Human Capital 2

The duration of schooling

- So far, just a binary decision: attend college or not.
- More relevant: how many years of schooling to acquire, beyond compulsory schooling?
- The distribution of years of schooling has spikes at 12 and 16 years, but also a fair amount of people in the middle (high school and college dropouts).
- Also, this will give a theoretical justification to the typical regression equation:

$$\ln y = \beta_0 + \beta_1 EDUC + \gamma' X + u$$

The duration of schooling

- Dynamic model (Card, 2001; adapted from Willis, 1986)
  - individuals begin life at the end of compulsory schooling, must choose how much additional schooling to acquire.

- Assumption: individuals make once and for all decision on when to leave school.

- Variables and parameters:
  - $y(S,t)$: real earnings of individual who has completed S years of schooling at date t.
  - $c(t)$: consumption at date t
  - $\phi(t)$: disutility of school at date t.
  - $p(t)$: part-time earnings when in school.
  - $T(t)$: direct costs of schooling.
  - ρ : individual discount rate.
  - R : fixed interest rate, perfect capital markets.

Individual maximization problem

- Agent chooses S, total amount of post-compulsory schooling, to maximize:

$$\begin{aligned}
\max V\left(S, c\left(t\right)\right) &= \int_0^S \left[u\left(c\left(t\right)\right) - \phi\left(t\right)\right] e^{-\rho t} dt \\
&\quad + \int_S^\infty u\left(c\left(t\right)\right) e^{-\rho t} dt \\
s.t. \quad &: \int_0^\infty c\left(t\right) e^{-Rt} dt \\
&= \int_0^S \left[p\left(t\right) - T\left(t\right)\right] e^{-Rt} dt + \int_S^\infty y\left(S, t\right) e^{-Rt} dt.
\end{aligned}$$

- Write down Lagrangian

$$\begin{aligned}
\Omega\left(S, c\left(t\right), \lambda\right) &= V\left(S, c(t)\right) + \\
&\quad \lambda \left\{ \begin{array}{c} \int_0^\infty c\left(t\right) e^{-Rt} dt - \int_0^S \left[p\left(t\right) - T\left(t\right)\right] e^{-Rt} dt \\ - \int_S^\infty y\left(S, t\right) e^{-Rt} dt \end{array} \right\}
\end{aligned}$$

- Simplifying assumptions:
  - Constant earnings: $y(S,t) = y(S)$
  - No disutility from schooling ($\phi \equiv 0$)
  - Tuition and part-time earnings while in school cancel out: $p(t) \approx T(t)$
  - Linear utility function.

- Easy to see that, since now from budget constraint $\int_0^\infty c(t)\, e^{-Rt} dt = \int_S^\infty y(S,t)\, e^{-Rt} dt$, problem reduces to one of maximizing present value of earnings stream (again, independent of preferences ρ with perfect capital markets):

$$\begin{aligned} \max V(S) &= \int_S^\infty y(S)\, e^{-Rt} dt \\ &= y(S)\, e^{-RS}/R. \end{aligned}$$

- FOCs w.r.t. S:

$$\begin{aligned} \frac{1}{R}\left[y'(S)\,e^{-RS} - Ry(S)\,e^{-RS}\right] &= 0 \\ &\Rightarrow \frac{y'(S)}{y(S)} = R. \end{aligned}$$

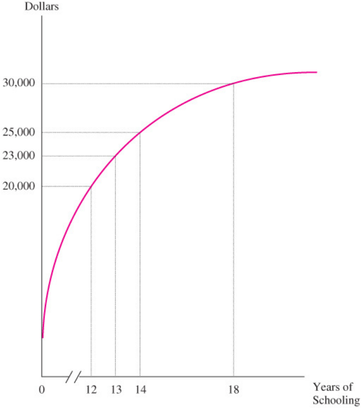
- $y'(S)/y(S)$: marginal benefit of additional unit of schooling, expressed in percentage terms.
- R : marginal cost of additional unit of schooling (opportunity cost of delaying entry into labor market, by not investing in R).

Invest up to the point where marginal benefits of additional year of schooling are equal to marginal costs.

- With these simplifying assumptions, you obtain the textbook version of the model. Assuming that education is productive:

FIGURE 6-2 **The Wage-Schooling Locus**

The wage-schooling locus gives the salary that a particular worker would earn if he completed a particular level of schooling. If the worker graduates from high school, he earns $20,000 annually. If he goes to college for one year, he earns $23,000.



[5] Sherwin Rosen, "Human Capital: A Survey of Empirical Research," *Research in Labor Economics* 1 (1977): 3–39; and David Card, "The Causal Effect of Education on Earnings," in Orley Ashenfelter and David Card, editors, *Handbook of Labor Economics*, vol. 3A. Amsterdam: Elsevier, 1999, pp. 1801–63.

