher knows the results of accurate tests of attributes like intelligence, perseverance or a taste for additional learning, if the firm does not have that direct information available, then the sorting model predicts that including these variables in the wage equation will not affect the coefficient on schooling.

Because there has been some misunderstanding of the differences between human capital and sorting interpretations, it is worth reemphasizing the point that sorting models subsume all the features of human capital models. In particular, both approaches allow for learning in school (and human capital models require it). In both approaches, profit-maximizing firms compete for utility-maximizing workers, and the expected lifetime compensation of a worker with a given set of observed characteristics is equal to the expected lifetime productivity of a randomly selected worker with those characteristics. Both human capital and sorting models assume that individuals choose a length of schooling that equates their marginal return from schooling to their cost of schooling. The models differ in that sorting models allow for attributes that are not observed by the firm to be correlated with schooling.

Much policy-oriented research has been devoted to calculating returns to education, by adjusting for all traits that are observed by firms. This is often done by expanding the set of attributes that are observed by the researcher and assuming that everything the researcher observes is observed by the firm. When policy is being formulated, these estimates of private returns are frequently used as estimates of the social return. From a policy viewpoint, the key difference between human capital and sorting is that in sorting models, even after correcting for all traits that are observed by the firm, the coefficient on education may be a very biased measure of the effects of either schooling or experience on productivity. If sorting considerations matter, the coefficient on education offers a good estimate only of the private return to education, not the social return to education.

If the sorting approach is correct, the outcome of the market is inefficient, since the private and social returns differ. However, it is not clear whether there will be too much or too little education. On one side, individuals may pursue too much education as a means of signalling their love of learning, or firms may demand more education than is required for a job to deter applications from people who have difficulty succeeding in school. In these cases, the private return to education would exceed the social return. On the other side, as Stiglitz (1975) pointed out, an indirect effect of sorting may be to improve the match between workers and jobs, in which case the social return from schooling may exceed the private return. For instance, suppose people for whom schooling is unpleasant have an absolute advantage in unskilled jobs, and people for whom schooling is relatively pleasant have an absolute advantage in skilled jobs, and employers cannot directly observe the productivity of workers nor identify the different types. Then, when workers for whom education is relatively pleasant choose more education to separate themselves, average productivity and wages at the low-skill job rises. The resulting increase in wages of people with low levels of education leads to an underestimate of the social return to education. (Note that the Stiglitz argument departs from the usual assumption made in sorting and human capital models: that abilities that are correlated with schooling positively affect productivity on all jobs.)

Ability Differences and Educational Choices

People choose different levels of schooling. One reason for their different choices might be that some receive a higher benefit from a given amount of schooling, perhaps because they learn more readily than others, or because they value future earnings more highly, or because they enjoy learning.

Human capital models do not naturally generate a positive correlation between ability differences and education (Weiss, 1971). If higher-ability people are more productive at every schooling level, they will have a higher opportunity cost of schooling, which would lead them to leave school sooner. They would, however, stay in school longer if they cared more about the future, or enjoyed school more than the average student, or learned more rapidly. These preferences make workers desirable employees: they would be less likely to quit or be absent (both quits and absenteeism involve short-term benefits and long-term costs) and more likely to participate successfully in training programs. Of course, if people with desirable preferences go to school longer, firms would use education in their hiring criteria as a means of selecting workers with these desirable traits.

Leaving aside differences in preferences, more able people may go to school longer because they derive greater benefits from schooling. The positive correlation between the ability to learn and the length of schooling chosen is central to sorting models such as Weiss (1983) and Cho and Kreps (1987).

The available evidence suggests that the benefit to schooling is greater for more able individuals, so that we would expect education to sort by ability. In the Netherlands and Singapore, for example, outcomes on a certification exam have large effects on the earnings of school-leavers (Liu and Wong, 1982; Hartog, 1983). Altonji (1995) has shown that in the United States, a composite measure of aptitude—based on grades in secondary school, scores on standardized tests, and the student's own self-appraisal of ability—is correlated with returns to postsecondary education. High-ability men have more than twice the return to postsecondary education as do low-ability men.[4] The effect of this composite measure on rates of return to postsecondary education appears to be due to high-ability people being more likely to complete a course of study. The aspects of ability included by Altonji are not usually directly observed by firms (or researchers) and are likely to be correlated with other unobserved attributes such as perseverance. Altonji (1995) also finds that students who take more courses in high school have more years of postsecondary schooling. This relationship holds both within and across high schools. However, when the high school a student attended is used as an instrument to predict courses taken then this instrument is uncorrelated with postsecondary schooling. These instrumental variable results suggest that the relationship between high school courses and postsecondary schooling is not due to learning in school, but is rather a consequence of the same unobserved attributes that lead some people to take more courses, also leading them to stay in school longer.

[4] High-ability students have scores that are one standard deviation above the mean for this composite measure, while low-ability students have scores that are one standard deviation below the mean.

One indirect implication of sorting models is that the ratio of the wage paid to people who succeed in school to the wage paid to workers who failed in school will increase with schooling (Weiss, 1983). In the Netherlands this effect is quite pronounced at high education levels (Hartog, 1984) and could be causing the positive correlation between years of schooling and the variance of earnings (Mincer, 1974).

Direct Evidence of the Effects of Learning on Earnings

If the positive relationship between wages and years of secondary schooling is due to learning in secondary school, then the higher wages of better-educated people should be due to skills that were learned during those years of additional education. Altonji (1995) examines the effect of course work in school on earnings using data from the National Longitudinal Survey of the High School Class of 1972 and various follow-ups, including earnings in 1986. Everyone in the sample graduated from high school. However, not everyone took the same number of courses, making it possible to estimate the effects on future earnings of taking an additional course. Altonji estimates the increase in earnings associated with particular courses, holding years of education fixed.[5]

If the return to education is due to learning in secondary school, and learning in one course does not decrease learning in other courses, and course selection is uncorrelated with the error term of the wage equation, then the sum of the individual effects on earnings of each course in the standard curriculum should equal the usual estimates of the effect of a year of schooling on earnings—that is, 7 to 10 percent. Altonji addresses the following question: if an individual was to take seven periods of lunch and recess instead of a standard curriculum, what would be the effect on his earnings? He finds that taking the average high school course load, rather than registering and getting a "social promotion," either has no effect on wages or actually decreases wages. Course work fails to have a significantly positive effect on wages even 13 years after individuals have graduated from high school. By that time employers would have had considerable opportunity to observe the productivity of workers. On the other hand, course work (and ability) does affect returns to postsecondary education. Thus while secondary schoolwork may not directly affect productivity, it may be complementary to learning in postsecondary school.

