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Economic Success and the Evolution of Schooling and Mental Ability

ONE OF THE MORE ENDURING controversies of social policy has been whether education can reduce inequality and improve the lot of the poor in America. In his 1972 book, *Inequality*, Christopher Jencks argued that since the effects of education on economic success are modest relative to overall inequality, equalizing educational attainment in the United States would only modestly reduce differences in economic success.[1] As a result, although education has important effects on success, it is not, as some on the political left had argued, a panacea for reducing social inequality.

More recently, Charles Murray and the late Richard Herrnstein have taken an even more pessimistic position. In their controversial book *The Bell Curve*, they claim that education has few, if any, direct effects on social and economic success, and that the apparent effects of education mainly represent the indirect effects of "intelligence." They further argue that formal education and other types of educational interventions do little to increase intelligence: "Taken together, the story of attempts to raise intelligence is one of high hopes, flamboyant claims, and disappointing results. For the foreseeable future, the problems of low cognitive ability are not going to be solved by outside interventions to make children smarter."[2]

1. Jencks and others (1972).
2. Herrnstein and Murray (1994, p. 389).

Others, however, take an opposing view. In *Inequality by Design*, a book-length response to *The Bell Curve* based on analysis of the same data, Claude Fischer and coauthors contend that the Armed Forces Qualifications Test (AFQT), which Herrnstein and Murray use to measure intelligence, is predominantly determined by educational attainment: "In some ways, the AFQT might be a good measure of instruction, but not one of native intelligence. What it captures best is how much instruction people encountered and absorbed."[3] They go on to argue that education has both direct effects on success and indirect effects through its effect on cognitive skills. In another critique William Dickens, Thomas Kane, and Charles Schultze point out that if cognitive skills are as important in determining success as Herrnstein and Murray claim, then even if education's effect on cognitive skills is modest, its indirect effects on social and economic success through such skills may be substantial.[4]

Certainly the controversy over the importance of education as a means of reducing inequality and poverty is enduring. Within the current debate, the nature of the interrelationship between education and cognitive skills and their effects on economic success are contested. The present paper seeks to shed light on these controversies. Our purpose is to present and estimate a model for the interrelationships among schooling, cognitive skills, and economic success. Our model is simple and should be regarded as a starting point for exploring these issues. With this model, we investigate a number of hypotheses.

We examine whether there is a reciprocal relationship between schooling and cognitive skills. We then focus on the implications of this relationship for understanding the mutual effects of schooling and cognitive skills on economic success, in particular, family income and earnings. We present evidence that schooling and cognitive skills affect each other; that they both have important effects on social and economic success; and that these effects are in part direct and in part indirect, working through one another. Greater recognition of the possibility that schooling and cognitive skills reinforce each other may further progress toward consensus in the literature.

We begin by presenting our basic model. Following a brief discussion of previous research, we describe our data, the National Longitudinal Survey of Youth (NLSY)—used also by Herrnstein and Murray, Fischer and coauthors, and Dickens, Kane, and Schultze. Our subsequent analysis falls

3. Fischer and others (1996, p. 62).

4. Dickens, Kane, and Schultze (forthcoming).

into three subsections. First, we examine the mutual effects of schooling and cognitive skills. We show that individuals with greater early cognitive skills are likely to get more schooling, and that schooling increases an individual's later cognitive skills. We find reciprocal effects of schooling and cognitive skills that are comparable in size. Second, we estimate the direct effects of cognitive skills and schooling on economic success. Third, we combine results from the two previous subsections and describe the different components of the effects of schooling and cognitive skills on economic success. We find that about half of each variable's effects on economic success are direct and independent of the other variable, but half are indirect and related to their mutually reinforcing relationship.[5] Finally, we review our findings and discuss their implications.

The Basic Model

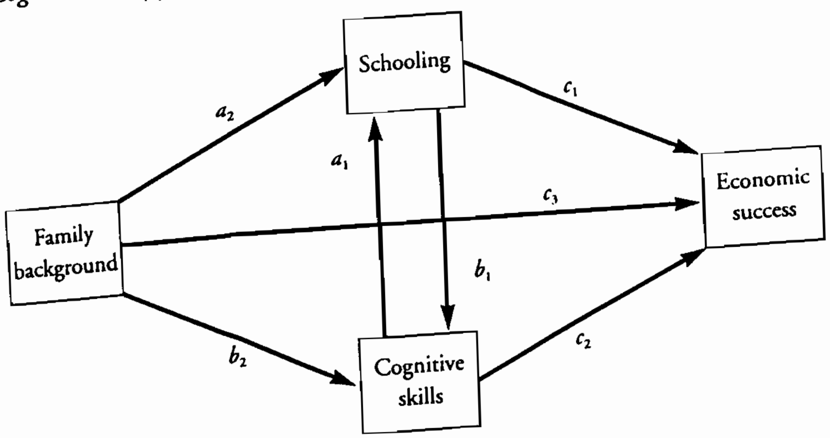
Figure 3-1 presents the path model for interrelationships among schooling, cognitive skills, and family income that are the main interest of this paper. It has several components. First are the possible effects of family background on schooling, cognitive skills, and economic success (a_2, b_2, c_3). Our previous paper, as well as a host of studies in sociology and economics, have estimated these effects.[6] The effects of family background, however, are not at issue in the present paper: it is only important that we control for family background in estimating the effects of schooling and cognitive skills on each other and on economic success. In the analyses presented below, we also control for demographic characteristics, including age, race and ethnicity, and gender.

Second, the path diagram in figure 3-1 indicates that there is a possible reciprocal relationship between schooling and cognitive skills—that is, greater cognitive skills should lead to higher schooling attainment (a_1), and schooling should increase cognitive skills (b_1). The question of whether a_1 or b_1 is zero or nearly so, or schooling and cognitive skills instead have substantial mutual effects, is critical to understanding how these variables

5. Throughout the paper we measure economic success around 1990, when individuals in the sample are in their late twenties and early thirties. Cawley and others (1997) argue that the effect of education on wages measured at relatively young ages may dramatically overstate lifetime effects, and partly reflects the greater tendency of young high-ability individuals to invest in education when the economic return to "skill" rises, as it did in the 1980s.

6. Korenman and Winship (forthcoming).

Figure 3-1. *Path Model for Interrelationships among Schooling, Cognitive Skills, and Family Income*



Source: Authors' model as described in text.

affect economic success. Finally, the path diagram indicates possible direct and independent effects of schooling and cognitive skills on economic success. The independent effect of schooling on success is denoted by c_1, which indicates the amount by which a one-unit increase in schooling increases success, holding constant cognitive skills and family background. The independent effect of cognitive skills on success is denoted by c_2, which indicates the amount by which a one-unit increase in cognitive skill increases success, holding constant schooling and family background. The equations corresponding to figure 3-1 are given in appendix 3A.

Our model can be used to describe a variety of hypotheses that appear in the literature. Jencks's argument about the inability of schooling to reduce inequality essentially concerns the magnitude of the direct and indirect effects, or total effect, of schooling.[7] Formulas for these effects are given in appendix 3A. The square of the effect of a one standard deviation change in schooling is equal to the proportion of the variance in success that is due independently to schooling. It thus tells one by how much equalizing schooling across individuals might reduce inequality, as measured by the variance of success.