FIGURE 6-3 **The Schooling Decision**

The *MRR* schedule gives the marginal rate of return to schooling, or the percentage increase in earnings resulting from an additional year of school. A worker maximizes the present value of lifetime earnings by going to school until the marginal rate of return to schooling equals the rate of discount. A worker with discount rate r goes to school for s^* years.

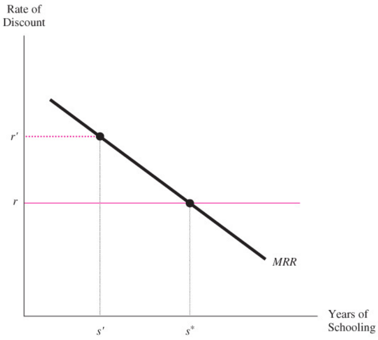


FIGURE 6-4 Schooling and Earnings When Workers Have Different Rates of Discount

Al has a higher rate of discount (r_{AL}) than Bo (r_{BO}), so that Bo graduates from high school but Al drops out. Al chooses point P_{AL} on the wage-schooling locus and Bo chooses point P_{BO}. The observed data on wages and schooling in the labor market trace out the common wage-schooling locus of the workers.

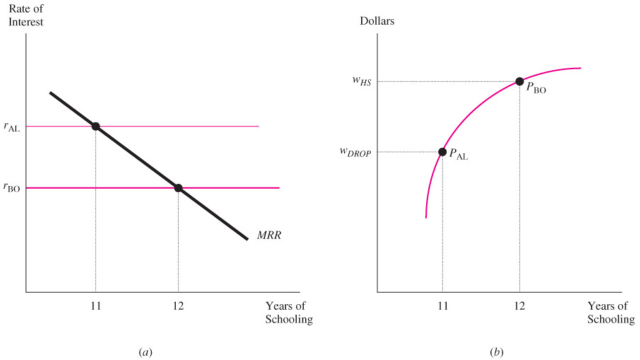
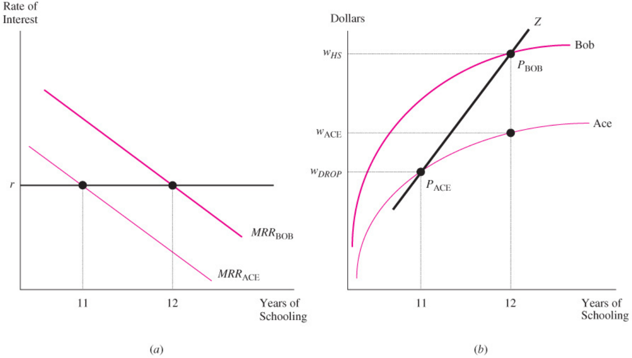


FIGURE 6-5 Schooling and Earnings When Workers Have Different Abilities
Ace and Bob have the same discount rate (r), but each worker faces a different wage-schooling locus. Ace drops out of high school and Bob gets a high school diploma. The wage differential between Bob and Ace (or $w_{HS} - w_{DROP}$) arises both because Bob goes to school for one more year and because Bob is more able. As a result, this wage differential does not tell us by how much Ace's earnings would increase if he were to complete high school (or $w_{\text{ACE}} - w_{DROP}$).



Estimating the Returns to Schooling

- Model yields first order conditions

$$\frac{y'(S)}{y(S)} = R$$

- Implies

$$\frac{d \ln y}{dS} = R$$

or, by integrating on both sides

$$\ln y = RS$$

- Add in more covariates and an error term, you obtain the *Mincer wage equation*

$$\ln y_i = \beta_0 + RS_i + \gamma' X_i + u_i$$

- Main interest in parameter R, can be interpreted as the rate of return to schooling.

Potential Biases in the Mincer equation

- Omitted variable bias:
  - More able individuals are more successful in school and also have higher earnings. Therefore, estimated returns to schooling is biased upwards.
- Measurement error bias
  - schooling is measured with error:
    - people have very different schooling paths (especially after high school), difficult to say exactly how many years of schooling one has attained.
    - large variance in the *quality* of schooling. Number of years of schooling only a very imperfect measure of quality-adjusted schooling.

- Huge literature in economics that has tried to address these biases and come up with a credible estimate of the *causal* effect of schooling on earnings.
- Most of the evidence suggests that the causal effect of schooling is not too far away from the simple OLS estimate.
- Empirical studies
    - First generation: controls for IQ and family background.
    - Twins studies
    - Instrumental variables.

First generation studies: Griliches and Mason (1972)

- Use data on sample of military veterans in 1964. (mean age: 29)
- Key info: AFQT score, interpreted as a measure of cognitive ability (IQ).
- Estimate returns to schooling with and without controls for AFQT.