In an earlier paper, using a different data set, different estimate techniques, and only sampling high school graduates who did not continue their education, Kang and Bishop (1986) also found that academic courses had insignificant effects on wages. Their estimates imply that a year of a full academic curriculum of mathematics, English, foreign language, social sciences and science is, holding all other courses fixed, associated with $.11 lower hourly wages. The only academic courses

[5] Altonji's (1995) results are robust to the inclusion of controls for measures of family background and scores on aptitude and achievement tests.

that had a statistically significant effect on hourly wages were social science courses, which were associated with $.12 lower hourly wages.

Altonji's (1995) results (and to a lesser extent the results in Kang and Bishop, 1986) provide a serious challenge to explanations of the relationship between secondary schooling and wages that are based on learning in secondary school. The small or negative returns to course work are especially striking, since they include both the learning and signalling effects of those courses. These results are a strong refutation of the huge literature that interprets the correlation between wages and secondary schooling as due to learning in secondary school.

Of course, there are ad hoc explanations of these results that are consistent with learning in secondary school generating the relationship between wages and schooling, although these explanations are far from compelling.

First, perhaps adding courses subtracts from the effort in other courses. If the courses from which effort is being drained are the ones with the high returns for the individual, then adding courses could decrease earnings. Under this scenario, the value of what is learned in a year of schooling could rise or fall with the number of courses. For instance, taking a foreign language could decrease the amount of time a student spent on vocational subjects and thus might decrease wages. We don't know if students who are induced to take additional courses spend significantly less time on courses in which the marginal units of effort are having large effects on personal productivity, but such behavior would surely seem irrational if productivity was observed by firms. In addition, students report spending on average less than one hour per day on homework, suggesting that for most students crowding out effects are not very important—most of their learning is taking place in school.

A second objection to the Altonji-Kang-Bishop results is that students who took different courses in school, even if they had the same number of total years of schooling, are likely to differ in other ways. Since returns to postsecondary schooling are higher for people who took more courses in high school, the cost of quitting school is higher for those students. Thus, we might expect students who took more courses in high school to have higher reservation wages and thus higher wages conditional on leaving school. This effect would cause an upward bias in the measured effect of secondary school courses on wages. On the other hand, a student who is guaranteed a highly paid job upon completion of high school (perhaps with a parent's union?) may take few courses, introducing a downward bias in estimates of returns to courses. These biases offset one another, and I would expect their net effect to be small.

A third possibility is that the curriculum results are due to omitting high school dropouts from the samples. However, this sample bias would only explain the results if people who complete high school derived less benefit from their course work than do high school dropouts. This seems unlikely.

A fourth possibility is that less able students take more courses because they must repeat those courses. However, Altonji (1995) found a positive correlation between hours of science, foreign language, English, and math and both grades and achievement test scores.

While the previous four explanations seem implausible, if one is willing to give up on the estimated coefficient on secondary schooling as a reasonable estimate of returns to that schooling, there is a reasonable way to resurrect learning as the cause of the relationship between secondary schooling and wages. It is implausible that learning in *secondary* school is generating the relationship—since courses are not affecting wages even 13 years after graduation, by which time the learned skills will presumably have been observed by employers. However, learning in *primary* school may be generating the positive correlation between secondary schooling and wages. In primary school children are taught to cooperate, to persevere, to delay gratification. Children who learn these affective skills are likely to stay in school longer. So the positive correlation between schooling and wages could be due to the correlation between schooling and the earlier acquisition of affective skills in primary school. If employers do not observe what workers have learned in primary grades, schooling decisions later on will be distorted in the ways implied by sorting models.[6]

Consider the types of jobs taken by people with no more than 12 years of schooling. Few of those jobs require a knowledge of chemistry, algebra or trigonometry, or history or geography. On the other hand, punctuality, perseverance, self-discipline, good manners, literacy, and the ability to perform simple calculations accurately are all valuable for a wide range of jobs—and all are skills that are primarily taught in the early years of school. Schooling also affects preferences, including the preference for present versus future rewards.

To sum up: the most plausible explanation for the Altonji-Kang-Bishop results is that employers do not observe transcripts and thus do not use course work as a signal. They do observe years of secondary schooling, which is an unbiased predictor of productivity. Courses taken in school do not significantly improve the predictive value of merely persevering through four years of high school.

Grades, Test Scores and Earnings

If the focus shifts from curriculum to measures of schooling like test scores, there still seems to be little connection between these measures of education and the earnings of high school graduates. There is a long history of researchers failing to find an economically significant relationship between scores on achievement tests and wages.

Altonji (1995, Table A-2) finds that while vocabulary, reading ability, and basic competence in math are positively correlated with log wages, the correlations are neither economically nor statistically significant. Kang and Bishop (1986) found

[6] If, on the other hand, the productivity differences associated with different levels of secondary schooling are due to learning in primary school that is directly observed by employers, standard estimates of rates of return to secondary education would bear little relationship to the productivity-enhancing effects of learning in secondary school.

that a one standard deviation increase in math, reading, and vocabulary test scores was associated with a $.003 fall in hourly wages, a $.001 rise in hourly wages, and a $.002 increase in hourly wages, respectively—and none of these changes was statistically significant. (A one standard deviation differences in achievement test scores is usually associated with three years of schooling, so these effects are trivial compared with the usual estimates of the effects of three years of schooling on wages.) Meyer (1982) reports that a shift of one standard deviation in a variable he labels as "test" (a composite of various test scores) increases earnings by up to 4 percent—again this finding is not statistically significant. Bishop (1990b) finds similar results. All of these studies reject the hypothesis that cognitive learning in secondary school classrooms is making a substantial contribution to the positive relationship between schooling and earnings at the individual level.

Researchers have also looked at possible effects of secondary school grades and class rank on wages (Kang and Bishop, 1986; Meyer, 1982). In some regressions, small results are found some of the time. But the main message from studies on course work, test scores, and grades is that learning in high school does not seem to be a significant factor in explaining the correlation between secondary schooling and wages.

These small or statistically insignificant results are especially striking since these estimates are almost certainly upwardly biased estimates of the effects of test scores on wages. Individuals with high test scores and good grades are likely to have some other traits that are observed by employers and are directly rewarded in the labor market.

