Web Appendix to

"Estimating Marginal Returns to Education"

September 27, 2010

Description of the Data

Our sample is white males from the NLSY.[1] We define participation in college as having attended some college or having completed more than 12 grades in school. The wage variable that is used is an average of deflated (to 1983) non-missing hourly wages reported in 1989, 1990, 1991, 1992 and 1993. We delete all wage observations that are below 1 or above 100. Experience is actual work experience in weeks (we divide it by 52 to express it as a fraction of a year) accumulated from 1979 to 1991 (annual weeks worked are imputed to be zero if they are missing in any given year). The remaining variables that we include in the X and Z vectors are mother's years of schooling, number of siblings, urban residence at 14, schooling corrected AFQT, dummies indicating the year of birth, the presence of a four-year college in the county of residence at age 14 (from Kling, 2001),[2] average tuition in public four year colleges in the county of residence at age 17 (deflated to 1993) local average earnings in the county of residence at 17 and local unemployment rate in state of residence at age 17, and in 1991. Permanent local earnings and unemployment are computed by location of residence at 17 (county for wages, state for unemployment), by averaging values of (deflated) local labor market variables between 1973 and 2000. County earnings correspond to the average wage per job in the county constructed using data from the Bureau of Economic Analysis, deflated to 2000. The state unemployment rate data come from the BLS website. However, from the BLS website it is not possible to get state unemployment data for all states for all the 1970s. Data are available for all states from 1976 on, and for 29 states for 1973, 1974 and 1975. Therefore for some of the individuals we have to assign them the unemployment rate in the state of residence in 1976 (which will correspond to age 19 for those born in 1957 and age 18 for those born in 1958). Annual records on tuition, enrollment, and location of all public four year colleges in the United States were constructed from the Department of Education's annual Higher Education General Information Survey and Integrated Postsecondary Education Data System "Institutional Characteristics" surveys. By matching location with county of residence, we determined

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[1]For a description of the NLSY 1979, see Bureau of Labor Statistics (2001).

[2]The distance variable we use is the one used in Kling (2001), available at the *Journal of Business and Economics Statistics* website.

the presence of four-year colleges. Tuition measures are taken as enrollment weighted averages of all public four-year colleges in a person's county of residence (if available) or at the state level if no college is available. County and state of residence at 17 are not available for everyone in the NLSY, but only for the cohorts born in 1962, 1963 and 1964 (age 17 in 1979, 1980 and 1981). However, county and state of residence at age 14 is available for most respondents. Therefore, we impute location at 17 to be equal to location at 14 for cohorts born between 1957 and 1962 unless location at 14 is missing, in which case we use location in 1979 for the imputation. Many individuals report having obtained a bachelors degree or more and, at the same time, having attended only 15 years of schooling (or less). We recode years of schooling for these individuals to be 16. This variable is only used to annualize the returns to schooling (divide returns to college by 4, which is the average difference in years of schooling between individuals in each schooling group. The NLSY79 has an oversample of poor whites which we exclude from this analysis. We also exclude the military sample. To remove the effect of schooling on AFQT we implement the procedure of Hansen, Heckman, and Mullen (2004). See the estimates reported in Table A-2.

References

Bureau of Labor Statistics. 2001. *NLS Handbook 2001: The National Longitudinal Surveys*. Washington, DC: U.S. Department of Labor.

Hansen, Karsten T., James J. Heckman, and Kathleen J. Mullen. 2004. "The Effect of Schooling and Ability on Achievement Test Scores." *Journal of Econometrics*, 121(1-2):39–98.

Kling, Jeffrey R. 2001. "Interpreting Instrumental Variables Estimates of the Returns to Schooling." *Journal of Business and Economic Statistics*, 19(3):358–364.

Treatment Effects and Estimands as Weighted Averages
of the Marginal Treatment Effect

$ATE(x) = \int_0^1 MTE(x, u_S) du_S$
$TT(x) = \int_0^1 MTE(x, u_S) h_{IV}(x, u_S) du_S$
$TUT(x) = \int_0^1 MTE(x, u_S) h_{TUT}(x, u_S) du_S$
$PRTE(x) = \int_0^1 MTE(x, u_S)\, h_{PRTE}(x, u_S)\, du_S.$
$IV(x) = \int_0^1 MTE(x, u_S) h_{IV}(x, u_S) du_S$
$OLS(x) = \int_0^1 MTE(x, u_S) h_{OLS}(x, u_S) du_S$