7. Jencks and others (1972).

Herrnstein and Murray's argument that schooling does not affect cognitive skills is equivalent to b_1 being essentially zero and a_1 being relatively large, large enough to explain most of the variance in schooling.[8] Fischer and coauthors argue the reverse, that is, that the AFQT measures educational attainment and what an individual has learned in school.[9] This implies that a_1 should be relatively small and b_1 should be large, sufficiently so to explain most of the variance in cognitive skills. Herrnstein and Murray's claim that education should not be included in models predicting economic success can be seen either as an argument that schooling has no direct effect on economic success—that is, c_1 is zero or nearly so—or that the effect of cognitive skills on schooling (a_1) is so substantial that there is little variation in schooling independent of cognitive skills. Finally, Dickens, Kane, and Schultze's observation is that even if the effect of schooling on cognitive skills is small, because the effect of cognitive skills on economic success is large schooling's effect on economic success may nonetheless be large, due to its indirect effect through cognitive skills.[10] This is equivalent to saying that even if b_1 is small, because c_2 is large the product of b_1 and c_2 maybe still be substantial.

Previous Research

Different literatures are relevant to the various components of the path diagram in figure 3-1. Little attention has been paid to the effects of cognitive skills on schooling (a_1), though the finding that individuals with better cognitive skills are likely to have higher educational attainment is well documented.[11] Jencks and coauthors provide an extensive array of analyses involving multiple data sets. They report that cognitive skill, as measured by the first principal component of scores on a set of thirty tests, explains 34.2 percent of the variance in schooling. The thirty test scores together explain only 37.1 percent.

The figure indicates that both schooling and cognitive skills directly affect economic success. The extent to which schooling affects economic success has been perhaps the most thoroughly examined issue in labor economics

8. Herrnstein and Murray (1994).
9. Fischer and others (1996).
10. Dickens, Kane, and Schultze (forthcoming).
11. See, for example, Jencks and others (1979); Duncan, Featherman, and Duncan (1972); Herrnstein and Murray (1994); Winship and Korenman (1997).

in the past several decades. The main concern has been the market valuation of additional years of schooling. In estimating such returns to schooling, a major preoccupation has been how to control for the fact that individuals with more cognitive skill are likely to get more schooling.

In a recent review, Orley Ashenfelter and Cecilia Rouse discuss a vast literature demonstrating that schooling leads to higher wages among individuals with comparable cognitive skills.[12] In fact, the issue in labor economics has not been whether schooling affects earnings net of ability—the evidence is overwhelming that it does—but rather, how to obtain a precise estimate of the effect. Ashenfelter and Rouse review a number of the more recent analytic strategies. In order to control for genetic differences and differences in family background, some authors have compared fathers and sons, siblings, or identical twins.[13] Researchers have also taken advantage of natural experiments to study the effects of plausibly exogenous variation in schooling, including compulsory school laws, sex of siblings, distance to the nearest college, and differences in birth weight.[14] All of these studies find significant effects of schooling on earnings, typically in the range of 4 to 10 percent.

Ashenfelter and Rouse also examine whether returns to schooling differ by race, sex, social class, or cognitive skills. They find little difference in the return to schooling by race or sex. Individuals from lower socioeconomic backgrounds and individuals with lower cognitive skills have somewhat higher returns to schooling. In short, across various demographic groups and different samples, and using different methods, economists have consistently found significant and substantial effects of schooling on earnings, net of differences in cognitive skills.

In the past several decades there has also been considerable and acrimonious debate about the effects of schooling on cognitive skills, particularly as to whether additional years of schooling raise an individual's "intelligence." This debate was reignited with the publication of *The Bell Curve* by

12. Ashenfelter and Rouse (forthcoming).

13. On fathers and sons, see Ashenfelter and Zimmerman (1993). On siblings, see Altonji and Dunn (1995); Ashenfelter and Zimmerman (1993); Corcoran, Jencks, and Olney (1976); Chamberlain and Griliches (1975, 1977); as well as Griliches (1979) for a review of earlier work. On identical twins, see Ashenfelter and Krueger (1994); Ashenfelter and Rouse (forthcoming); Behrman, Rosenzweig, and Taubman (1994); Miller, Mulvey, and Martin (1995).

14. On compulsory school laws, see Angrist and Krueger (1991); also Mayer and Knutson in chapter 4 below. On siblings, see Butcher and Case (1994); Kaestner (1997). On distance to the nearest college, see Card (1993). On differences in birth weight, see Berhman, Rosenzweig, and Taubman (1994).

Herrnstein and Murray's controversial claim that schooling has little or no effect on cognitive skills. In a recent paper, we review the literature on this subject and replicate Herrnstein and Murray's analysis.[15] We focus on twelve studies that attempt to estimate the magnitude of the effect of schooling on cognitive skills. Stephen Ceci provides a broader review.[16] Estimates of the effect of a year of schooling on cognitive skills range from one-fifteenth to nearly one-half of a standard deviation of cognitive skills.[17] Most studies, however, have found that a year of school produces an increase of about one-fifth of a standard deviation in cognitive skills. The studies that produce the more extreme estimates appear to have methodological problems. In our replication of Herrnstein and Murray's analysis, we find that they had not adequately handled missing data on schooling and had failed to include an important control variable. In particular, they included seven cases in their analysis where schooling was missing and coded as –5. Also, they did not include as a control variable the age at which the earlier test of cognitive skills was taken, although in the book they stated that they had done so. Correction of these two errors results in an estimated effect of schooling more than twice as large as that reported in *The Bell Curve*. We have carried out further analyses, most important, including a control for family background and corrections for measurement error. From these, our preferred estimate is that a year of schooling increases cognitive skills by about 0.18 standard deviation.[18]

A smaller literature has examined the effects of cognitive skills on economic success. Researchers have examined the effects of cognitive skills on job performance and criminal behavior.[19] The economics literature on the returns to schooling establishes that cognitive skills affect economic success, but has been relatively unconcerned with the size of this effect. In the 1970s a vast sociological literature based on path analysis examined the

15. Winship and Korenman (1997).

16. Ceci (1991).

17. For the smaller estimate, see Herrnstein and Murray (1994) and Jencks and others (1972); for the larger, see Green and others (1964).

18. In an incomplete study based on the same data as *The Bell Curve* but using quite different methods, Lillard and Kilburn (1997) find much smaller schooling effects: about 0.08 standard deviation per year of schooling for men, and 0.06 for women. Interestingly, they find that the graduate equivalency diploma (GED) has substantial effects: about one-fifth of a standard deviation of cognitive skills for men and women.

19. On performance, see Gottfredson (1986), Hartigan and Wigdor (1989); on criminality, see Gordon (1976, 1980).

effects of cognitive skills on economic success, culminating in *Who Gets Ahead?* by Jencks and coauthors.[20] Using data from seven different studies, Jencks and coauthors estimate that a one standard deviation increase in cognitive skills increases earnings from 3 to 27 percent.