Taken together, these estimates suggest that courses, test scores, and measurable learning in secondary school can explain at most one-quarter of the increased earning associated with completion of high school, and probably substantially less.

A Sorting Explanation

If less than one-quarter of the higher earnings of high school graduates is due to learning in secondary school, what accounts for the other three-quarters of their higher earnings?

One possible explanation is that some individuals have (unobserved) traits that make schooling less costly to them. We can call these traits various aspects of perseverance. Individuals with more perseverance are likely to have lower quit rates and rates of absenteeism after leaving high school, as well as being more likely to graduate high school. Along these lines, Klein et al. (1991) found that individuals who had more education than would be expected from their observed demographic characteristics were likely to have unexpectedly low propensities to quit a job. Along similar lines, Weiss (1988) presents evidence and a simulation study suggesting that substantially all of the relationship between high school graduation and earnings can be explained by the lower quit propensities and lower rates of absenteeism of high school graduates. If perseverance is not directly observable by firms, then high school graduation will be rewarded because of the lower rates of absenteeism and lower quit behavior of high school graduates. Students need not be consciously "signalling" these traits. The sorting explanation only requires that some students have unobserved traits that lower their cost of schooling and that these traits are valued by firms.

An important empirical study that bears on the relative usefulness of the sorting and learning approaches for understanding wage determination is Card and Krueger (1992). That study finds that individuals who were born in states with small class sizes and high relative teacher salaries had higher rates of rate of return to education as well as more schooling. They also found that increases in those school inputs were associated with lower wages for students who fail to complete high school and higher wages for students with more than 12 years of schooling. The increase in schooling associated with small class sizes and high relative teacher wages generated higher wages at every percentile of the population.

Card and Krueger (1992) present their findings as evidence that learning in school is generating the correlation between schooling and wages, but there are several problems with this interpretation. First, it is hard to see why better instruction in primary and secondary school would cause a *fall* in wages for people with no postsecondary schooling. (The schooling inputs they measure are inputs into primary and secondary education.) At the education levels chosen by most of their sample, increased school inputs either had no effect or a negative effect on wages.

Second, if increased learning is causing the wage-education locus to become steeper (pivoting roughly around its midpoint), it is surprising that length of school term has no effect on this slope when they control for other characteristics of the state-cohort.

Third, relative teacher wage is likely to be highly correlated with the ratio of college wages to the wages of high school graduates—and thus with returns to education in the state of birth. Card and Krueger (1992) attempt to control for that problem by using differences in the returns to education of a state's emigrants and the residents of the state in which they reside to estimate returns to school inputs. However, since the change of wages conditional on emigrating affects the probability of migration, we would expect that the rates of return to education for migrants to be highly correlated with the return in the state from which they migrated.[7] Thus, the Card and Krueger focus on migrants does not avoid the problem that relative teacher salaries are highly correlated with returns to education in the state of birth.

Fourth, the teacher/pupil ratio may also be correlated with the relative demand for skilled workers in the state, which may in turn be correlated with per capita income. To test this hypothesis I added the natural log of per capita income in the worker's state of birth when the average worker in a cohort was 23, as an additional explanatory variable in the Card and Krueger regressions estimating

[7] Speakman and Welsh (1994) treat this issue at some length.

effects of school inputs on rates of return. With that specification, the coefficient on the teacher/pupil ratio becomes insignificant while the coefficient on per capita income is both economically and statistically significant.[8]

A sorting explanation for the Card and Krueger (1992) results is that states with high per capita income will tend to spend more on instruction and also build more schools and provide better transportation, which would reduce differences in access to schools. Those expenditures would reduce the noise in the relationship between unobserved ability and schooling. In addition, in more prosperous states fewer students are likely to leave school because of family financial pressures—further reducing the noise in the relationship between ability and schooling. To the extent that schooling decisions are governed by random factors rather than observed ability differences, the coefficient on schooling in a wage equation will be biased toward zero—reflecting the zero correlation between those random factors and productivity. This is the usual problem of measurement error of a right-hand variable. As the noise in the relationship between unobserved ability and schooling is decreased, this bias will also decrease, and the estimated coefficient on schooling in the wage equation will rise, reflecting the true relationship between unobserved ability differences and wages. Thus the sorting model predicts that controlling for per capita income reduces the effect of school expenditures on rates of return to schooling.[9] The actual results are quite striking. The effects of every schooling input is eliminated once we control for per capita income at the time the students were in school. The *t*-statistics for pupil/teacher ratio and term length are both near zero. The *t*-statistic for relative teacher wage is 1.40, and thus the borderline significance; but, as we've argued, that variable is capturing the relative demand for educated workers. (These calculations are available from the author.)[10]

Many other studies purport to measure the relative importance of sorting and learning for explaining returns to education. Typically these studies can only do so if they make strong auxiliary assumptions. Space limitations preclude a discussion of all these studies. Instead, we shall discuss three of the most influential approaches—the Angrist and Krueger (1990) study of the effect of birthdate on returns to schooling, studies of the relationship between wages and schooling for identical twins, and studies of returns to schooling in different occupations. Angrist and Krueger find that those people who are forced to continue in school because of the interaction between their date of birth and the school attendance law in their state get the same increase in wages from that education as do people who voluntarily continue their education. It might seem that this result supports a learning

[8] The coefficient on ln (per capita income) is 1.94, with a *t*-statistic of 4.78.

[9] Prediction of novel facts is perhaps the most widely accepted criterion for evaluating competing scientific research programs. This criterion has been used, for example, to explain the success of Copernican astronomy, of the Newtonian theory of gravity and its replacement by Einstein's theory, and the supplanting of classical physics by quantum mechanics. See Lakatos (1978).