TABLE 1

MEANS AND STANDARD DEVIATIONS OF VARIABLES: VETERANS AGE 21–34 IN 1964 CPS SUBSAMPLE

Variable	Mean or Fraction in Sample	SD	Symbol in Subsequent Tables	Group Name
Personal background:				
Age (years)	29.0	3.5	Age	
Color (white)	0.96	*	C	
Schooling before service (years)	11.5	2.3	SB	
Total schooling (years) ..	12.3	2.5	ST	
Schooling increment (years)	0.8	1.4	SI	
AFQT (percentile)	54.6	24.8	AFQT	
Length of active military service (months)	30.7	16.9	AMS	
Father's schooling (years)	8.7	3.2	FS	Fa. stat.
Father's occupational SES	29.0	20.6	FO	
Grew up in South	0.29	*	ROS	Reg. bef.
Grew up in large city	0.22	*	POC	
Grew up in suburb of large city	0.05	*	POS	
Current location:				
Now living in the South ..	0.27	*	RNS	Reg. now
Now living in the West ..	0.15	*	RNW	
Now living in an SMSA ..	0.68	*	SMSA	
Current achievement:				
Length of time in current job (months)	54.3	42.8	LCJ	Curr. exp.
Never married	0.14	*	NM	
Current occupational SES	39.2	22.7	...	
Log current occupational SES	3.47	0.68	LOSES	
Actual income (weekly, [illegible]	[illegible]	[illegible]		

TABLE 3

REGRESSION EQUATIONS WITH LOG INCOME AS DEPENDENT VARIABLE

Regression No.	Coefficient (Standard Error) of: Color	SB	SI	ST	AFQT	Other Variables in Equation*	R^2
1	.2548 (.0472)	.0502 (.0042)	.0528 (.00702)	...	...	Age, AMS	.1666
2	.2225 (.0479)	.0418 (.0049)	.0475 (.0072)	...	.00154 (.00045)	Age, AMS	.1732
3	.1904 (.0473)	.0379 (.0045)	.0496 (.0070)	...	...	Age, AMS, fa. stat., reg. bef.	2129
4	.1714 (.0479)	.0328 (.0050)	.0462 (.0071)	...	.00105 (.00045)	Age, AMS, fa. stat., reg. bef.	2159
5	.2544 (.0471)	...	...	.0508 (.0039)	...	Age, AMS	.1665
6	.22245 (.04793)	...	...	.0433 (.0044)	.00150 (.00045)	Age, AMS	.1729
7	.1907 (.0473)	...	...	.0408 (.0041)	...	Age, AMS, fa. stat., reg. bef.	.2115
8	.1732 (.0479)	...	...	.0365 (.0046)	.00097 (.00044)	Age, AMS, fa. stat., reg. bef.	.2141
9	.1335 (.0487)	...	...	...	.00252 (.00041)	Age, AMS, fa. stat., reg. bef.	.1794
10	.1742 (.0488)	...	...	...	...	Age, AMS, fa. stat., reg. bef.	.1578
11	.2052 (.0456)	.0320 (.0048)	.0445 (.0068)	...	.00115 (.00045)	Age, fa. stat., reg. bef., reg. now, curr. exp., AMS	.2979
12	.2240 (.0449)	.0372 (.0046)	.0468 (.0068)	...	.00129 (.00043)	Age, reg. now, curr. exp., AMS	.2851

NOTE.—See table 1 for definitions.
* Variable groups are denoted as follows: fa. stat. = fa. occ. and fa. schooling; reg. bef. = ROS, POC, POS; reg. now = RNS, RNW, SMSA; curr. exp. = NM, LCJ.

Results

- Controlling for AFQT reduces estimated returns to schooling by about 15% (from 0.508 to 0.433).
- Some evidence of omitted variable bias, but not very large.
- Possible interpretations:
  - Lots of concern about ability bias, but bias is apparently not very large. Returns to schooling still substantial.
  - AFQT only a very imperfect measure of ability. If we could control for ability more accurately, maybe coefficient would drop even more.

Ashenfelter and Krueger (1994)

- AFQT only an imperfect measure of ability. How do we really hold constant "ability"?
- Basic idea: identical twins are genetically identical, and have very similar family backgrounds.
- Estimating equation:

$$y_{it} = \beta_0 + \beta_1 S_{it} + \beta_2' X_{it} + c_i + u_{it}$$

  - y_{it}, S_{it} : log earnings and schooling of twin t in family i $(t = 1, 2)$.
  - c_i : family fixed effect: captures genetic ability, unobservable family background, etc.
  - u_{it} : idiosyncratic error term, uncorrelated with S_{it}.