Table A-1B
Weights for $ATE, TT, TUT, PRTE, IV$ and OLS

$h_{ATE}(x, u_S) = 1$
$h_{TT}(x, u_S) = \left[\int_{u_S}^1 f(p \mid X = x) dp\right] \dfrac{1}{E(P \mid X = x)}$
$h_{TUT}(x, u_S) = \left[\int_0^{u_S} f(p \mid X = x) dp\right] \cdot \dfrac{1}{E((1-P) \mid X = x)}$
$h_{PRTE}(x, u_S) = \left[\dfrac{F_{P^*,X}(u_S) - F_{P,X}(u_S)}{\Delta P}\right]$
$h_{IV}(x, u_S) = \left[\int_{u_S}^1 (p\text{-}E(P \mid X = x)) f(p \mid X = x) dp\right] \dfrac{1}{Var(P \mid X = x)}$ [for $P(Z)$ as the instrument]*
$h_{OLS} = \dfrac{E(U_1 \mid X = x, U_S = u_S) h_1(x, u_D)\text{-}E(U_0 \mid X = x, U_S = u_S) h_0(x, u_S)}{MTE(x, u_S)}$
$h_1(x, u_S) = \left[\int_{u_S}^1 f(p \mid X = x) dp\right] \dfrac{1}{E(P \mid X = x)}$
$h_0(x, u_S) = \left[\int_0^{u_S} f(p \mid X = x) dp\right] \dfrac{1}{E((1-P) \mid X = x)}$

Source: Heckman and Vytlacil (2005).
*For a general instrument, see Heckman, Urzua, and Vytlacil (2006) or Heckman and Vytlacil (2007b).

Table A-2
Regression of AFQT on Schooling at Test Date
and Completed Schooling

Schooling at Test Date	Coefficient
9	12.6802
	(1.5105)
10	16.9406
	(1.5158)
11	22.0232
	(1.5354)
12	23.1203
	(1.4901)
13 to 15	26.6032
	(1.7298)
16 or greater	29.0213
	(2.1278)

Note: These are coefficients of the AFQT score on schooling at test date and completed schooling:

$$\text{AFQT} = \delta_0 + \Sigma_{ST} D_{ST} \delta_{ST} + \Sigma_{SC} D_{SC} \delta_{SC} + \eta$$

D_{ST} are dummy variables, one for each level of schooling at test date and δ_{ST} are the coefficients on these variables. D_{SC} are dummy variables, one for each level of completed schooling and δ_{SC} are the coefficients on these variables. The omitted category in the table is "less or equal to eight years of schooling."

	$S = 0$ ($N = 882$)	$S = 1$ ($N = 865$)
Log of Average Hourly Wage 1989-1993	2.2089	2.5496
	(0.4412)	(0.4959)
Years of Actual Experience	10.1042	6.8404
	(3.1260)	(3.2522)
Corrected AFQT	-0.0446	0.9515
	(0.8673)	(0.7498)
Mother's Years of Schooling	11.3083	12.9121
	(2.1056)	(2.2789)
Number of Siblings	3.2630	2.5849
	(2.0842)	(1.6450)
Urban Residence at 14	0.6995	0.7895
	(0.4587)	(0.4078)
Local Log Earnings in 1991	10.2645	10.3220
	(0.1597)	(0.1660)
Local Unemployment in 1991	6.7971	6.8226
(in %)	(1.3310)	(1.1983)
Presence of a 4 Year College at 14	0.4625	0.5884
	(0.4988)	(0.4924)
Local Log Earnings at 17	10.2780	10.2736
	(0.1619)	(0.1651)
Local Unemployment Rate at 17	7.0804	7.0846
(in %)	(1.7846)	(1.8449)
Tuition in 4 Year Public Colleges at 17	22.0164	21.1105
(in $100)	(7.8730)	8.0683
"Permanent" Local Log Earnings at 17	10.2673	10.2991
	(0.1798)	(0.1945)
"Permanent" Local Unemployment Rate at 17	6.2942	6.2077
	(1.0156)	(0.9536)

Note: Corrected AFQT corresponds to a standardized measure of the Armed Forces Qualifying Test score corrected for the fact that different individuals have different amounts of schooling at the time they take the test (see Hansen, Heckman and Mullen, 2004). This variable is standardized within the NLSY sample to have mean zero and variance 1. Local earnings and unemployment rates are averages across all individuals in the population residing in a given area (county for log earnings, state for unemployment), independent of age, gender, race, and skill level. For each location, "Permanent" local earnings and unemployment are based on the average of each variable between 1973 and 2000 (and then assigns it to the location of residence at 17). We use only white males from the NLSY79, excluding the oversample of poor whites and the military sample. Standard deviations are in parentheses.