Herrnstein and Murray revisit this question in *The Bell Curve.* They conclude that for a host of different measures of economic and social success, intelligence is far more important than socioeconomic background, and is the dominant determinant of individual success. For example, they show that a one standard deviation increase in the AFQT, which they use to measure cognitive skills, increases family income by about $7,000 (in 1990 dollars), whereas a one standard deviation increase in an individual's socioeconomic background increases income only by about $4,600. A peculiarity of their study that has been noted by others and is germane to this paper is their decision to exclude schooling from most analyses.[21]

We have replicated Herrnstein and Murray's analysis using more extensive measures of family background.[22] Specifically, we use a variety of observed measures of family characteristics and we compare siblings, whose family backgrounds are presumably more similar than among unrelated adolescents. We find that estimates of the effect of cognitive skills are only modestly affected by using better controls or better methods of controlling for family background. For example, we find that a one standard deviation increase in AFQT score results in a $5,600 increase in family income. Our results differ from Herrnstein and Murray's in the finding that the importance of family background is comparable to that of cognitive skills. For example, we find that a one standard deviation increase in a very inclusive composite measure of family background increases family income by $6,100.

Furthermore, throughout our analyses we find that when we control for schooling, the effect of cognitive skills on success is substantially reduced. For example, including schooling as a control reduces the effect of a one standard deviation increase in AFQT score on family income from nearly $7,000 to about $4,100. And schooling has a comparable effect on family income: a one standard deviation increase in schooling (2.45 years) increases family income by about $4,600. Our results are similar for other measures of economic and social success. But none of the studies discussed

20. Duncan (1968); Jencks and others (1972); Duncan, Featherman, and Duncan (1972); Sewell and Hauser (1975); Hauser and Daymont (1977); Jencks and others (1979).

21. See, for example, Hauser (1995); Heckman (1995).

22. Korenman and Winship (forthcoming).

above explicitly considers the reciprocal relationship between schooling and cognitive skills. As a result, they may misrepresent the effects of schooling and cognitive skills on economic success.

Data and Methods

Our empirical analyses are based on data from the National Longitudinal Survey of Youth. The NLSY is an ongoing longitudinal study of a national sample of 12,686 individuals who were between the ages of fourteen and twenty-one on January 1, 1979.[23] The survey contains extensive information on labor market, schooling, and family formation histories. For the present purpose, the importance of the NLSY is that it contains a high-quality measure of cognitive skills, the Armed Services Vocational Aptitude Battery (ASVAB), which was administered to nearly the whole sample in April 1980. The ASVAB consists of ten tests aimed at measuring both general cognitive skills and knowledge of specific topics. Our measure of cognitive skills is an equally weighted combination of four of the items that collectively constitute the Armed Forces Qualifications Test (AFQT): word knowledge, paragraph comprehension, arithmetic reasoning, and mathematical knowledge. The AFQT's reliability is quite high, probably 0.95 and certainly higher than 0.9.[24]

Whether the AFQT is a measure of "innate intelligence" has been debated in the recent literature.[25] Fischer and coauthors claim that the AFQT is essentially a measure of educational achievement (we return to this point below).[26] Research is needed to examine whether schooling influences other components of the ASVAB, as well as the possible effects of these components on different measures of social and economic success. A recent study by Jill Corcoran is an effort in this direction.[27] The question of whether intelligence is appropriately conceptualized as a one-dimensional variable has also been highly contentious.[28] Psychometricians typically believe that intelligence is unidimensional and that it is

23. Center for Human Resources Research (1994).

24. Bock and Moore (1986).

25. See Herrnstein and Murray (1994); Cawley and others (1997).

26. Fischer and others (1996).

27. Corcoran (1996).

28. See Brody (1992); Carroll (1992).

well measured by IQ tests.[29] Others, most notably Robert Sternberg and Howard Gardner, have argued that intelligence is multidimensional.[30] Until there is further research on different cognitive skills and the degree to which they may be measured by the various ASVAB and other tests, one is in the unfortunate position of having to choose a measure of cognitive skills arbitrarily. The AFQT is a convenient choice as a measure cognitive skills, whether innate or acquired.

The NLSY is suited to our research objectives for an additional reason. For a small subsample (1,408 cases), an additional and earlier measure of cognitive skills is available. This allows us to estimate the effect of schooling on cognitive skills, while controlling for earlier cognitive skills. Many studies have used a similar design. Unfortunately, in the case of the NLSY the earlier measures of cognitive skills were taken at different ages and with different tests. The reliabilities of these measures are unknown. Typically, such tests have reliabilities over 0.9. Given that the scores for the NLSY subsample come from school administrative records and are based on a variety of tests, treating them as a single variable may well result in a lower reliability, possibly as low as 0.8.

In estimating the effects of cognitive skills and schooling, we control for an individual's family background with Herrnstein and Murray's index of socioeconomic status (SES), which is a simple combination of family income, mother's and father's schooling, and head of household's occupation. We do not use more elaborate measures since, as discussed above, in most cases more extensive controls for family background or the use of sibling comparisons did not substantially change estimates of the effect of AFQT or schooling on success.[31]

The other key variable in our analysis is completed schooling, measured in 1980 and 1990. The reliability of the schooling variable in the NLSY is unknown. Other research is of some help. Examining a variety of different sources, Jencks and coauthors provide estimates of its reliability ranging from 0.854 to 0.933. Ashenfelter and Alan Krueger's work on twins suggests a reliability of 0.9 for schooling.[32]

29. See Linda S. Gottfredson, "Mainstream Science on Intelligence," *Wall Street Journal,* December 13, 1994.

30. Sternberg (1985, 1990); Gardner (1983). For recent discussions, see Hunt (1997); Carroll (1997).

31. Korenman and Winship (forthcoming).

32. Jencks and others (1979, table A2.14); Ashenfelter and Krueger (1994).

Analysis

In this section, we first examine the reciprocal effects of schooling and cognitive skills. We then report estimates of the direct effects of schooling and cognitive skills on family income and annual earnings for year-round workers. Finally, we attempt to integrate these findings in order to examine the overall effects of schooling and cognitive skills on economic success. Table 3-1 presents summary statistics for the variables used in the analysis.

We estimate the effect of schooling and cognitive skills on each other, family income, or annual earnings. Both schooling and cognitive skills are measured with error. Since they are also highly related in the NLSY, with correlations as high as 0.65, assumptions about the measurement error in each variable substantially affect both its own effect and that of the other variable.

In the tables below, we first present estimates under the assumption that all variables have reliability of one; that is, they are measured perfectly. We then check the sensitivity of estimates to different assumptions about reliability. As our preferred values, we choose estimates with an intermediate set of reliabilities: 0.95 for AFQT, 0.9 for early cognitive skills, and 0.9 for schooling. All our models include controls for socioeconomic background, age, race or Hispanic origin, and gender. We assume that the reliabilities of these variables are equal to one.[33] In order to compare the size of the effects of schooling and cognitive skills, we present standardized as well as unstandardized estimates. Readers may find it easiest to think about schooling in unstandardized units, that is, a year of schooling; and cognitive skills in standardized units, one standard deviation equal to fifteen points.