- OLS is biased because of potential correlation between c_i and S_{it} : more "able" individuals acquire more schooling and have higher wages.
- But, with identical twins, one can "difference out" the individual effect c_i.
- In first differences:

$$\Delta y_{it} = \beta_1 \Delta S_{it} + \beta_2' \Delta X_{it} + \Delta u_{it}$$

- Error term in the differenced equation is uncorrelated with RHS variable.

- Ashenfelter-Krueger: sampled 298 twins (149 pairs) at the annual Twins Day Festival in Twinsburg, OH.
- Every twin was asked about education, earnings, family background, other questions very similar to CPS questionnaire.
- Key question: every twin was also asked to report his/her sibling's level of schooling: get two independent measures of schooling to assess the extent of measurement error in years of schooling.

TABLE 3—ORDINARY LEAST-SQUARES (OLS), GENERALIZED LEAST-SQUARES (GLS), INSTRUMENTAL-VARIABLES (IV), AND FIXED-EFFECTS ESTIMATES OF LOG WAGE EQUATIONS FOR IDENTICAL TWINS[a]

Variable	OLS (i)	GLS (ii)	GLS (iii)	IV[a] (iv)	First difference (v)	First difference by IV (vi)
Own education	0.084 (0.014)	0.087 (0.015)	0.088 (0.015)	0.116 (0.030)	0.092 (0.024)	0.167 (0.043)
Sibling's education	—	—	−0.007 (0.015)	−0.037 (0.029)	—	—
Age	0.088 (0.019)	0.090 (0.023)	0.090 (0.023)	0.088 (0.019)	—	—
Age squared (÷100)	−0.087 (0.023)	−0.089 (0.028)	−0.090 (0.029)	−0.087 (0.024)	—	—
Male	0.204 (0.063)	0.204 (0.077)	0.206 (0.077)	0.206 (0.064)	—	—
White	−0.410 (0.127)	−0.417 (0.143)	−0.424 (0.144)	−0.428 (0.128)	—	—
Sample size:	298	298	298	298	149	149
R^2:	0.260	0.219	0.219	—	0.092	—

Notes: Each equation also includes an intercept term. Numbers in parentheses are estimated standard errors.

[a]Own education and sibling's education are instrumented for using each sibling's report of the other sibling's education as instruments.

Results

- FD estimate is higher than OLS estimate.
- IV (using twins' report on years of schooling) is also higher than OLS.
- Ashenfelter-Krueger interpretation: omitted ability bias not important, but measurement error bias is.
- Critique: even among identical twins there are differences, parents may either *compensate* or *reinforce.*
    - Omitted ability bias may be even more severe with the differenced data.

Angrist-Krueger (1991)

- Quarter of birth as an instrument for years of schooling.
- Compulsory schooling laws: students must stay in school until they turn 16.
- If students start 1^{st} grade in September of the calendar year in which they turn 6:
  - Students born in January turn 16 in the middle of 10th grade, can drop out with only 9 years of completed schooling.
  - Students born in December must wait until middle of 11th grade before they can drop out: 10 years of completed schooling.

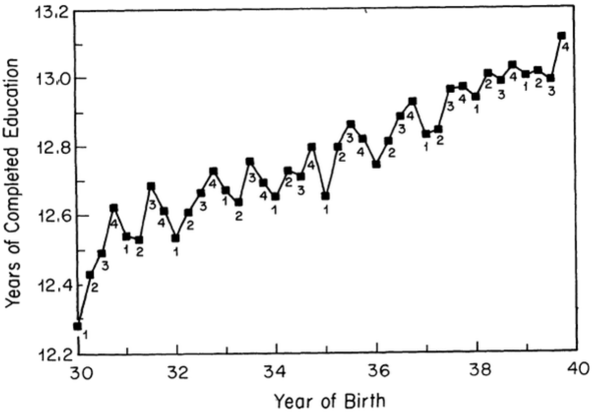


FIGURE I
Years of Education and Season of Birth
1980 Census
Note. Quarter of birth is listed below each observation.

- Consistent pattern that those born in Q1 have lower completed years of schooling.