	Coefficient	Average Derivative
CONTROLS (X):		
Corrected AFQT	8.2491	0.2826
	(5.1332)	(0.0114)***
Corrected AFQT Squared	0.3560	
	(0.0725)***	
Mother's Years of Schooling	-2.8522	0.0441
	(2.0466)	(0.0059)***
Mother's Years of Schooling Squared	0.0159	
	(0.0070)**	
Number of Siblings	-7.0471	-0.0233
	(2.3462)***	(0.0068)***
Number of Siblings Squared	0.0032	
	(0.0118)	
Urban Residence at 14	0.1819	0.0340
	(0.1481)	(0.0274)
"Permanent" Local Log Earnings at 17	-95.5184	0.1820
	(31.1053)***	(0.0941)**
"Permanent" Local Log Earnings at 17 Squared	4.6890	
	(1.5180)***	
"Permanent" State Unemployment Rate at 17	0.5161	0.0058
	(0.6713)	(0.0165)
"Permanent" State Unemployment Rate at 17 Squared	-0.0386	
	(0.0511)	
INSTRUMENTS (Z):		
Presence of a College at 14	1.2247	0.0529
	(0.9240)	(0.0273)**
* AFQT	0.2817	
	(0.1734)*	
* Mother's Education	-0.0981	
	(0.0726)*	
* Number of Siblings	0.0340	
	(0.0737)	
Local Log Earnings at 17	-6.4594	-0.2687
	(2.6744)**	(0.1008)***
* AFQT	-0.7114	
	(0.5086)	
* Mother's Education	0.2838	
	(0.2019)	
* Number of Siblings	0.6867	
	(0.2324)***	
Local Unemployment Rate at 17	0.7294	0.0149
(in %)	(0.2506)***	(0.0100)
* AFQT	-0.0261	
	(0.0464)	
* Mother's Education	-0.0505	
	(0.0193)***	
* Number of Siblings	-0.0106	
	(0.0198)	
Tuition in 4 Year Public Colleges at 17	-0.1229	-0.0027
(in $100)	(0.0617)**	(0.0017)*
* AFQT	0.0125	
	(0.0113)	
* Mother's Education	0.0095	
	(0.0049)**	
* Number of Siblings	-0.0043	
	(0.0049)	
Test for joint significance of instruments: p-value	0.0001	

Note: This table reports the coefficients and average marginal derivatives from a logit regression of college attendance (a dummy variable that is equal to 1 if an individual has ever attended college and equal to 0 if he has never attended college but has graduated from high school) on polynomials in the set of variables listed in the table and on cohort dummies (not reported). For each individual we compute the effect of increasing each variable by one unit (keeping all the others constant) on the probability of enrolling in college and then we average across all individuals. Bootstrapped standard errors (in parentheses) are presented below the corresponding parameters (250 replications). At the bottom we present p-value for the test of joint significance of coefficients on the instruments (bottom 12 variables of the table). Corrected AFQT corresponds to a standardized measure of the Armed Forces Qualifying Test score corrected for the fact that different individuals have different amounts of schooling at the time they take the test (see Hansen, Heckman and Mullen, 2004). This variable is standardized within the NLSY sample to have mean zero and variance 1. Local earnings and unemployment rates are averages across all individuals in the population residing in a given area (county for log earnings, state for unemployment), independent of age, gender, race, and skill level. For each location, "Permanent" local earnings and unemployment takes the average of each variable between 1973 and 2000 (and then assigns it to the location of residence at 17). *** Significant at 1%. ** Significant at 5%. * Significant at 10%.

Table A-5

Test of Linearity of $E\left(Y \mid X, P=p\right)$ using polynomials in P[a]

Degree of Polynomial	2	3	4	5
p-value of joint test of nonlinear terms	0.004	0.006	0.022	0.026
Adjusted critical value		0.0518		
Outcome of test:		Reject		

The size of the test is controlled using a critical value constructed by the bootstrap method of Romano and Wolf (2005) (10% significance level). Standard errors account for the fact that P is estimated, by using the bootstrap (double-bootstrap procedure).