The Reciprocal Relationship between Schooling and Cognitive Skills

What is the effect of cognitive skills on schooling? Specifically, if one could increase an individual's cognitive skill, holding all other variables constant, how much more schooling would he or she be likely to get? Table 3-2 presents both standardized and unstandardized estimates of the effects of an

33. The reliability of our measure of SES is almost certainly less than one. However, we have investigated the effects of measurement error in parental SES. As noted, our measure of SES is a combination of mother's education, father's education, occupational status of the head of household, and family income. Jencks and others (1979) report reliabilities for these component variables ranging from 0.72 to 0.96. Thus the reliability of our measure of SES will be higher. In general, we find that different assumptions about the reliability of SES have little impact on our estimates of the effects of schooling and cognitive skills.

Table 3-1. *Summary of Variables Used in the Analysis of the National Longitudinal Survey of Youth*[a]

Variable	*Mean*	*Number of observations*	*Description*
Family income	34,345 (27,080)	7,977	Total net family income in 1989, 1990 dollars. Excludes persons not working because of school in 1989 or 1990.
Annual earnings	24,225 (16,083)	4,974	Year-round workers.
Schooling in 1980 (*Ed80*)	11.07 (1.95)	12,844	Years of school completed in 1980.
Schooling in 1990 (*Ed90*)	12.76 (2.46)	10,506	Years of school completed in 1990.
AFQT	101.31 (15.02)	12,038	Armed Forces Qualifying Test.
Early cognitive skills	100.3 (15.2)	1,216	Test score from school transcript.
Age in 1990	29.10 (2.27)	10,585	...
Black	0.2483 (0.432)	12,846	...
Latino	0.1565 (0.363)	12,486	...
Other race	0.045 (0.207)	12,846	...
Female	0.495 (0.500)	...	...
SES	–0.348 (1.07)	12,036	Equally weighted combination of parents' income and education, and occupation of head of household.
Years between tests	6.12 (2.74)	1,216	Number of years between initial school-based test and AFQT.

a. Standard deviations are in parentheses.

individual's educational attainment in 1980 and AFQT score in 1980 on educational attainment in 1990, holding constant SES and demographic characteristics.[34]

For the full cross-sectional NLSY sample, table 3-2 indicates that a one-year increase in schooling in 1980 is associated with an increase of 0.72 year in schooling in 1990. A one-point increase in the AFQT score is associated with an increase of 0.063 year in schooling in 1990. Equivalently a one standard deviation increase in the AFQT score increases schooling by 0.39 year. Different assumptions about the reliability of schooling and the AFQT score have substantial effects on the estimates. The effect of a one-year increase in schooling in 1980 on years of schooling in 1990 ranges from about 0.66 to 1.5 years, and the effect of a one-point increase in AFQT score on schooling ranges from 0.022 to 0.079 years.[35]

However, the full NLSY sample comprises respondents aged between fifteen and twenty-two in 1980. A number of respondents had completed their schooling by this time, and including them in the sample may overstate the effect of current schooling on future schooling. Table 3-2 also reports the results from running the same models with the sample of individuals who were less than eighteen years old in 1980, and thus were likely to still be in school. In this sample, a year of schooling in 1980 is associated with an additional 0.58 year of schooling in 1990, a reduction of about 20 percent from the full-sample estimate, while a one-point increase in the AFQT score is associated with 0.081 additional years of schooling, an increase of nearly 30 percent. Again, the estimated effects of schooling in 1980 and AFQT score vary with the assumptions about reliability. The effect of a one-year increase in 1980 on schooling in 1990 ranges from 0.49 year to 0.96 year, and the effect of a one-point increase in AFQT score ranges from 0.072 year to 0.099 year. Our preferred estimate is model 6, where the reliabilities of AFQT and schooling in 1980 are assumed to be 0.95 and 0.90, respectively. In this case, the effect on schooling in 1990 of a one-year increase in schooling in 1980 is 0.675 year, and the effect of a one-point increase in the AFQT score is 0.085 year. Put

34. Estimates are from the following equation:

$$Ed90 = \alpha_0 + (Ed80)\alpha_1 + (AFQT)\alpha_2 + \text{controls}.$$

The standardized coefficients are derived by scaling the dependent variable (schooling in 1990) and the independent variables (schooling in 1980 and AFQT) to have variance 1.

35. In Korenman and Winship (forthcoming) we find that the use of sibling comparisons reduces the effect of AFQT score on schooling by approximately 25 percent.

Table 3-2. *Effects of Cognitive Skills on 1990 Educational Attainment in the NLSY*[a]

	Full sample[b]					Less than 18 years old in 1980[c]				
	Unstandardized		Standardized			Unstandardized		Standardized		
Model	Ed80	AFQT	Ed80	AFQT	Reliability	Ed80	AFQT	Ed80	AFQT	Reliability
1	0.719	0.063	0.584	0.386	Ed80 = 1.00	0.582	0.081	0.473	0.499	Ed80 = 1.00
	0.012	0.000	0.010	0.009	AFQT = 1.00	0.043	0.003	0.035	0.018	AFQT = 1.00
2	1.458	0.029	1.185	0.182	Ed80 = 0.80	0.822	0.089	0.669	0.551	Ed80 = 0.80
	0.023	0.000	0.019	0.012	AFQT = 0.90	0.071	0.004	0.058	0.024	AFQT = 0.90
3	1.486	0.025	1.208	0.155	Ed80 = 0.80	0.899	0.080	0.731	0.491	Ed80 = 0.80
	0.022	0.002	0.018	0.011	AFQT = 0.95	0.067	0.004	0.057	0.022	AFQT = 0.95
4	1.507	0.022	0.123	0.135	Ed80 = 0.80	0.960	0.072	0.781	0.443	Ed80 = 0.80
	0.021	0.002	0.017	0.009	AFQT = 1.00	0.069	0.003	0.056	0.020	AFQT = 1.00
5	0.905	0.067	0.735	0.394	Ed80 = 0.90	0.614	0.095	0.499	0.588	Ed80 = 0.90
	0.017	0.002	0.014	0.012	AFQT = 0.90	0.054	0.004	0.043	0.022	AFQT = 0.90
6	0.943	0.056	0.767	0.344	Ed80 = 0.90	0.675	0.085	0.549	0.527	Ed80 = 0.90
	0.016	0.002	0.013	0.010	AFQT = 0.95	0.053	0.003	0.043	0.020	AFQT = 0.95
7	0.973	0.049	0.791	0.305	Ed80 = 0.90	0.725	0.077	0.589	0.478	Ed80 = 0.90
	0.016	0.002	0.013	0.009	AFQT = 1.00	0.053	0.003	0.043	0.019	AFQT = 1.00
8	0.656	0.079	0.533	0.489	Ed80 = 1.00	0.490	0.099	0.398	0.610	Ed80 = 1.00
	0.013	0.002	0.011	0.011	AFQT = 0.90	0.043	0.004	0.035	0.022	AFQT = 0.90
9	0.691	0.070	0.562	0.432	Ed80 = 1.00	0.541	0.089	0.440	0.549	Ed80 = 1.00
	0.013	0.002	0.010	0.010	AFQT = 0.95	0.043	0.003	0.035	0.020	AFQT = 0.95

Source: Authors' calculations as described in text. In this and subsequent tables, underlying source for NLSY data is Center for Human Resources Research (1994).
a. Controls include socioeconomic status (SES) of family, age, race or ethnicity, and gender.
b. $N = 10{,}033$.
c. $N = 3{,}014$.

another way, a one standard deviation increase in schooling in 1980 is associated with a 0.549 standard deviation increase in schooling in 1990, and a one standard deviation increase in the AFQT score is associated with a 0.527 standard deviation increase in schooling in 1990. This suggests that schooling in 1980 and the AFQT in 1980 are of approximately equal importance in determining schooling in 1990.

