Causal Inference for Complex Observational Data Using Stata

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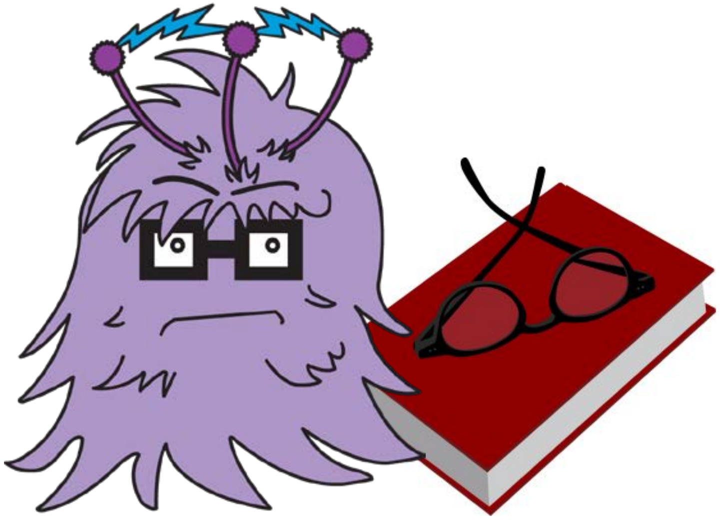
ERMs Outline

- Description of the dataset
- Unobserved confounding and endogeneity
- Nonrandom treatment assignment
- Missing not at random (MNAR) and selection bias
- Treatment effects

The Research Question

- Fictional State University (FSU) has developed a new study-skills program with the goal of improving the grade point averages of their students.



The Data

```
. use gpa.dta, clear
(Simulated GPA Dataset for ERMs seminars)


. describe

Contains data from gpa.dta
  obs:         1,000                          Simulated GPA Dataset for ERMs seminars
 vars:             9                          22 Jan 2018 16:06
 size:        22,000                          (_dta has notes)
--------------------------------------------------------------------------------------------------
              storage   display    value
variable name   type    format     label      variable label
--------------------------------------------------------------------------------------------------
id              int     %9.0g                 Student Identification Number
gpa             float   %9.0g                 Final College Grade Point Average
hsgpa           float   %9.0g                 High School Grade Point Average
program         byte    %9.0g      YesNo      Student participated in the study skills program?
graduate        byte    %9.0g      YesNo      Did the student graduate college?
income          float   %9.0g                 Parent's Income (x $100,000)
hs_comp         float   %9.0g                 High School Competitiveness
roommate        byte    %9.0g      YesNo      Students's roommate is also a student?
scholarship     byte    %9.0g      YesNo      Student received scholarship funds?
--------------------------------------------------------------------------------------------------
Sorted by: id
```

The Data

```
. summarize
```

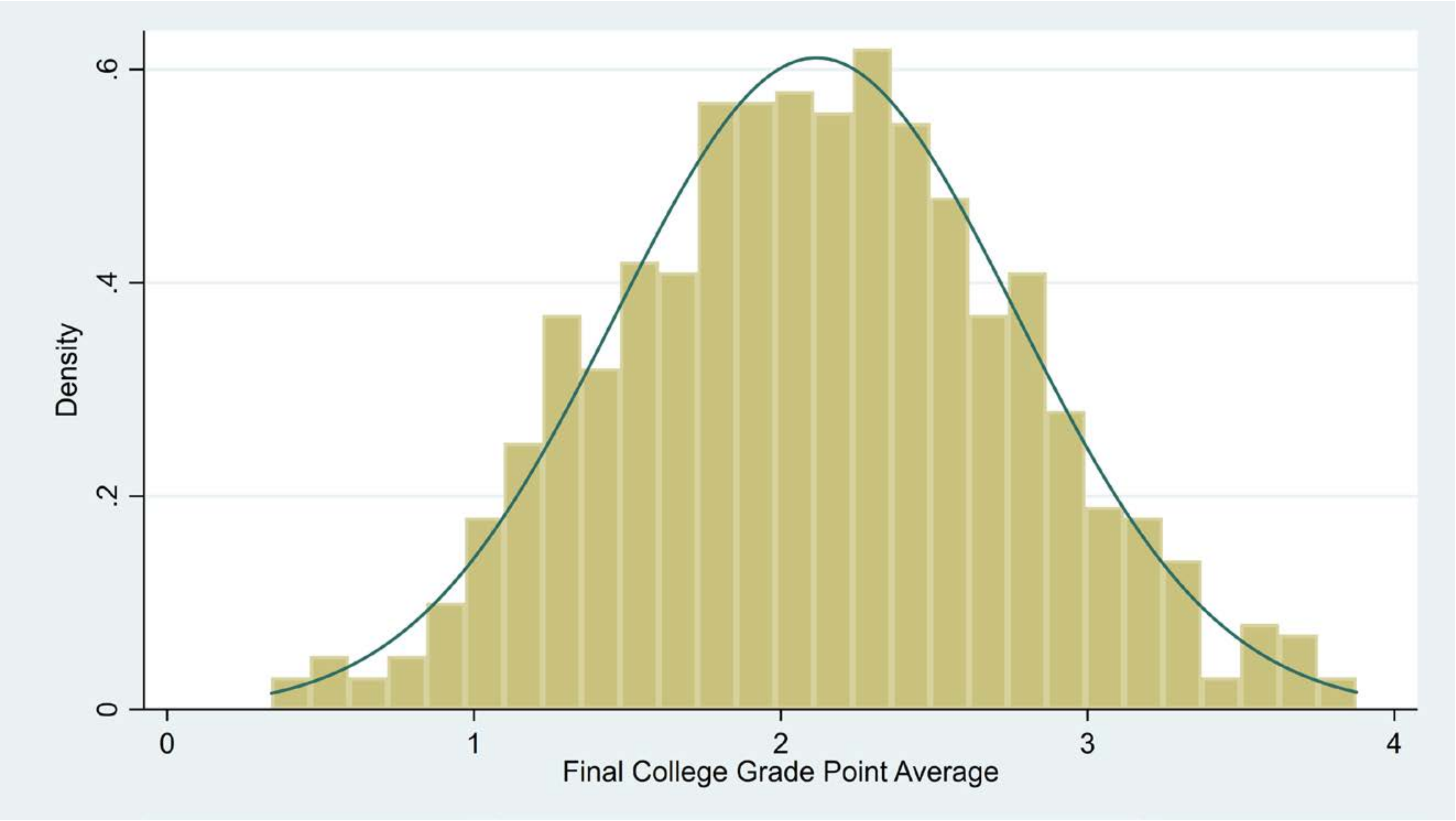
Variable	Obs	Mean	Std. Dev.	Min	Max
id	1,000	500.5	288.8194	1	1000
gpa	$\boxed{792}$	2.115962	.6529961	.3392706	3.876919
hsgpa	1,000	2.294384	.5714525	.6758502	3.786486
program	1,000	.3	.4584869	0	1
graduate	1,000	.792	.4060799	0	1
income	1,000	.5031867	.2848887	.0004344	.9969745
hs_comp	1,000	.4946027	.286164	.0001878	.9985294
roommate	1,000	.321	.4670944	0	1
scholarship	1,000	.32	.4667096	0	1