TABLE I
THE EFFECT OF QUARTER OF BIRTH ON VARIOUS EDUCATIONAL OUTCOME VARIABLES

Outcome variable	Birth cohort	Mean	Quarter-of-birth effect[a] I	II	III	F-test[b] [P-value]
Total years of education	1930–1939	12.79	−0.124	−0.086	−0.015	24.9
			(0.017)	(0.017)	(0.016)	[0.0001]
	1940–1949	13.56	−0.085	−0.035	−0.017	18.6
			(0.012)	(0.012)	(0.011)	[0.0001]
High school graduate	1930–1939	0.77	−0.019	−0.020	−0.004	46.4
			(0.002)	(0.002)	(0.002)	[0.0001]
	1940–1949	0.86	−0.015	−0.012	−0.002	54.4
			(0.001)	(0.001)	(0.001)	[0.0001]
Years of educ. for high school graduates	1930–1939	13.99	−0.004	0.051	0.012	5.9
			(0.014)	(0.014)	(0.014)	[0.0006]
	1940–1949	14.28	0.005	0.043	−0.003	7.8
			(0.011)	(0.011)	(0.010)	[0.0017]
College graduate	1930–1939	0.24	−0.005	0.003	0.002	5.0
			(0.002)	(0.002)	(0.002)	[0.0021]
	1940–1949	0.30	−0.003	0.004	0.000	5.0
			(0.002)	(0.002)	(0.002)	[0.0018]
Completed master's degree	1930–1939	0.09	−0.001	0.002	−0.001	1.7
			(0.001)	(0.001)	(0.001)	[0.1599]
	1940–1949	0.11	0.000	0.004	0.001	3.9
			(0.001)	(0.001)	(0.001)	[0.0091]
Completed doctoral degree	1930–1939	0.03	0.002	0.003	0.000	2.9
			(0.001)	(0.001)	(0.001)	[0.0332]
	1940–1949	0.04	−0.002	0.001	−0.001	4.3
			(0.001)	(0.001)	(0.001)	[0.0050]

a. Standard errors are in parentheses. An $MA(+2, -2)$ trend term was subtracted from each dependent variable. The data set contains men from the 1980 Census, 5 percent Public Use Sample. Sample size is 312,718 for 1930–1939 cohort and is 457,181 for 1940–1949 cohort.

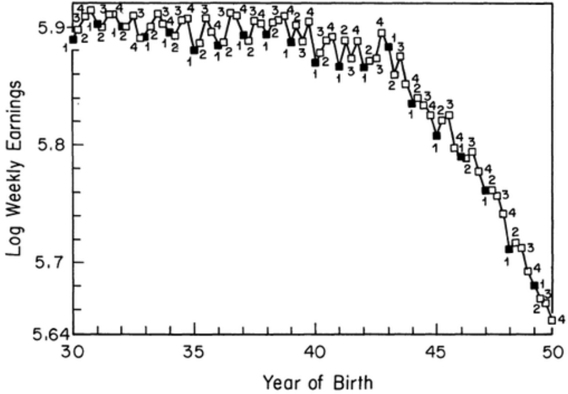


FIGURE V
Mean Log Weekly Wage, by Quarter of Birth
All Men Born 1930–1949; 1980 Census

- Q1 births have systematically lower earnings.

TABLE III

PANEL A: WALD ESTIMATES FOR 1970 CENSUS—MEN BORN 1920–1929[a]

	(1) Born in 1st quarter of year	(2) Born in 2nd, 3rd, or 4th quarter of year	(3) Difference (std. error) (1) − (2)
ln (wkly. wage)	5.1484	5.1574	−0.00898
			(0.00301)
Education	11.3996	11.5252	−0.1256
			(0.0155)
Wald est. of return to education			0.0715
			(0.0219)
OLS return to education[b]			0.0801
			(0.0004)

Panel B: Wald Estimates for 1980 Census—Men Born 1930–1939

	(1) Born in 1st quarter of year	(2) Born in 2nd, 3rd, or 4th quarter of year	(3) Difference (std. error) (1) − (2)
ln (wkly. wage)	5.8916	5.9027	−0.01110
			(0.00274)
Education	12.6881	12.7969	−0.1088
			(0.0132)
Wald est. of return to education			0.1020
			(0.0239)
OLS return to education			0.0709
			(0.0003)

a. The sample size is 247,199 in Panel A, and 327,509 in Panel B. Each sample consists of males born in the United States who had positive earnings in the year preceding the survey. The 1980 Census sample is drawn from the 5 percent sample, and the 1970 Census sample is from the State, County, and Neighborhoods 1 percent samples.

b. The OLS return to education was estimated from a bivariate regression of log weekly earnings on years of education.

TABLE IV
OLS AND TSLS ESTIMATES OF THE RETURN TO EDUCATION FOR MEN BORN 1920–1929: 1970 CENSUS[a]

Independent variable	(1) OLS	(2) TSLS	(3) OLS	(4) TSLS	(5) OLS	(6) TSLS	(7) OLS	(8) TSLS
Years of education	0.0802	0.0769	0.0802	0.1310	0.0701	0.0669	0.0701	0.1007
	(0.0004)	(0.0150)	(0.0004)	(0.0334)	(0.0004)	(0.0151)	(0.0004)	(0.0334)
Race (1 = black)	—	—	—	—	0.2980	−0.3055	−0.2980	−0.2271
					(0.0043)	(0.0353)	(0.0043)	(0.0776)
SMSA (1 = center city)	—	—	—	—	0.1343	0.1362	0.1343	0.1163
					(0.0026)	(0.0092)	(0.0026)	(0.0198)
Married (1 = married)	—	—	—	—	0.2928	0.2941	0.2928	0.2804
					(0.0037)	(0.0072)	(0.0037)	(0.0141)
9 Year-of-birth dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8 Region of residence dummies	No	No	No	No	Yes	Yes	Yes	Yes
Age	—	—	0.1446	0.1409	—	—	0.1162	0.1170
			(0.0676)	(0.0704)			(0.0652)	(0.0662)
Age-squared	—	—	−0.0015	−0.0014	—	—	−0.0013	−0.0012
			(0.0007)	(0.0008)			(0.0007)	(0.0007)
χ^2 [dof]	—	36.0 [29]	—	25.6 [27]	—	34.2 [29]	—	28.8 [27]