	$\mu_1(X)$	$\mu_0(X)$	$\mu_Z(X)$
CONTROLS (X):			
Years of Experience	0.0794	0.0540	
	(0.0180)	(0.0203)	
Years of Experience Squared	-0.0035	0.0004	
	(0.0012)	(0.0011)	
Local Log Earnings in 1991	0.8319	0.5766	
	(0.1080)	(0.1066)	
Local Unemployment in 1991	0.0032	-0.0037	
	(0.0155)	(0.0147)	
Corrected AFQT	0.1222	0.0506	3.6671
	(0.0468)	(0.0267)	(2.8315)
Corrected AFQT Squared	0.0546	-0.0494	0.2008
	(0.0186)	(0.0168)	(0.0384)
Mother's Years of Schooling	-0.0097	-0.0186	-1.8348
	(0.0460)	(0.0300)	(1.1254)
Mother's Years of Schooling Squared	0.0014	0.0009	0.0096
	(0.0017)	(0.0014)	(0.0040)
Number of Siblings	-0.0102	0.0043	-4.2234
	(0.0277)	(0.0173)	(1.3538)
Number of Siblings Squared	0.0002	-0.0005	0.0016
	(0.0036)	(0.0017)	(0.0067)
Urban Residence at 14	0.0547	0.0077	0.1058
	(0.0403)	(0.0307)	(0.0864)
"Permanent" Local Log Earnings at 17	0.8999	12.5816	-52.9084
	(7.0669)	(7.2287)	(17.4845)
"Permanent" Local Log Earnings at 17 Squared	-0.0431	-0.6056	2.5985
	(0.3445)	(0.3532)	(0.8533)
"Permanent" State Unemployment Rate at 17	0.1459	0.0717	0.2693
	(0.1683)	(0.1356)	(0.3829)
"Permanent" State Unemployment Rate at 17 Squared	-0.0135	-0.0059	-0.0205
	(0.0132)	(0.0104)	(0.0292)
INSTRUMENTS (Z):			
Presence of a College at 14			0.7519
			(0.5037)
* AFQT			0.1585
			(0.0948)
* Mother's Education			-0.0559
			(0.0397)
* Number of Siblings			0.0103
			(0.0423)
Local Log Earnings at 17			-4.0536
			(1.4791)
* AFQT			-0.3072
			(0.2805)
* Mother's Education			0.1846
			(0.1112)
* Number of Siblings			0.4107
			(0.1343)
Local Unemployment Rate at 17 (in %)			0.4251
			(0.1401)
* AFQT			-0.0075
			(0.0255)
* Mother's Education			-0.0309
			(0.0107)
* Number of Siblings			-0.0026
			(0.0116)
Tuition in 4 Year Public Colleges at 17 (in $100)			-0.0520
			(0.0337)
* AFQT			0.0065
			(0.0061)
* Mother's Education			0.0044
			(0.0026)
* Number of Siblings			-0.0033
			(0.0029)

Note: This table reports the maximum likelihood estimates of the coefficients of the variables in the selection and outcome equations for the normal selection model. The model also includes cohort dummies which are not reported.

Table A-7

Average Derivatives for the Wage Equation - Estimates from the Partially Linear Model

|	$\mu_0(X)$	$\mu_1(X) - \mu_0(X)$
Years of Experience	0.0439	-0.0608
	(0.0014)***	(0.0209)***
Local Log Earnings in 1991	0.4550	0.6570
	(0.1645)***	(0.3002)**
Local Unemployment in 1991	0.0020	0.0030
	(0.0240)	(0.0436)
Corrected AFQT	-0.1297	0.3723
	(0.1064)	(0.2112)*
Mother's Years of Schooling	0.0094	0.0016
	(0.0200)	(0.0325)
Number of Siblings	0.0270	-0.0277
	(0.0521)	(0.0305)
Urban Residence at 14	0.0173	-0.0280
	(0.0165)	(0.0957)
"Permanent" Local Log Earnings at 17	0.1249	-0.3051
	(0.1639)	(0.2594)
"Permanent" State Unemployment Rate at 17	-0.0005	-0.0395
	(0.0303)	(0.0557)

Note: *** Significant at 1%. ** Significant at 5%. * Significant at 10%. This table reports the coefficients on the variables in the outcome equations for the semi-parametric selection model. These coefficients are obtained using Robinson's (1989) partially linear regression method. The model also includes cohort dummies which are not reported. Standard Errors are Bootstrapped (250 Replications).