[10] The per capita income measure may, however, be measuring the effects of school inputs, rather than differences in demand conditions; that is, if the model is misspecified the income measure could be a better measure of school inputs than are the inputs themselves.

explanation for returns to schooling. However, sorting also generates that result if employers are paying workers according to their observed characteristics and level of schooling, without adjusting for the effects of school attendance laws on individual education choices.[11] The human capital model, on the other hand, can only generate that result if there are no aspects of individual productivity that are omitted from the wage equation and that are correlated with schooling. However, as we've discussed, postsecondary schooling is correlated with courses taken in high school, with grades on those courses, and with scores on both achievement and intelligence tests, thus it seems unlikely that schooling would be uncorrelated with all other unobserved variables. In addition, in the absence of unobserved ability differences, it is difficult to explain the discontinuous changes in earnings associated with completion of high school and college.[12]

Twin studies use the relationship between wages and education levels across identical twins to isolate the effect of education on earnings, holding ability differences constant. The most recent and sophisticated study of twins, by Ashenfelter and Krueger (1992), finds that returns to education across twins may be as large as that across the population as a whole. However, even leaving aside the issue of why identical twins would choose different levels of schooling, it is clear that a sorting model would generate that result, as long as employers did not observe the education choices of both twins. The reasoning is the same as for the birthdate problem. In a sorting model, if employers don't know the education level of the worker's twin, they infer a worker's unobserved ability from the education choices of the individual worker: recall that in the sorting model employers are using schooling as a proxy for unobserved characteristics, so that the twin with more schooling would receive the wage associated with his level of schooling—not with his unobserved abilities. Thus for the Ashenfelter and Krueger results to confirm sorting models, it is only necessary that employers do not know the education choices of a worker's twin. One check of whether the twin studies are confirming the sorting models is to see if wage differences of twins with different education levels decline over time. If the sorting model is correct we would expect the return to schooling across twins would decline over time compared to the return for the population as a whole. Using the Ashenfelter and Krueger data we found some evidence of this decline, but the data were not sufficient to measure it accurately.

Finally, if screening is important, then workers who look the same to the researcher should look the same to the firm, and hence get the wages predicted by a correctly specified model in which the right-hand variables only include observed

[11] This lack of adjustment is perhaps not surprising given that labor economists studied rates of return to education for almost half a century before Angrist and Krueger (1990) thought of using school attendance laws as an exogenous instrument.

[12] Hungerford and Solon (1987) found the following percentage changes in wages were associated with completion of different grades: 11th grade +0.7%, 12th grade +8.6%, 15th grade −4.9%, 16th grade +17.6%. Heckman et al. (1994) also found discontinuous changes in wages associated with completion of grades 12 and 16. Jaeger and Page (1994) find that returns to the 12th and 16th years of schooling more than double when those years are associated with graduation from high school or college.

characteristics such as education. Testing this implication, Riley (1979) finds that a standard wage equation fits much better for people who are in occupations in which screening seems to be important. Riley also finds that rates of return to education are higher in the unscreened occupations (see his Figure 3). This second result is also a consequence of the distortion of schooling decisions in sorting equilibria. Since almost every type of worker in the screened occupations is increasing schooling to separate itself from lower-ability types, ability will increase more slowly with schooling in occupations in which screening is important. Given some reasonable assumptions about the production technology and preferences, wages will also increase more slowly with schooling in those occupations.

Answering Objections to the Sorting Approach

The evidence presented thus far seems to support the idea that sorting considerations are playing an important role in school choices. However, there are several objections to this point of view.

Why Not Other Sorting Mechanisms?

The most strongly voiced objection to the sorting approach is: "There must be cheaper ways to learn about workers!" The implicit complaint is that if unobserved differences were important, firms would test for them directly, or workers would test themselves.

Such a solution poses several difficulties. For starters, it is hard to think of cost-effective tests of affective traits. For instance, a high score on a test of perseverance, given to those who have dropped out of school to take the test, might suggest a particularly low level of perseverance, since this individual performs well on tests and yet wishes to quit school. Moreover, if those tests have disparate impact by race or sex, the firms would have to prove that the tests are valid and that there is no other equally valid test which would have less of an adverse impact on minority groups or women.

It is also difficult to see how such a test would be introduced. The first firm that substituted tests for education as a hiring criterion would have monopsony power over its workers; that is, workers who quit school to take the test would be bearing the risk that their employer would fire them because of a fall in demand, and no other firm would recognize the test score. In addition, firms might well have unfavorable expectations about the first worker who appears at its door with high test scores and a low level of education and even doubt the integrity of that particular test score. In general, testing by either a worker or a firm is an out-of-equilibrium move, and assumptions of rationality are not sufficient to predict responses to such moves.

The Cross-Country Correlation Between Education and Productivity

A second general objection to the sorting explanation of the relationship between wages and education is that countries with high levels of education tend to have both high levels of per capita GDP and high growth rates. The magnitude of these cross-country relationships suggest that education is directly affecting productivity.

However, such correlations can be interpreted in many ways. For example, wealth may be affecting schooling, and the same factors that affect growth may affect schooling. Wealthier countries tend to supply better access to schooling and to enforce child labor laws more strictly. Thus, the cost of schooling would tend to be lower in those countries, leading to more schooling. In addition, if education is a normal good, richer people will consume more of it. Finally, in more highly developed societies, a greater proportion of jobs seems to be in occupations in which productivity is not directly observed. As we noted, the sorting model predicts that those occupations will be associated with higher levels of education.

Turning to the relationship between schooling and future growth in productivity, people with low rates of time preference will have more schooling. Low time discount rates will also lead to more savings and investment, and thus greater future growth. Even in agrarian societies, many components of private investment, such as whether to plant crops that often do not generate positive cash flow for many years (like citrus or olives), are strongly affected by rates of time preference. Thus, looking across countries, the choice of high-return, long-term investments may be highly correlated with schooling choices. Despite these caveats, I find the relationship between literacy and growth to be the strongest evidence of a close relationship between learning (or at least primary schooling) and productivity.

Finally, even if school learning is the cause of the wealth of nations, sorting models may still provide the best explanations of the relationship between wages and education within countries. If the ability to learn is correlated with the nonpecuniary costs of education, the length of schooling could serve as a signal of how much was learned per year of school, and schooling choices would be distorted in the ways predicted by sorting models.

Job Tenure and Wages

Labor market economists distinguish between experience, which represents overall time in the labor market, and tenure, which represents the time on a particular job. Along with the relationship between education and wages, the second major set of facts that human capital theory and sorting models have attempted to explain is why wages rise with tenure at a particular job, holding the effect of experience on wages fixed.

Many explanations of the wage-tenure relationship have been proposed, including the idea that longer tenures represent better "job matching," agency models in which rising wage-tenure profiles are intended to induce more effort or reduce the probability of an individual worker quitting, and psychological models in which people prefer steep wage-tenure profiles. All of these approaches have considerable validity. However, the discussion here will focus on human capital theory and sorting models, because the human capital model is most commonly used, and because one purpose of this paper is to show how sorting models can be extended to situations other than education choices. In the particular sorting models discussed here, firms offer wages that are conditional on observed performance or test results. These conditional wages are designed to deter applications from workers who have bad private information about their own ability.