a. Standard errors are in parentheses. Sample size is 247,199. Instruments are a full set of quarter-of-birth times year-of-birth interactions. The sample consists of males born in the United States. The sample is drawn from the State, County, and Neighborhoods 1 percent samples of the 1970 Census (15 percent form). The dependent variable is the log of weekly earnings. Age and age-squared are measured in quarters of years. Each equation also includes an intercept.

Critique of Angrist-Krueger

- Is instrument exogenous?
  - seasonal patterns in birth for certain occupations (farmers, teachers).
  - children who enter school older are more mature, could have long-term effects on educational attainment and earnings (more learning, more self-esteem, maybe less incentive to please the teacher).
- Is instrument correlated with schooling?
  - yes, but correlation is not very strong.
  - problems with inference when instruments are weak, or there are too many of them (Bound, Jaeger and Baker, JASA 1995).
  - Stock and Staiger rule of thumb: first stage F-test should be above 10 for reliable IV inference.
- Still, AK is the mother of all IV studies.

TABLE II

OLS AND IV ESTIMATES OF THE RETURN TO EDUCATION WITH INSTRUMENTS BASED ON FEATURES OF THE SCHOOL SYSTEM

Author	Sample and Instrument		Schooling Coefficients OLS	IV
1. Angrist and Krueger (1991)	1970 and 1980 Census Data, Men. Instruments are quarter of birth interacted with year of birth. Controls include quadratic in age and indicators for race, marital status, urban residence.	1920–29 cohort in 1970	0.070 (0.000)	0.101 (0.033)
		1930–39 cohort in 1980	0.063 (0.000)	0.060 (0.030)
		1940–49 cohort in 1980	0.052 (0.000)	0.078 (0.030)
2. Staiger and Stock (1997)	1980 Census, Men. Instruments are quarter of birth interacted with state and year of birth. Controls are same as in Angrist and Krueger, plus indicators for state of birth. LIML estimates.	1930–39 cohort in 1980	0.063 (0.000)	0.098 (0.015)
		1940–49 cohort in 1980	0.052 (0.000)	0.088 (0.018)
3. Kane and Rouse (1993)	NLS Class of 1972, Women. Instruments are tuition at 2 and 4-year state colleges and distance to nearest college. Controls include race, part-time status, experience. Note: Schooling measured in units of college credit equivalents.	Models without test score or parental education	0.080 (0.005)	0.091 (0.033)
		Models with test scores and parental education	0.063 (0.005)	0.094 (0.042)
4. Card (1995b)	NLS Young Men (1966 Cohort) Instrument is an indicator for a nearby 4-year college in 1966, or the interaction of this with parental education. Controls include race, experience (treated as endogenous), region, and parental education	Models that use college proximity as instrument (1976 earnings)	0.073 (0.004)	0.132 (0.049)
		Models that use college proximity × family background as instrument	—	0.097 (0.048)

5. Conneely and Uusitalo (1997)	Finnish men who served in the army in 1982, and were working full time in civilian jobs in 1994. Administrative earnings and education data. Instrument is living in university town in 1980. Controls include quadratic in experience and parental education and earnings.	Models that exclude parental education and earnings	0.085 (0.001)	0.110 (0.024)
		Models that include parental education and earnings	0.083 (0.001)	0.098 (0.035)
6. Harmon and Walker (1995)	British Family Expenditure Survey 1978–86 (men). Instruments are indicators for changes in the minimum school leaving age in 1947 and 1973. Controls include quadratic in age, survey year, and region.		0.061 (0.001)	0.153 (0.015)
7. Ichino and Winter-Ebmer (1998)	Austria: 1983 Census, men born before 1946. Germany: 1986 GSOEP for adult men. Instrument is indicator for 1930–35 cohort. (Second German IV also uses dummy for father's veteran status). Controls include age, unemployment rate at age 14, and father's education (Germany only). Education measure is dummy for high school or more.	Austrian Men	0.518 (0.015)	0.947 (0.343)
		German Men	0.289 (0.031)	0.590/0.708 (0.844) (0.279)
8. Lemieux and Card (1998)	Canadian Census, 1971 and 1981: French-speaking men in Quebec and English-speaking in Ontario. Instrument is dummy for Ontario men age 19–22 in 1946. Controls include full set of experience dummies and Quebec-specific cubic experience profile.	1971 Census:	0.070 (0.002)	0.164 (0.053)
		1981 Census:	0.062 (0.001)	0.076 (0.022)
9. Meghir and Palme (1999)	Swedish Level of Living Survey (SLLS) data for men born 1945–55, with earnings in 1991, and Individual Statistics (IS) sample of men born in 1948 and 1953, with earnings in 1993. Instrument is dummy for attending "reformed" school system at age 13. Other controls include cohort, father's education, and county dummies. Models for IS data also include test scores at age 13.	SLLS Data (Years of education)	0.028 (0.007)	0.036 (0.021)
		IS Data (Dummy for 1–2 years of college relative to minimum schooling)	0.222 (0.020)	0.245 (0.082)