Table A-8 - OLS and IV Estimates of the Return to a Year of College

	OLS	IV					
		Presence of a college	Local earnings of unskilled workers	Local unemployment	Average Tuition in 4 year colleges	Two stage least squares using all instruments	$P(Z)$ as the instrument
Return to College	0.0836	0.0576	0.1736	0.1582	0.1211	0.1253	0.0951
	(0.0068)	(0.0727)	(0.0788)	(0.1897)	(0.0909)	(0.0433)	(0.0386)

Note: This table reports OLS and IV estimates of the return to college attendance (a dummy variable that is equal to 1 if an individual has ever attended college and equal to 0 if he has never attended college but has graduated from high school). The coefficient on college is divided by 4 to reflect the difference in years of schooling between those with and without college. Instruments are the presence of a college in the county of residence at 14, local earnings and local unemployment in the area of residence at 17, and average tuition in public 4 year colleges in the county of residence at 17 (interacted with AFQT, mother's education and number of siblings). Standard Errors are bootstrapped (250 replications).

Figure A-1: Weights for IV and two other versions of the MPRTE
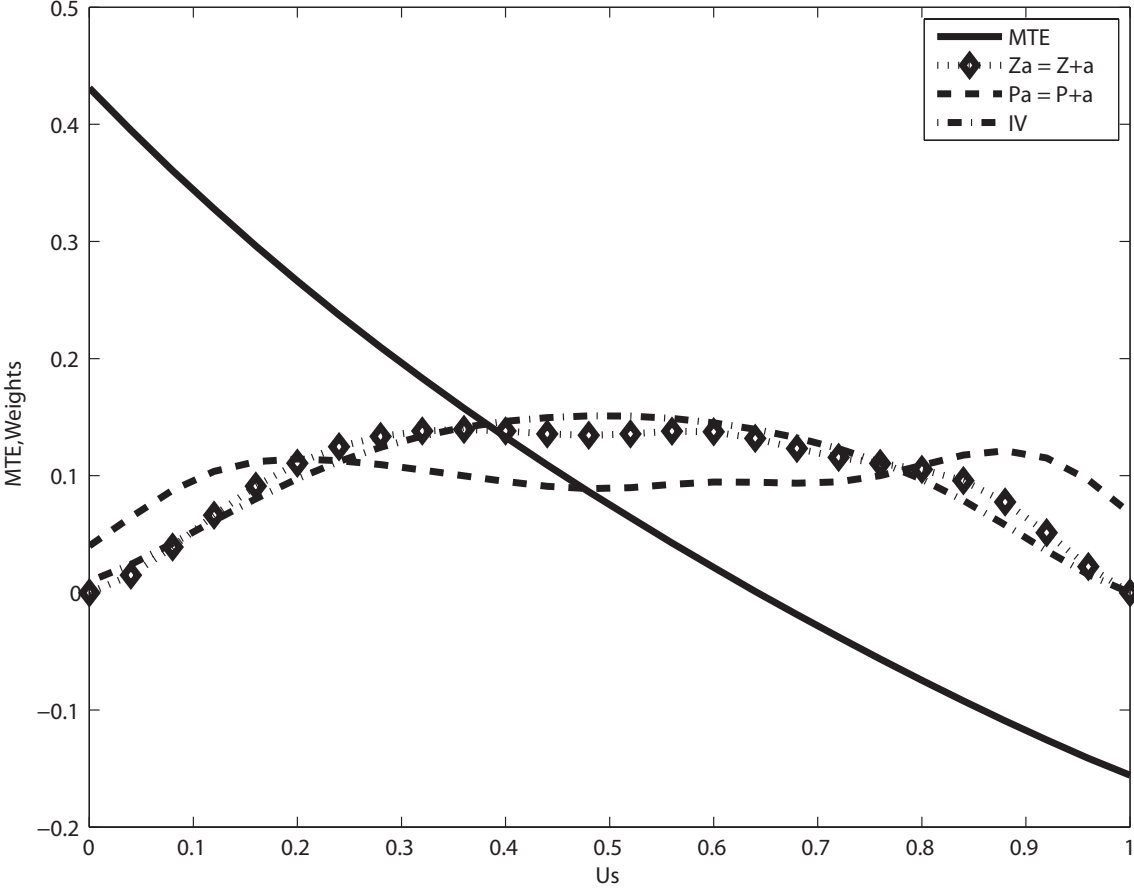
Notes: The scale of the y-axis is the scale of the MTE, not the scale of the weights, which are scaled to fit the picture.