The Human Capital Explanation for Wages and Tenure

In standard human capital models, wages rise with the length of time spent on a job because workers learn on the job. Learning occurs either through on-the-job training or learning-by-doing. These models commonly divide human capital into two categories: general and firm-specific. General human capital includes skills that are valued by many firms. In an economy with perfect information, it has the same effect on a worker's wage whether or not that worker continues to be employed at the firm where those skills were acquired. Thus, general human capital affects returns to experience, regardless of whether that experience happens at one job or many. However, human capital that is applicable only at a worker's current employer—that is, firm-specific human capital—affects the correlation between tenure and wages. The usual assumption is that the difference between a worker's productivity at the firm in which that worker acquired tenure and that worker's productivity elsewhere is shared between the worker and the firm. The worker's share generates the correlation between tenure and wages.

Human capital models are also used to explain the frequency of job turnover. In such models, turnover declines with tenure as workers acquire firm-specific human capital. Quits decline with experience (and the amount of general capital) if there are lump sum costs of changing jobs, and the expected duration of subsequent jobs is a decreasing function of experience. Layoffs also decline with firm-specific human capital. At low levels of tenure, firm-specific human capital will be positively correlated with tenure. At high tenure levels, depreciation of firm-specific human capital could reverse that relationship.

Sorting by the Private Information of Workers

Firms can use their wage contracts to discourage applications from workers with unfavorable private information about themselves, while attracting workers with favorable private information.

Firms with high costs for hiring and training new workers have an incentive to hire workers who are less likely to quit. Because workers have information about their own quit propensities that is readily available, firms for whom quits are especially costly would like to offer pay schedules that discourage applications from people who have high quit propensities.

The first rigorous asymmetric information model to explain why wages might rise with tenure in this context was Salop and Salop (1976). In their model, workers are perfectly informed about their own quit rates, and the firms are completely ignorant of the quit rates of particular workers. All firms, except those for whom quits are least costly, then offer rising wage-tenure profiles to deter workers with high quit propensities from applying to them.

In another class of sorting models, workers have private information about their own productivity, which is correlated with other direct measures of productivity—which means that both the workers' private information and the direct measures of performance contain information that is not otherwise available to the firm. However, by a judicious choice of the relationship between measured performance and wages, the firm is able to deter workers from applying who have bad private information about their own productivities.[13] Workers are paid low wages during the testing period (or are charged an application fee). Then, workers who pass the test are paid more than their best alternative wage, while workers who fail are either dismissed or paid a wage that makes them indifferent between staying with the firm and quitting. Thus, firms screen workers both directly through tests and indirectly by overpaying for success and penalizing failure.

Probably the most common form of such a "test" is a probationary period during which the worker's performance is evaluated. The interpretation of the test as a probationary period is supported by Loh (1994), which finds that workers in jobs with probationary periods had significantly higher wage growth, and holding tenure and other observable characteristics fixed, wage growth was a good predictor of whether a job had a probationary period.[14]

Using Empirical Evidence to Differentiate

These sorting models of the relationship between tenure and wages have several implications. For example, one implication is that workers with the worst private information will gravitate to those firms that don't do any testing. Since it is difficult to measure the private information of workers, this implication is difficult to test. However, other inferences have been tested.

When firms suffer financial distress, or when there is a change in control of the firm, sorting models predict that senior workers would be more likely to be fired or to be pushed into early retirement. When Lumsdaine, Stock and Wise (1990) investigated a bonus plan to induce early retirement at a Fortune 500 firm, they found that to justify the amounts paid to induce workers to retire (all of whom were over 55), it must be true that those workers were being paid more than 2.7 times the value of their output. Along similar lines, Shleifer and Summers (1988) found that senior workers suffered most from hostile takeovers. This is a direct implication of the sorting model: since new owners are not bound by the implicit contracts of previous owners, they are more likely to renege on contracts that are generating current losses—in the sorting context these are workers with more tenure. In a human capital framework, the wages of senior workers are adversely af-

[13] Examples of such sorting/testing models include Guasch and Weiss (1982), Nalebuff and Scharfstein (1987), and Wang and Weiss (1993).

[14] Over 70 percent of the jobs surveyed by the National Center for Research in Vocational Education had probationary periods. Because low-wage jobs are oversampled this ratio may be atypical.

fected by changes in control only if the relative bargaining power of the new owners is stronger than that of the previous owners, and changes in control should not be accompanied by dismissals of senior workers.

The implications of sorting and human capital models can also be tested by examining the effects of plant closings and layoffs on the wages of people with different amounts of seniority. Sorting models predict that people with long tenure who are displaced because of plant closings or other factors beyond their control are more likely to have passed the firm's appraisal and consequently to be relatively able. This favorable evaluation is likely to be valued by other firms, especially firms in the same industry, leading displaced workers with longer tenure to receive higher wages. However, some of the return to tenure is lost after plant closings because workers with long seniority will tend to be paid more than the value of their output. These predictions are confirmed by Gibbons and Katz (1991). They find that people with long tenure tend to suffer relatively large wage falls when they are laid off or when their plant closes, and the effect of plant closings is much smaller than the effect of layoffs for senior workers.[15] It is difficult to explain the differential impact of layoffs and plant closings in a human capital context.

Another class of studies seeks a link between wage increases and when training actually occurs to confirm the importance of on-the-job training for wages. In perhaps the most influential of these studies, Brown (1989) found that the rise of wages with tenure can be explained largely by the increase in wages during periods in which workers report that a typical worker would be learning his job. Brown assumes that those training periods occur when the worker is first employed on the job. However, since the initial months on a job are likely to coincide with probationary testing periods, testing/self-selection models would also predict sizable wage increases during those periods, and Brown's results would not help in distinguishing between the sorting and human capital approaches. In a recent study using the survey data of employers from the National Center for Research in Vocational Education, Loh (1994) finds that on-the-job training has no statistically significant effect on wage growth for jobs that do not have probationary periods—and thus where sorting is less likely to be occurring. Loh also finds that the length of reported on-the-job training is a good predictor of whether the job has a probationary period, and length of tenure is negatively correlated with whether the job had a probationary period. Thus it appears that the Brown results are being generated by low-wage probationary periods.