The Data

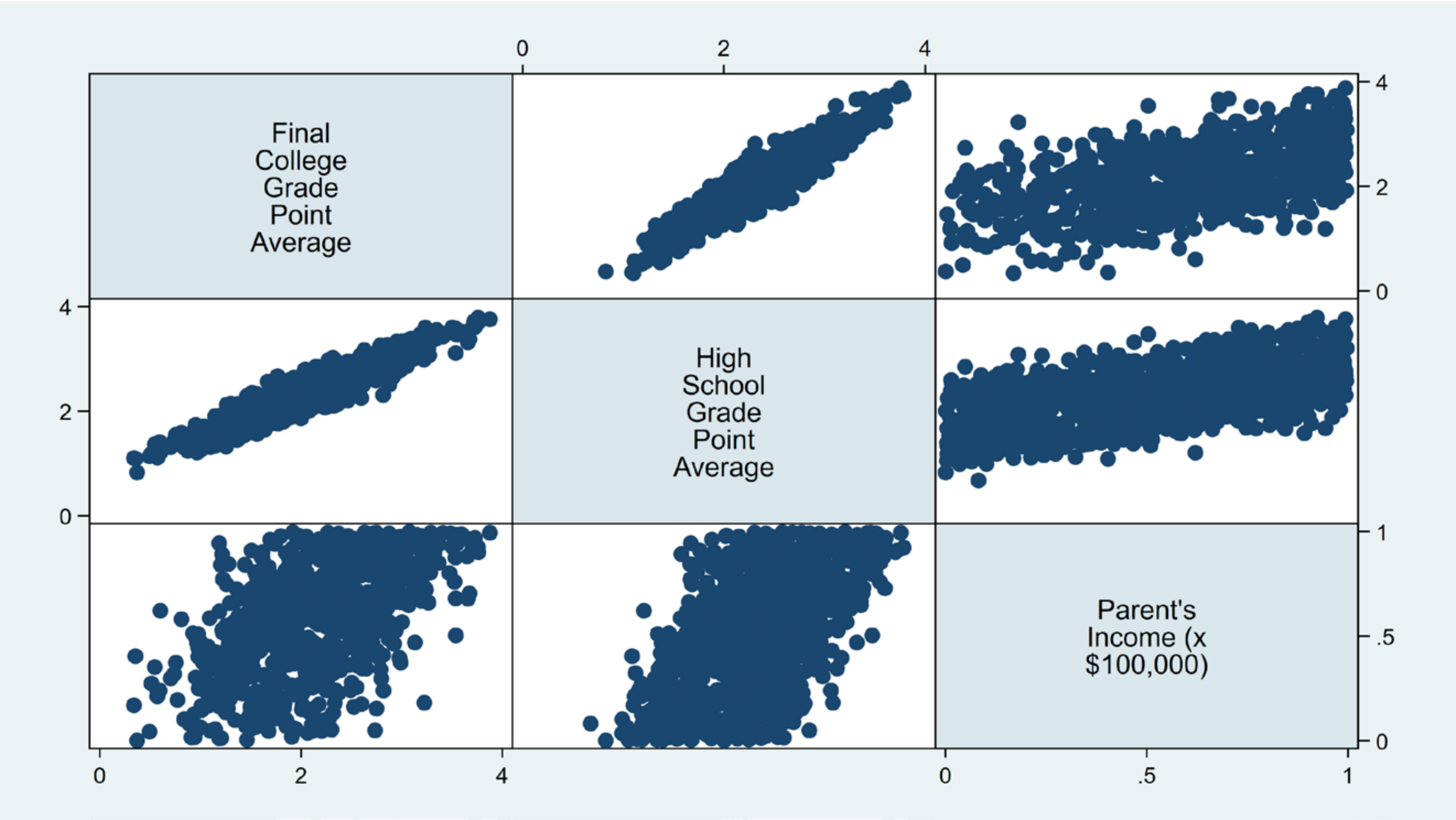
```
. tab graduate
```

Did the student graduate college?	Freq.	Percent	Cum.