What effect does schooling have on cognitive skills? Specifically, if schooling increases by one year, holding all other variables constant, how much does cognitive skill increase? To answer this question, we estimate the effect of schooling in 1980 and earlier tests of cognitive ability on AFQT score in 1980, controlling family background and demographic characteristics. We report these results in table 3-3.[36] In this case, the sample is small because only a small portion of the NLSY sample has an early measure of cognitive skill.

The first model in table 3-3 reports estimates of the effect of schooling and early cognitive skills on AFQT scores, assuming reliabilities of 1. An additional year of schooling increases an individual's AFQT score by 2.46 points. This effect is significant. A one-point increase in score on a test of early cognitive skills is associated with an additional 0.60 point on the AFQT. The effect of a one standard deviation increase of schooling (0.40) is two-thirds of that of early cognitive skills. This suggests that AFQT score responds both to schooling, as argued by Fischer and coauthors, and to early cognitive skills, as argued by Herrnstein and Murray, though early skills are approximately 50 percent more important than schooling.[37]

Models 2 through 9 in table 3-3 report estimates for the effects of schooling and early cognitive skills on the AFQT for different assumptions about the reliabilities of these variables. The effect of schooling on AFQT ranges from 1.63 points to 5.47 points per year of school completed. The effect of early skills ranges from 0.52 point to 0.89 point. Our preferred estimates are those of model 6, where the effect of schooling is 2.95 and the effect of early skills is 0.69. As in model 1, the effect of a one standard deviation increase in schooling (0.48) is approximately 70 percent as large as that for early skills (0.69).[38]

36. Estimates are from the following equation:

$$AFQT = (Ed80)\theta_1 + (\textit{early cognitive skills})\theta_2 + \text{controls}.$$

37. Fischer and others (1996); Herrnstein and Muray (1994).

38. These estimates are somewhat higher than those in Winship and Korenman (1997) because in the present paper we use a more extensive set of demographic controls.

Table 3-3. *Effects of Schooling on Cognitive Skills in the NLSY*[a]

	Unstandardized		Standardized		
Model	Ed80	Early skills	Ed80	Early skills	Reliability
1	2.464 0.207	0.601 0.020	0.404 0.034	0.601 0.020	Ed80 = 1.00 Skills = 1.00
2	3.793 0.375	0.814 0.026	0.622 0.061	0.814 0.026	Ed80 = 0.80 Skills = 0.80
3	4.816 0.409	0.637 0.023	0.789 0.067	0.637 0.022	Ed80 = 0.80 Skills = 0.90
4	5.473 0.425	0.523 0.021	0.897 0.070	0.523 0.021	Ed80 = 0.80 Skills = 1.00
5	2.283 0.235	0.869 0.024	0.374 0.039	0.869 0.024	Ed80 = 0.90 Skills = 0.80
6	2.954 0.263	0.693 0.022	0.484 0.043	0.693 0.022	Ed80 = 0.90 Skills = 0.90
7	3.399 0.279	0.577 0.020	0.557 0.046	0.577 0.020	Ed80 = 0.90 Skills = 1.00
8	1.634 0.171	0.893 0.023	0.268 0.028	0.893 0.023	Ed80 = 1.00 Skills = 0.80
9	2.131 0.194	0.718 0.022	0.349 0.032	0.718 0.022	Ed80 = 1.00 Skills = 0.90

Source: Authors' calculations as described in text.
a. Sample comprises individuals with measures of early cognitive skills (N = 1,215). Controls include family SES, age, race or ethnicity, gender, and number of years between tests.

In these models schooling in 1990 and AFQT score are the dependent variables, and schooling in 1980 and early cognitive skills have been used simply as controls. It is of interest, however, to ask how the reciprocal effects of schooling and cognitive skills compare in size. To do this, we compare estimates for the effect of AFQT score on schooling in 1990 for the smaller sample in table 3-2, with the effect of schooling in 1980 on AFQT score in table 3-3. Focusing on standardized estimates for model 6, we find that the effect of AFQT score on schooling is 0.527, and the effect

of schooling in 1980 on AFQT score is 0.484. The effects are of approximately equal size.

In additional analyses (not shown), we have explored whether schooling raises AFQT score more among those with higher or lower early cognitive skills by adding an interaction term between schooling and early skills to the models reported in table 3-3. The interaction term has a negative sign and is statistically significant in all models, which suggests that those with lower cognitive skills benefited most, in terms of their future AFQT score, from additional years of schooling. This result contrasts with the hypothesis that the brightest students gain the most from additional years of schooling, at least for the ages represented in the sample.

The Direct Effects of Schooling and Cognitive Skills on Economic Success

In this section we examine the independent effects of schooling and of cognitive skills on family income and the earnings of year-round workers. We ask how additional schooling is related to success, holding other variables constant, including cognitive skills. Holding AFQT score constant, schooling may affect earnings either by developing skills not measured by the AFQT (for example, noncognitive skills such as specialized training) or by increasing earnings independent of cognitive skills (for example, through qualification for a professional license). Analogously, we ask how higher cognitive skills are related to economic success, holding other variables constant, including schooling.[39]

Table 3-4 reports estimates of the effects of schooling and cognitive skills on the log of family income. Because the dependent variable is in log form, the unstandardized coefficients can be interpreted as indicating that a one-unit increase in an independent variable produces a percentage change in the dependent variable equal to approximately 100 times the coefficient. The standardized coefficients (which involve standardization of the independent variables) multiplied by 100 approximately indicate the percentage change in the dependent variable for a one standard deviation change in the independent variable. Table 3-4 shows that the effect of schooling on the log of family income is 0.054, or that one additional year

39. Estimates are from the equation

$$\textit{Economic success} = (\textit{Ed90})\gamma_1 + (\textit{AFQT})\gamma_2 + \text{controls}.$$

Table 3-4. *Effects of Schooling and AFQT Score on Log of 1989 Family Income in the NLSY*[a]

	Unstandardized		*Standardized*		
Model	*Ed90*	*AFQT*	*Ed90*	*AFQT*	*Reliability*
1	0.054 0.005	0.012 0.001	0.130 0.013	0.180 0.015	*Ed90* = 1.00 *AFQT* = 1.00
2	0.074 0.001	0.012 0.002	0.177 0.024	0.182 0.023	*Ed90* = 0.80 *AFQT* = 0.90
3	0.082 0.009	0.010 0.001	0.198 0.021	0.151 0.020	*Ed90* = 0.80 *AFQT* = 0.95
4	0.089 0.008	0.009 0.001	0.212 0.020	0.129 0.017	*Ed90* = 0.80 *AFQT* = 1.00
5	0.054 0.007	0.015 0.001	0.129 0.017	0.217 0.020	*Ed90* = 0.90 *AFQT* = 0.90
6	0.062 0.007	0.013 0.001	0.148 0.016	0.185 0.017	*Ed90* = 0.90 *AFQT* = 0.95
7	0.067 0.006	0.011 0.001	0.161 0.015	0.161 0.015	*Ed90* = 0.90 *AFQT* = 1.00
8	0.042 0.006	0.016 0.001	0.102 0.014	0.237 0.018	*Ed90* = 1.00 *AFQT* = 0.90
9	0.049 0.005	0.014 0.001	0.118 0.013	0.205 0.016	*Ed90* = 1.00 *AFQT* = 0.95

Source: Authors' calculations as described in text.

a. Full cross-sectional sample (*N* = 7,984). Controls include family SES, age, race or ethnicity, and gender. 1989 income is in 1990 dollars.

of schooling increases family income by about 5.4 percent. An increase of one standard deviation in schooling increases family income by approximately 14.8 percent. The effect of AFQT score is 0.012, or equivalently, that a one standard deviation increase in AFQT score (fifteen points) increases family income by 18.5 percent.