Other researchers have attempted to distinguish sorting from learning effects of on-the-job training programs by using different data sets: the National Longitudinal Survey youth cohort (Lynch, 1992); the January 1983 Current Population Survey (Lillard and Tan, 1986; Pergamit and Shack-Marquez, 1986); an EEOP survey (Baron, Black, and Loewenstein, 1989); or the Columbia Business School Human Resources Survey (Bartel, 1994). Without attempting to summarize all of these

[15] See also Podgursky and Swaim (1987), Kletzer (1989) and Ruhm (1987).

papers, and others that have attempted to measure the effects of on-the-job training on productivity, it is fair to say that the evidence is inconclusive.[16]

The effect of training in a previous job on current wages can also help distinguish between learning and sorting effects of probationary training periods. If the rise in wages in those periods is due to acquisition of human capital, it should affect subsequent wages either by directly affecting productivity or by indirectly affecting the workers reservation wage for a new job. However, Lynch (1992), Blanchflower and Lynch (1994) and Bishop (1994) all find that on-the-job training on a previous job has no effect on current wages.

Why the Resistance to Sorting Models?

The sorting approach has gained broad acceptance among microeconomic theorists, but many labor economists remain skeptical. Considering the inherent plausibility of the sorting models, and their ability to explain empirical regularities that are not explained by other models, this hesitancy is surprising. As discussed in this paper, sorting models do an especially good job of explaining why rates of return to education far exceed returns to any of the cognitive skills taught in school or even returns to courses taken in secondary school; why the variance of wages increases with education; why wage changes after involuntarily dismissals are strongly related both to previous tenure and to whether the dismissal was due to a plant closing or a layoff; why wage gains associated with reported on-the-job training are absent from jobs for which there are no probationary periods; and why training on previous jobs has no effect on current wages.

So why the resistance to sorting models? I believe there are several sources. First, sorting models are mistakenly grouped with credentialism, in which wage differences are independent of productivity differences, or with models in which education has no effect on productivity.

A second obstacle is that sorting models are Pareto inefficient. Among some researchers it is an article of faith that markets would arise to remove those inefficiencies. The main candidate for such a market is direct testing to reveal previously unobserved employee characteristics. However, such testing presents serious practical difficulties, as this paper has pointed out.

A third source of resistance comes from the desire to "know" the social rate of return to education. In a sorting context, even the use of extraordinarily clever instrumental variables does not reduce the effects of unobserved characteristics on estimates of returns to education, since those characteristics are not observed by firms.

[16] Bartel (1994) finds an increase in labor productivity associated with changes in formal training, but she also finds that firms with training programs do not have higher levels of labor productivity than do firms without those programs. Since she was not able to control for changes in labor force composition, it is not possible to know if the training programs improved productivity by improving the output of existing workers or by improving the firm's labor force.

Fourth, it often seems to be assumed that sorting models generally imply that the impact of education is overstated, and thus weaken the case for increased spending on education. However, while sorting models suggest that schooling decisions are being distorted, they are mute on whether expenditures on schooling are too high or too low.

For example, to the extent that unobserved ability differences are generated in early childhood, the importance of sorting considerations might be heavily determined by the breadth of high-quality primary schooling. Data from less-developed countries suggests that the slope of the wage-education locus is extremely steep when estimated over the primary grades. While those results could be generated by unobserved ability differences, it seems plausible that primary education affects productivity. Similarly, while many factors contribute to the correlation between education and national wealth, the productivity-enhancing effect of literacy is surely a powerful influence. Thus, even while human capital estimates of social returns to an additional year of secondary schooling may be overstated, there may still be large returns from increased expenditures on improved primary education.

In addition, education surely improves productivity at certain technical and managerial jobs. If increases in productivity at highly skilled jobs increases the demand for less-skilled labor, or if skilled and unskilled labor are complements, then the coefficient on schooling in a wage regression could leave out the effect of schooling on the less skilled and underestimate the effects of schooling on labor productivity. Another part of the productivity-enhancing effects of secondary schooling may accrue to entrepreneurs or to consumers, or simply to all other workers. If better-educated people have an absolute disadvantage on the jobs taken by the less well educated, there will be additional downward biases in estimated returns to schooling. These general equilibrium effects and technological externalities would depress the private return to education relative to the social return, and could outweigh the sorting effects that cause private returns to overestimate social returns to schooling. The positive correlation between national literacy rates or levels of education on the one hand and economic growth on the other also suggests the presence of important spillover effects from schooling.

Finally, education does not have to be justified solely on the basis of its effect on labor productivity. This was certainly not the argument given by Plato or de Tocqueville and need not be ours. Students are not taught civics, or art, or music solely in order to improve their labor productivity, but rather to enrich their lives and make them better citizens. According to those criteria, investment in secondary education may well be too low. I leave it to the reader to consider other social benefits of education.

■ *Many, if not most, of the ideas in this paper stem from conversations with Kevin Lang. I have also benefited from comments and suggestions by Joseph Altonji, Paul Beaudry, David Card, Robert Costrell, Bruce Greenwald, Alan Krueger, Jacob Mincer, Carl Shapiro, Joseph Stiglitz and Yoram Weiss. I am especially grateful to Timothy Taylor for invaluable editorial assistance. Any remaining errors are, of course, my fault.*

References

Abraham, Katharine, and Henry Farber, "Job Duration, Seniority and Earnings," *American Economic Review,* June 1987, *77,* 278–97.

Addison, John, and Pedro Portugal, "Job Displacement, Relative Wage Changes, and Duration of Unemployment," *Journal of Labor Economics,* July 1989, *7,* 281–302.

Akerlof, George, and Lawrence Katz, "Workers' Trust Funds and the Logic of Wage Profiles," *Quarterly Journal of Economics,* August 1989, *104,* 525–37.

Altonji, Joseph, "Accounting for Uncertain Educational Outcomes in Estimating the Return to Education," *Journal of Labor Economics,* January 1993, *11,* 48–83.

Altonji, Joseph, "The Effects of High School Curriculum on Education and Labor Market Outcomes," *Journal of Human Resources,* forthcoming, 1995.

Altonji, Joseph, and Robert Shakotko, "Do Wages Rise with Job Seniority?," *Review of Economic Studies,* June 1987, *54,* 437–60.

Angrist, Joshua, and Alan Krueger, "Does Compulsory School Attendance Affect Schooling and Earnings?," *Quarterly Journal of Economics,* November 1991, *106,* 979–1014.

Ashenfelter, Orley, and Alan Krueger, "Estimate of the Economic Return to Schooling from a New Sample of Twins," working paper, Princeton University, 1992.

Barron, John, Dan Black, and Mark Loewenstein, "Job Matching and On-The-Job Training," *Journal of Labor Economics,* January 1989, *7,* 1–19.