Summary

- Most IV estimates of the returns to schooling are higher than corresponding OLS estimates.
- Possible explanations:
  - Measurement error bias more important than omitted ability bias.
  - Small violations of exogeneity assumption are magnified in IV, especially if instruments are not very strong.
  - IV estimates only "Local Average Treatment Effect" (LATE), possible that students affected by compulsory schooling laws or proximity to college are those with relative high marginal costs/marginal returns.

Signaling

- All previous models assumed perfect information, variation in schooling is the result of rational agent's optimal intertemporal choice.
- Invest in education up to the point where marginal benefits of additional year of schooling are equal to marginal costs.
- All models assumed that investment in human capital is actually productive.
- But education may serve another purpose: select individuals of high ability for jobs.
- Even if education is completely unproductive, workers may still choose to invest in education to signal their high ability.

Spence's signaling model

- Two types of workers, productivity θ_H and θ_L, unrelated to level of schooling. Type is private information.
- Costs of acquiring education: $c_i\left(s,\theta\right) = s/\theta_i$.
  - high ability workers have lower costs of acquiring education.
- Utility:

$$U\left(w,s\right) = w - c\left(s,\theta\right)$$

- Sequence of the game:
  1. Workers choose s
  2. Firms enter market freely and make simultaneous wage offers.
  3. Workers accept or refuse offers.

Equilibrium

- Benchmark case: perfect information.
  - Worker ability is observed, every worker gets paid his/her marginal product θ_i.

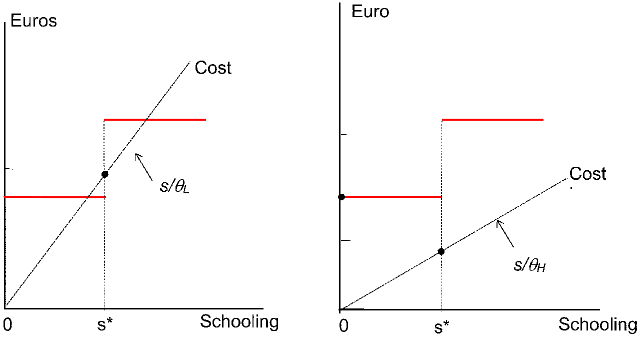
- Imperfect information: firms can't observe worker ability. Type of equilibrium depends on how large is the difference in c_i between high and low ability workers

- Pooling equilibrium: all workers are paid the same amount, $p\theta_H + (1-p)\,\theta_L$, where p is the proportion of high ability workers in the society.
    - high ability workers are worse off relative to perfect information case, low ability workers are better off.
    - high ability workers would like to have a way to credibly tell employers (to *signal*) that they are high ability.

- Separating equilibrium (one of many), either pay θ_H or θ_L:
    - low ability workers choose $s = 0$
    - high ability workers choose $s^* > 0$, where s^* is the minimum level of s necessary to induce separation:

$$\theta_H - s^*/\theta_H = \theta_L.$$

    - inefficient investment in education (relative to perfect information)
    - low ability workers definitely worse-off relative to pooling equilibrium
    - high ability workers can be better or worse off.


Euros
Cost
s/θ_L
0
s*
Schooling
Euro
Cost
s/θ_H
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s*
Schooling

Empirical evidence for signaling

- Jaeger and Page (RESTAT, 1996): "sheepskin effects".
- Does staying in school 12 years *without* completing a high school degree the same as staying in school and completing the degree? (i.e., getting a diploma, printed on sheepskin)
- Exploit transition in CPS between two different ways of measuring schooling: years of schooling, versus diplomas received.
- 1991-1992 CPS asked the question in both forms.