The effects of schooling and AFQT score on family income vary widely, depending on the assumptions about reliability. The effect of schooling on family income ranges from 4.2 to 8.9 percent. The effect of a one standard deviation increase in AFQT score on family income ranges from 12.9 to

21.7 percent. We prefer model 6, in which reliabilities for schooling and AFQT score are 0.9 and 0.95, respectively. Accordingly, the effect of a year of schooling on family income is approximately 6.2 percent, and the effect of a standard deviation change in AFQT score is approximately 18.5 percent.[40]

Table 3-5 presents estimates of the effects of schooling and AFQT score on the log of annual earnings for year-round workers. The ordinary least squares estimate of the effect of schooling is 0.068, or approximately 6.8 percent, which lies within the range of estimates found in the labor economics literature.[41] The effect of AFQT is .012. The effect of a one standard deviation increase in AFQT score is approximately 17.1 percent, while the effect of a one standard deviation increase in schooling is approximately 16.2 percent.

As in the other analyses, the effects of schooling and the AFQT vary depending on the assumptions about reliabilities. The effect of a one-year change in schooling on earnings ranges from 5.7 percent to 11.0 percent. The effect of a one standard deviation increase in AFQT score ranges from 10.9 percent to 22.4 percent. We prefer model 6, which, with reliabilities for schooling and AFQT score of, respectively, 0.9 and 0.95, produces estimates of 7.9 percent for each additional year of school and 16.9 percent for a one standard deviation increase in AFQT score.[42]

40. An important objection to the models we estimate in table 3-4 is that AFQT score is measured in 1980 rather than in 1990. Since our analyses above show that AFQT score is affected by schooling, one would expect 1990 AFQT score to be more highly correlated than 1980 score with schooling in 1990. One might also expect that 1990 AFQT score would be more highly correlated than 1980 score with economic success, if current rather than past cognitive skills determine economic success. Unfortunately, 1990 AFQT scores are not available for our sample. The net impact of using 1980 AFQT score instead should be to overstate the effect schooling and understate the effect of cognitive skills. In analyses not presented here, we have investigated this issue for family income and annual earnings. We create a predicted 1990 AFQT score based on the results from model 6 in table 3-3. We then use this predicted AFQT instead of 1980 AFQT as the regressor in a two-stage least squares procedure. Our estimates of the effect of AFQT score change only modestly. In the case of family income, the ordinary least squares estimate of family income is 0.054 and the two-stage least squares estimate is 0.050; the effects of AFQT score are, respectively, 0.0122 and 0.0105—a decrease, the opposite of what would be predicted. In the case of annual earnings, the coefficients for schooling are, respectively, 0.068 and 0.060; and for AFQT score they are, respectively, 0.012 and 0.011. Jencks and coauthors (1997) report similar findings from using an earlier as opposed to a current measure of cognitive skill to predict earnings. Since using the predicted variable adds substantial complications to the analysis and the discussion and yields only modest changes in the estimates, we use AFQT score in 1980 as the dependent variable.

41. Ashenfelter and Rouse (forthcoming).

42. There are no significant or large interaction effects between education and AFQT scores in the models of income or wages that we have analyzed.

Table 3-5. *Effects of Schooling and AFQT Score on Log of Annual Earnings in the NLSY*[a]

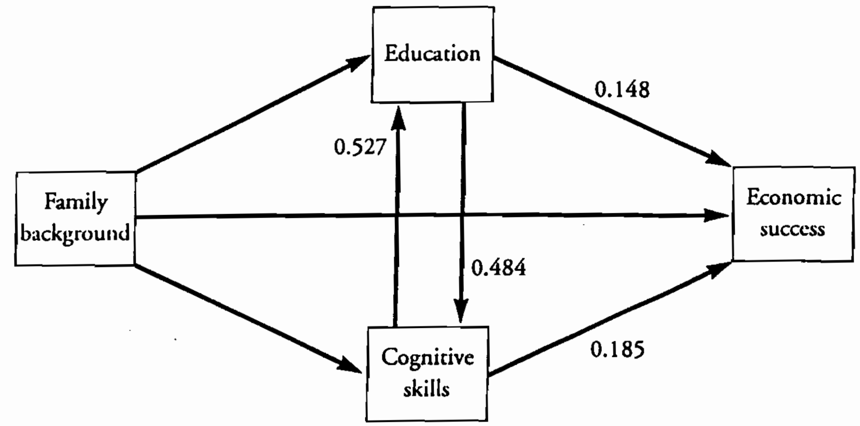
	Unstandardized		Standardized		
Model	*Ed90*	*AFQT*	*Ed90*	*AFQT*	*Reliability*
1	0.068	0.012	0.162	0.171	*Ed80* = 1.00
	0.006	0.001	0.015	0.018	*AFQT* = 1.00
2	0.098	0.010	0.234	0.152	*Ed80* = 0.80
	0.012	0.002	0.028	0.028	*AFQT* = 0.90
3	0.105	0.009	0.250	0.127	*Ed80* = 0.80
	0.011	0.002	0.026	0.024	*AFQT* = 0.95
4	0.110	0.007	0.262	0.109	*Ed80* = 0.80
	0.100	0.001	0.024	0.020	*AFQT* = 1.00
5	0.072	0.013	0.172	0.197	*Ed80* = 0.90
	0.009	0.002	0.021	0.024	*AFQT* = 0.90
6	0.079	0.011	0.188	0.169	*Ed80* = 0.90
	0.008	0.001	0.019	0.021	*AFQT* = 0.95
7	0.084	0.010	0.200	0.147	*Ed80* = 0.90
	0.008	0.001	0.018	0.018	*AFQT* = 1.00
8	0.057	0.015	0.136	0.224	*Ed80* = 1.00
	0.007	0.002	0.016	0.022	*AFQT* = 0.90
9	0.063	0.013	0.151	0.194	*Ed80* = 1.00
	0.007	0.001	0.016	0.019	*AFQT* = 0.95

Source: Authors' calculations as described in text.
a. Sample comprises full-year workers (N = 6,780). Controls include family SES, age, race or ethnicity, and gender.