Barron, John, and Mark Loewenstein, "On Employer-Specific Information and Internal Labor Markets," *Southern Economic Journal,* October 1985, *52,* 431–44.

Bartel, Ann, "Productivity Gains from the Implementation of Employee Training Programs," *Industrial Relations,* October 1994, *33,* 411–25.

Bartel, Ann, and George Borjas, "Wage Growth and Job Turnover: An Empirical Analysis." In Rosen, S., ed., *Studies in Labor Markets.* Chicago: University of Chicago Press, 1981, pp. 65–90.

Becker, Gary, *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education.* 3rd edition. New York: Columbia University Press for the National Bureau of Economic Research, 1994.

Behrman, Jere, Zdenik Hrubec, Paul Taubman, and Terence Wales, *Socioeconomic Success: A Study of the Effects of Genetic Endowments, Family Environment, and Schooling.* Amsterdam: North-Holland Publishing Co., 1980.

Bishop, John, "Incentives for Learning: Why American High School Students Compare so Poorly to their Counterparts Overseas," *Research in Labor Economics,* 1990a, *11,* 17–53.

Bishop, John, "The Productivity Consequences of What is Learned in High School," *Journal of Curriculum Studies,* 1990b, *22:*2, 101–12.

Bishop, John, "The Impact of Previous Training on Productivity and Wages." In Lynch, Lisa, ed., *Training and the Private Sector.* Chicago: University of Chicago Press, 1994, pp. 161–200.

Bishop, John, and Shin Kang, "Why Do Employers Underinvest in On-The-Job Training?" In Bishop, J., ed., *Hiring and Training Workers.* Columbus, Ohio: National Center for Research in Vocational Education, 1984, pp. 59–106.

Blanchflower, David, and Lisa Lynch, "Training at Work: A Comparison of U.S. and British Youths." In Lynch, Lisa, ed., *Training and the Private Sector.* Chicago: University of Chicago Press, 1994, pp. 233–60.

Brown, James, "Why Do Wages Increase with Tenure? On-The-Job Training and Life-Cycle Wage Growth Observed within Firms," *American Economic Review,* December 1989, *79,* 971–91.

Card, David, and Alan Krueger, "Does School Quality Matter Returns to Education and the Characteristics of Public Schools in the United States," *Journal of Political Economy,* February 1992, *100,* 1–40.

Cho, In-Koo, and David Kreps, "Signaling Games and Stable Equilibria," *Quarterly Journal of Economics,* May 1987, *102,* 179–221.

Farber, Henry, and Robert Gibbons, "Learning and Wage Determination," working paper, MIT, 1994.

Garen, John, "The Return to Schooling: a Selectivity Bias Approach with a Continuous Choice Variable," *Econometrica,* September 1984, *52,* 1199–218.

Gibbons, Robert, and Lawrence Katz, "Layoffs and Lemons," *Journal of Political Economy,* October 1991, *9,* 351–80.

Griliches, Zvi, "Estimating the Returns to Schooling: Some Econometric Problems," *Econometrica,* January 1977, *45,* 1–22.

Griliches, Zvi, "Sibling Models and Data in Economics: Beginnings of a Survey," *Journal of Political Economy,* October 1979, *87,* S37–S64.

Guasch, Jose L., and Andrew Weiss, "An Equilibrium Analysis of Wage Productivity Gaps," *Review of Economic Studies,* October 1982, *49,* 485–97.

Hanushek, Eric, "The Economics of Schooling," *Journal of Economic Literature,* 1986, *24*:3, 1141–77.

Hartog, Joop, "To Graduate or Not," *Economic Letters,* 1983, *12*:2, 1983, 193–99.

Hartog, Joop, "Weiss' Theory of Sorting: A Simple Test," mimeo, April 1984.

Hause, John, "Ability and Schooling as Determinants of Lifetime Earnings, or If You're So Smart, Why Aren't You Rich?" In Juster, F. T., ed., *Education, Income and Human Behavior.* New York: Columbia University Press for the National Bureau of Economic Research, 1975, pp. 123–49.

Hause, John, "The Fine Structure of Earnings and On-The-Job Training Hypothesis," *Econometrica,* May 1980, *48,* 1013–30.

Hausman, Jerry, and William Taylor, "Panel Data and Unobservable Individual Effects," *Econometrica,* November 1981, *49,* 1377–98.

Heckman, James, Anne Layne-Farrar, and Petra Todd, "Does Measured School Quality Matter," working paper, May 1994.

Hungerford, Thomas, and Gary Solon, "Sheepskin Effects in the Returns to Education," *Review of Economic Studies,* February 1987, *69,* 176–8.

Jaeger, David L., and Marianne Page, "Degrees Matter: New Evidence on Sheepskin Effects in the Returns to Education." University of Michigan Population Studies Center Research Report No. 94-307, 1994.

Kang, Shin, and John Bishop, "Effects of Curriculum on Labor Market Success Immediately After High School," *Journal of Industrial Teacher Education,* 1986, *23,* 14–29.

Klein, Roger, Richard Spady, and Andrew Weiss, "Factors Affecting the Productivity and Quit Propensities of Productions Workers," *Review of Economic Studies,* October 1991, *58,* 929–54.

Kletzer, Lori, "Returns to Seniority after Permanent Job Loss," *American Economic Review,* June 1989, *79,* 536–43.

Kotlikoff, Laurence, and David Wise, *The Wage Carrot and the Pension Stick.* Kalamazoo, Mich.: W. E. Upjohn Institute for Employment Research, 1989.

Lakatos, Imre, "The Methodology of Scientific Research Programmes." In Worrall, J., and G. Currie, eds., *Philosophical Papers.* Vol. 1. Cambridge: Cambridge University Press, 1978.

Lang, Kevin, "Does the Human Capital/Educational Sorting Debate Matter for Development Policy?" NBER Working Paper No. 4052, April 1992.

Lang, Kevin, "Estimation Bias, School Quality and the Return to Education," mimeo, July 1992.

Lang, Kevin, "Explaining Variation in Estimated Returns to Education Across Time and Place," working paper, Boston University, 1993.

Lang, Kevin, and David Kroop, "Human Capital vs. Sorting: The Effect of Compulsory Attendance Laws," *Quarterly Journal of Economics,* August 1986, *101,* 609–24.

Lazear, Edward, "Why is There Mandatory Retirement?," *Journal of Political Economy,* December 1979, *87,* 1261–84.