TABLE 1.—CROSS-TABULATION OF HIGHEST DEGREE RECEIVED BY COMPLETED YEARS OF EDUCATION

Years of Education	Highest Degree Received: None	High School	Some College	Occ. Assoc.	Acad. Assoc.	Bach.	Mast.	Prof.	Doct.	Year Total	Year Share
0 through 8	655	41	3	0	0	2	2	0	0	703	0.038
9	302	33	2	1	0	1	0	0	0	339	0.018
10	446	62	2	0	0	0	0	0	0	510	0.027
11	348	131	6	2	0	0	1	0	0	488	0.026
12	236	6,331	797	92	25	44	6	1	0	7,532	0.403
13	9	165	1,083	80	39	23	4	0	0	1,403	0.075
14	8	109	1,016	413	428	70	8	2	0	2,054	0.110
15	3	18	325	74	93	104	4	5	2	628	0.034
16	3	31	101	52	65	2,542	115	9	2	2,920	0.156
17	0	5	10	4		267	212	11	9	523	0.028
18 or more	0	13	12	4	8	197	987	211	167	1,599	0.086
Degree Total	2,010	6,939	3,357	722	663	3,250	1,339	239	180	18,699	
Degree Share	0.108	0.371	0.180	0.039	0.036	0.174	0.072	0.013	0.010		

Note: Tabulated from a matched sample of individuals 25 to 64 years old with positive wage and salary income, weeks worked, and usual hours worked from the 1991 and 1992 March Current Population Survey.

TABLE 2.—ESTIMATED DIPLOMA EFFECTS FOR WHITE MEN USING DIFFERENT SPECIFICATIONS

Coefficient	Model (1)	(2)	(3)	(4)
Completed Years of Education (Spline)				
Years of Education (S)	0.076	0.076		
	(0.018)	(0.018)		
$S \geq 8$	−0.141	−0.112		
	(0.080)	(0.078)		
$(S \geq 8) \cdot (S - 8)$	0.002	−0.022		
	(0.027)	(0.023)		
$S \geq 12$	0.034			
	(0.053)			
$(S \geq 12) \cdot (S - 12)$	−0.006	−0.019		
	(0.022)	(0.017)		
$S \geq 16$	0.114			
	(0.035)			
$S = 17$	−0.055			
	(0.042)			
$S = 18$	−0.006			
	(0.031)			
Completed Years of Education (Dummy)				
9			−0.227	−0.109
			(0.049)	(0.061)
10			−0.164	−0.046
			(0.040)	(0.054)
11			−0.137	−0.044
			(0.043)	(0.051)
12			ref.	ref.
13			0.089	0.020
			(0.027)	(0.033)
14			0.167	0.073
			(0.022)	(0.031)
15			0.166	0.052
			(0.038)	(0.044)
16			0.406	0.178
			(0.019)	(0.045)
17			0.422	0.164
			(0.039)	(0.057)
18 or more			0.544	0.224
			(0.023)	(0.054)
Diploma Effects				
High School		0.106		0.123
		(0.037)		(0.041)
Marginal Effect Over High School				
Some College, No Degree		0.074		0.083
		(0.022)		(0.027)
Occupational Associate's		0.074		0.076
		(0.039)		(0.043)
Academic Associate's		0.188		0.191

Altonji and Pierret (QJE, 1997)

- Basic idea: when workers are first hired, they can signal ability through education, returns to education large for newly hired workers.
- But, low returns to unobservable ability (AFQT scores) when first hired.
- As time goes by, employers learn about true ability, education signal becomes less important, true ability more important.
  - Returns to education decline with tenure
  - Returns to AFQT increase with tenure.
- (Caveat: the conclusion is correct only if one controls in the regression for both education and AFQT. If you don't have AFQT scores, then coefficient on education should not change over time)

TABLE I

THE EFFECTS OF STANDARDIZED AFQT AND SCHOOLING ON WAGES

Dependent Variable: Log Wage; OLS estimates (standard errors).

Panel 1—Experience measure: potential experience				
Model:	(1)	(2)	(3)	(4)
(a) Education	0.0586	0.0829	0.0638	0.0785
	(0.0118)	(0.0150)	(0.0120)	(0.0153)
(b) Black	−0.1565	−0.1553	0.0001	−0.0565
	(0.0256)	(0.0256)	(0.0621)	(0.0723)
(c) Standardized AFQT	0.0834	−0.0060	0.0831	0.0221
	(0.0144)	(0.0360)	(0.0144)	(0.0421)
(d) Education * experience/10	−0.0032	−0.0234	−0.0068	−0.0193
	(0.0094)	(0.0123)	(0.0095)	(0.0127)
(e) Standardized AFQT * experience/10		0.0752		0.0515
		(0.0286)		(0.0343)
(f) Black * experience/10			−0.1315	−0.0834
			(0.0482)	(0.0581)
R^2	0.2861	0.2870	0.2870	0.2873