The Compound Effects of Schooling and Cognitive Skills on Economic Success

We have shown, first, that schooling and cognitive ability appear to affect each other; and second, that they both have important and *independent* effects on family income and wages. In terms of figure 3-2, estimates for the log of family income taken from tables 3-2 (smaller sample), 3-3, and 3-4 yield the following standardized coefficients: $a_1 = 0.527$, $b_1 = 0.484$, $c_1 = 0.148$, and $c_2 = 0.185$.

Figure 3-2. *Path Model for Interrelationships among Education, Mental Ability, and Family Income in Standardized Coefficients*



Source: Authors' model as described in text.

We would now like to estimate how the indirect and direct effects of cognitive skills combine to determine economic success. To do so, we must assume that one can meaningfully use the estimates from tables 3-2 (smaller sample), 3-3, and 3-4 in a single analysis. This raises several problems. First, it would require a common time unit—for example, one year—over which to measure the interaction between schooling and skills. One would therefore need data on each individual's schooling and cognitive skills at each successive year. While we have a measure of schooling for each year after 1979, cognitive skill is measured only in 1980 for most of the sample, and for a small portion of the sample also prior to 1979, albeit poorly.

Second, our model assumes that schooling and cognitive skills adjust to each other dynamically and finally arrive at an equilibrium. The implication is that as a child gets a year of schooling, his cognitive skills increase, as a result of which he gets more schooling, and so on; but that these mutual increases diminish over time, until they disappear. The model lacks any clear specification of how schooling and cognitive skills evolve in relation to each other from year to year. Attempting to provide such specification introduces a difficult set of modeling issues. For example, there may be nonlinear increases in cognitive skills at particular years of schooling, for example, in the first year of college.

We leave these problems to future research. As a result, our estimates are crude, and probably biased. The absence of several repeated measures of cognitive skills and schooling may lead us to overstate the reciprocal effects of these variables. Nevertheless, it is worthwhile to illustrate roughly how the different components of figure 3-1 might interact as a system.

Consider the possible ways in which an increase in schooling might increase family income. First, there are direct effects. Our analysis suggests that a year of schooling increases income by 6.2 percent, or equivalently, that a one standard deviation increase in schooling (2.45 years) increases family income by 14.8 percent. This estimate is based on holding everything else, including cognitive skills, constant. That is, it indicates how much income increases when schooling increases for individuals who are similar in all other relevant respects, with equivalent family backgrounds and *equal levels of cognitive skill*.

Alternatively, imagine that the length of compulsory schooling were increased by one year. This would represent an exogenous increase in schooling that would raise cognitive skills. Thus schooling affects family income both directly and indirectly by increasing cognitive skills. The indirect effect is equal to the effect of schooling on cognitive skills multiplied by the effect of cognitive skills on family income. With unstandardized coefficients, this is (2.95)(0.013) = 0.038. The one-year increase in compulsory schooling would directly increase family income by 6.2 percent and indirectly increase it, through schooling's effect on cognitive skills, by an additional 3.8 percent. Table 3-6 reports these combined effects.

In the standard theory of path analysis reciprocal effects are not allowed, and the sum of a variable's direct and indirect effects is known as its total effect. As we discuss below, in the present model the reciprocal relationship between schooling and cognitive skills means that there are additional effects beyond each variable's direct and indirect effects. Therefore for clarity we refer to the combination of a variable's direct and indirect effects in our model as its composite effect.

The composite effect of schooling on the log of family income is 0.100, indicating that one year of schooling increases family income by approximately 10 percent: directly by 6.2 percent and indirectly, through AFQT score, by 3.8 percent. Thus one of the ways in which schooling increases income is to make one smarter, which in turn raises family income.

If an increase in schooling results in an increase in cognitive skill, this increase in cognitive skills could also increase schooling. The increase in schooling will then result in an additional increase in cognitive skill, leading to a further increase in schooling, and so on. This is a common situation in models with lag structures. Essentially, there is a repeated feedback loop. This process may either explode or converge. In the present case, equilibrium will be reached if the product of the effect of AFQT score on schooling (0.085) and the effect of schooling on AFQT score (2.95) is less than one. In fact, it is 0.251, indicating that the process will converge.

Table 3-6. *Decomposition of Effects of Schooling and AFQT Score in the NLSY*[a]

	Log of income				*Log of annual earnings*			
	Unstandardized		*Standardized*		*Unstandardized*		*Standardized*	
Type of effect	*Ed90*	*AFQT*	*Ed90*	*AFQT*	*Ed90*	*AFQT*	*Ed90*	*AFQT*
Direct	0.062	0.013	0.148	0.185	0.079	0.011	0.188	0.169
Indirect	0.038	0.005	0.090	0.078	0.032	0.007	0.082	0.099
Composite	0.100	0.018	0.238	0.263	0.111	0.018	0.270	0.268
Multiplier	1.335	1.335	1.335	1.335	1.335	1.335	1.335	1.335
Overall	0.134	0.024	0.317	0.351	0.149	0.024	0.360	0.358

Source: Authors' calculations based on estimates for model 6 in tables 3-2 (smaller sample) through 3-5.

As a result of the feedback process through cognitive skills, the effect of schooling on a given outcome is multiplied by a constant (see appendix 3A for derivation and formulas). From our estimates of the reciprocal effects of AFQT score and schooling, the multiplier is 1.335. Therefore the overall effect of schooling on the log of family income is its composite effect multiplied by (0.100)(1.335) = 0.1335. This estimate is more than twice as large as that of the direct effect of schooling on the log of family income (0.062). Thus, schooling's overall effect on the log of family income in part comes from its independent effect (0.062), but also in part from its interrelationship with AFQT score.

One can perform a similar analysis for the effect of AFQT score. For ease of interpretation we focus on the standardized effects in table 3-6. A one standard deviation increase in AFQT score, holding all other variables constant, increases the log of family income by 0.185, or increases family income by approximately 18.5 percent. If we allow the AFQT score to increase schooling, it has an additional indirect effect of 0.078, or an approximately 7.8 percent increase in family income. The combination of the direct and indirect effects of AFQT score is 0.263. Allowing for the feedback effects between AFQT score and schooling increases this combined effect by approximately 33.5 percent, resulting in an overall effect of 0.317, or approximately 31.7 percent—more than twice the size of the direct effect of AFQT score on family income. Thus for both schooling and AFQT score, somewhat less than half of the overall effect on family income is direct and somewhat more than half is the result of their mutually reinforcing relationship.

One can consider figure 3-1 in terms of the log of annual earnings. Table 3-6 breaks down the effects of schooling and AFQT score on the log of earnings. The direct effect of a year of schooling is to increase earnings by 7.9 percent; its indirect effect through AFQT score is 3.2 percent, and its overall effect is 14.9 percent. The direct effect of a one standard deviation increase in AFQT score is a 16.9 percent increase in earnings; its indirect effect through schooling is 8.2 percent, and its overall effect is 31.7 percent. As for family income, for both schooling and AFQT score, approximately half of the effect on log earnings is direct and half results from their mutually reinforcing relationship.

Conclusion

The picture that our model and parameter estimates offer is considerably at variance with many, though not all, of the claims in the existing literature. Our results appear to support Jencks's contention that equalizing schooling would only modestly reduce economic inequality.[43] The overall standardized effect of schooling on family income is 0.317, and on annual earnings is 0.360. Squaring these coefficients and multiplying by 100 indicates that 10.0 percent of the variance in family income and 12.3 percent of the variance in annual earnings is due to schooling.