Lazear, Edward, "Agency, Earnings Profiles, Productivity and Hours Restrictions," *American Economic Review,* September 1981, *71,* 606–20.

Lilliard, L., and Hwa Tan, "Private Sector Training: Who Gets It and What are Its Effects?" Rand Monograph R-3331-DOL/RC, 1986.

Liu, Pak-Wai, and Yue-Chim Wong, "Educational Screening by Certificates: An Empirical Test," *Economic Inquiry,* January 1982, *20,* 72–83.

Loh, Eng Seng, "Employment Probation as a Sorting Mechanism," *Industrial and Labor Relations Review,* April 1994, *47,* 471–86.

Lumsdaine, Robin, James Stock, and David Wise, "Efficient Windows and Labor Market Reduction." NBER Working paper No. 3369, 1990.

Lynch, Lisa, "Private Sector Training and its Impact on the Earnings of Young Workers," *American Economic Review,* March 1992, *82,* 299–312.

Lynch, Lisa, "Introduction." In Lynch, Lisa, ed., *Training and the Private Sector.* Chicago: University of Chicago Press, 1994, pp. 1–24.

Marshall, Robert, and Gary Zarkin, "The Effect of Job Tenure on Wage Offers," *Journal of Labor Economics,* July 1987, *5,* 301–24.

Meyer, Robert, "Job Training in the Schools." In Taylor, R., H. Rosen, and F. Pratzner, eds., *Job Training for Youth, the Contribution of the United States Employment Development System.* Columbus, Ohio: The National Center for Research in Vocational Education, Ohio State University, 1982, pp. 307–44.

Mincer, Jacob, *Schooling, Experience and Earnings.* New York: Columbia University Press, 1974.

Mincer, Jacob, and Boyan Jovanovic, "Labor Mobility and Wages." In Rosen, S., ed., *Studies in Labor Markets.* Chicago: University of Chicago Press, 1981, pp. 21–64.

Nalebuff, Barry, and David Scharfstein, "Testing in Models of Asymmetric Information," *Review of Economic Studies,* April 1987, *54,* 265–77.

O'Neill, June, "The Role of Human Capital in Earnings Differences Between Black and White Men," *Journal of Economic Perspectives,* Fall 1990, *4,* 25–46.

Pergamit, Michael, and Janice Shack-Marquez, "Earnings and Different Types of Training," mimeo, BLS and Board of Governors of the Federal Reserve, 1986.

Podgursky, Michael, and Paul Swaim, "Job Displacement and Earnings Loss: Evidence from the Displaced Worker Survey," *Industrial and Labor Relations Review,* October 1987, *41,* 17–29.

Psacharopoulus, George, "Returns to Education: an Updated International Comparison," *Comparative Education,* 1981, *17*:3, 321–41.

Riley, John, "Testing the Educational Screening Hypothesis," *Journal of Political Economy,* October 1979, *87,* S227–52.

Rosen, Sherwin, "Human Capital: Relations Between Education and Earnings." In Intriligator, M., ed., *Frontiers of Quantitative Economics,* Volume 111B. Amsterdam: North-Holland Publishing Co., 1977, pp. 731–54.

Ruhm, Christopher, "The Economic Consequences of Labor Mobility," *Industrial and Labor Relations Review,* October 1987, *41,* 30–42.

Rumberger, Russell, and Thomas Daymont, "The Economic Value of Academic and Vocational Training Acquired in High School." In Borus, Michael E., ed., *Youth and the Labor Market.* Kalamazoo, Mich.: W. E. Upjohn Institute for Employment Research, 1984, pp. 157–92.

Salop, Joanne, and Steven Salop, "Self-Selection and Turnover in the Labor Market," *Quarterly Journal of Economics,* November 1976, *90,* 619–27.

Salop, Steven, "A Model of the Natural Rate of Unemployment," *American Economic Review,* March 1979, *69,* 117–25.

Shleifer, Andrei, and Lawrence Summers, "Breach of Trust in Hostile Takeovers." In Auerbach, A., ed., *Corporate Takeovers: Causes and Consequences.* Chicago: University of Chicago Press, 1988, pp. 33–56.

Speakman, Robert, and Finis Welch, "Micro and Macro Estimates of the Value of School Resources," working paper, 1994.

Spence, A. Michael, "Job Market Signaling," *Quarterly Journal of Economics,* August 1973, *87,* 355–74.

Spence, A. Michael, *Market Signalling: Informational Transfer in Hiring and Related Processes.* Cambridge: Harvard University Press, 1974.

Stiglitz, Joseph, "The Theory of Screening Education and the Distribution of Income," *American Economic Review,* June 1975, *65,* 283–300.

Stiglitz, Joseph, and Andrew Weiss, "Sorting Out the Differences between Signaling and Screening Theories." In Dempster, Michael, et al., eds., *Papers in Commemoration of the Mathematical Economics Seminar at Oxford University.* Oxford: Oxford University Press, forthcoming 1995.

Topel, Robert, "Specific Capital, Mobility and Wages: Wage Rise with Job Seniority." NBER Working Paper No. 3294, March 1990.

Wang, Ruqu, and Andrew Weiss, "Adverse Selection, Testing and Firing," working paper, Boston University, 1993.

Weiss, Andrew, "A Sorting-Cum-Learning Model of Education," *Journal of Political Economy,* June 1983, *91,* 420–42.

Weiss, Andrew, "Determinants of Quit Behavior," *Journal of Labor Economics,* July 1984a, *2,* 371–87.

Weiss, Andrew, "Testing the Sorting Model." NBER Working Paper No. 1420, August 1984b.

Weiss, Andrew, "High School Graduation, Wage and Performance," *Journal of Political Economy,* August 1988, *96*:4, 785–820.

Weiss, Yoram, "Ability and the Investment in Schooling," *Journal of Economic Literature,* June 1971, *9,* 459–61.

Willis, Robert, "Wage Determinants: A Survey and Reinterpretation of Human Capital Earning Functions." In Ashenfelter, O., and R. Layard, eds., *Handbook of Labor Economics.* Amsterdam: North-Holland Publishing Co., 1986, pp. 525–602.

Wolpin, Kenneth, "Education and Screening," *American Economic Review,* December 1977, *67,* 949–58.

Wood, Robert, Mary Corcoran, and Paul Courant, "Pay Differences among the Highly Paid: The Male-Female Earnings Gap in Lawyers' Salaries," *Journal of Labor Economics,* July 1993, *11,* 417–41.