Dickens, Kane, and Schultze's claim that education may be important because of indirect effects through cognitive skills receives mixed support from our results.[44] Table 3-6 shows that schooling has strong direct effects on both family income and annual earnings: one year of schooling increases them by 6.2 percent and 7.9 percent, respectively. Schooling also

43. Jencks and others (1979).
44. Dickens, Kane, and Schultze (forthcoming).

has important indirect effects: one year of schooling increases family income and annual earnings by 3.8 percent and 3.2 percent, respectively. It is the combination of these direct and indirect effects with the multiplier, however, that produces large overall effects: a 13.4 percent increase in family income and a 14.9 percent increase in earnings. Thus the effect of schooling on economic success is important because of, first, its direct effect; second, its indirect effects through cognitive skills; and third, the interaction of the two through the multiplier.

Our results fly in the face of Herrnstein and Murray's claim that schooling should not be controlled in a model predicting economic outcomes, since it represents only the effects of intelligence.[45] Squaring the standardized coefficient for AFQT—$(0.527)^2 = 0.278$—indicates that 27.8 percent of schooling can be attributed to AFQT score. Thus most of the variance in years of schooling is unrelated to AFQT score. Even if we estimate our model without controls for earlier schooling, we find that the standardized coefficient for AFQT is 0.620, the square of which is 0.384. As noted, our results also demonstrate that among individuals with the same AFQT score, differences in schooling lead to differences in economic success. These findings imply that Herrnstein and Murray's failure to control for schooling leads them to overstate the effect of intelligence on social and economic success.[46]

Nor do our model and estimates support Fischer and coauthors' claim that AFQT score is primarily a function of education.[47] While schooling does affect cognitive skills, the reverse is also true, with the effect of cognitive skills on schooling being somewhat larger. The analyses reported in table 3-3 indicate that the effect of early cognitive skills on AFQT score is 50 percent larger than the corresponding effect of schooling.

Ultimately, our model and its estimates characterize schooling, cognitive skills, and their effects on economic success as follows. Schooling and cognitive skills affect each other, and each has substantial independent and direct effects on economic success. However, it is also possible that schooling and cognitive skills could substantially reinforce each other's effect on economic success. The direct effect of each could be as much as doubled by this mutual reinforcement. Neither schooling nor cognitive skills is clearly dominant in determining economic success. Rather, their roles appear to be roughly symmetrical, both in reinforcing each other and in determining economic success.

45. Herrnstein and Murray (1994).
46. See also Heckman (1995); Hauser (1995); Korenman and Winship (forthcoming).
47. Fischer and others (1996).

Appendix 3A
The Calculation of Different Effects

The path model in figure 3-1 is equivalent to the following three equations:

(3A-1) $$E = Ca_1 + Fa_2 + e_1$$

(3A-2) $$C = Eb_1 + Fb_2 + e_2$$

(3A-3) $$S = Ec_1 + Cc_2 + Fc_3 + e_3,$$

where E is education or schooling, C is cognitive skills, F is family background, and S is economic success.

Consider the effect of an exogenous increase in education on economic success. An exogenous increase in education is equivalent to increasing e_1. To calculate the effect on S of changing e_1, we differentiate equation 3A-3 with respect to e_1:

(3A-4) $$\partial S/\partial e_1 = (\partial E/\partial e_1)c_1 + (\partial C/\partial e_1)c_2 .$$

From equation 3A-1,

(3A-5) $$\partial E/\partial e_1 = (\partial C/\partial e_1)a_1 + 1 .$$

We then ask what is the effect of increasing e_1 holding cognitive skills (C) constant—that is, we assume that $\partial C/\partial e_1 = 0$. From equations 3A-5, $\partial E/\partial e_1 = 1$, and substituting this into equation 3A-4,

(3A-6) $$\partial S/\partial e_1 = (\partial E/\partial e_1)c_1 = c_1 .$$

In the language of path analysis, this is the direct effect of education on success.

Now consider allowing education to affect success both directly and indirectly, through cognitive skills. From equation 3A-2,

(3A-7) $$\partial C/\partial e_1 = \partial E/\partial e_1 \, b_1 .$$

For the moment, we allow education to increase only by a fixed amount δe_1, that is, we allow no feedback; or equivalently, we set $\partial E/\partial e_1 = 1$. Substituting into equation 3A-7, we get $\partial C/\partial e_1 = b_1$. Further substituting into equation 3A-4,

(3A-8) $$\partial S/\partial e_1 = c_1 + c_2 b_1 .$$

In the language of path analysis, this is the total effect. In our model, however, there are additional effects due to the potential self-reinforcing effect of education through cognitive skills. In order to avoid confusion, we call the effect in equation 3A-8 the composite effect.

If we allow feedback, neither $\partial E/\partial e_1$ nor $\partial C/\partial e_1$ are fixed, and both need to be solved for from equations 3A-5 and 3A-7:

(3A-9) $$\partial E/\partial e_1 = 1/(1 - a_1 b_1)$$

(3A-10) $$\partial C/\partial e_1 = b_1 (1 - a_1 b_1).$$

Substituting into equation 3A-4 and rearranging terms,

(3A-11) $$\partial S/\partial e_1 = c_1 [1 + (a_1 b_1)/(1 - a_1 b_1)] + c_2 b_1 [1 + (a_1 b_1)/(1 - a_1 b_1)].$$

Consider the components of equation 3A-11: c_1 is the direct effect of education on success, $c_2 b_1$ is the indirect effect of education on success through cognitive skills, and their sum is the composite effect. Finally, $1 + (a_1 b_1)/(1 - a_1 b_1)$ is the feedback multiplier, the amount by which an initial exogenous increase in education leads to a further increase in education, due to its feedback through cognitive skill. We term the entire right-hand side of equation 3A-11 the overall effect of education on success.

Using an analogous derivation, one can break down the effect of cognitive skills on success, as follows:

c_2	Direct effect
$c_1 b_2$	Indirect effect through education
$c_2 + c_1 b_2$	Composite effect
$1 + (a_1 b_1)/(1 - a_1 b_1)$	Feedback multiplier
$c_1 b_2 [1 + (a_1 b_1)/(1 - a_1 b_1)] + c_2 [1 + (a_1 b_1)/(1 - a_1 b_1)]$	Overall effect.

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4

Does the Timing of School Affect How Much Children Learn?

ALL STATES IN THE United States have compulsory school laws that specify both the age at which children are required to enroll in first grade and the age at which they are permitted to leave school. Between 1965 and 1990, states increased the number of required years of school. They did this both by lowering the age at which children were required to enroll in first grade and raising the age at which children were permitted to quit school. While most educators and social scientists agree that it is a good idea for students to stay in school longer, not all agree that they should start earlier, and there remains considerable variation across states in the age at which children are required to enroll.

In this chapter we show that children who enroll in first grade at a young age learn more in school and eventually earn more in the labor market than children who enroll in school at an older age. Early enrollment in first grade increases eventual wages partly because children who enroll earlier stay in school longer, and partly because children who enroll earlier

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