No	208	20.80	20.80
Yes	792	79.20	100.00
Total	1,000	100.00	

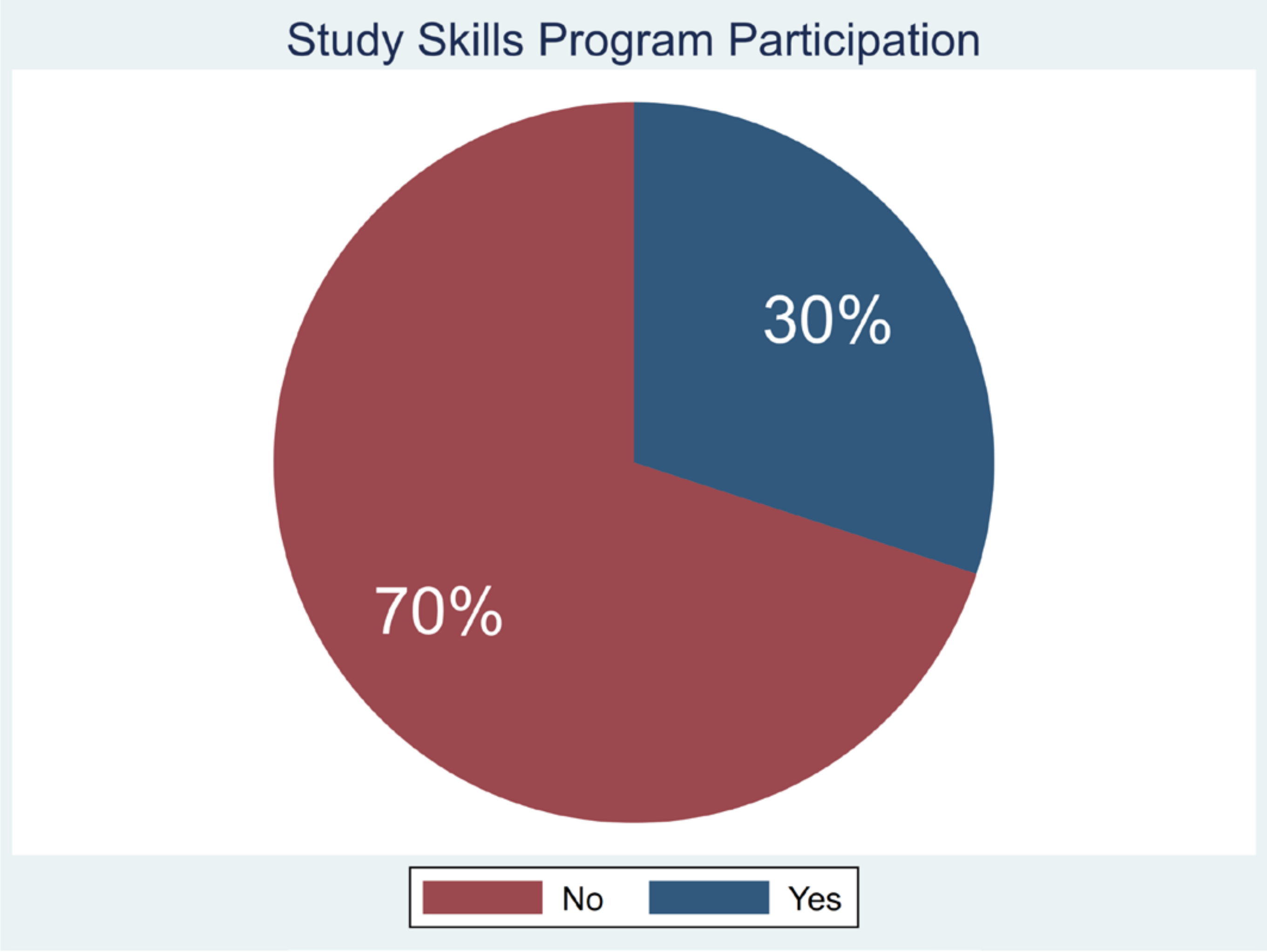
The Data



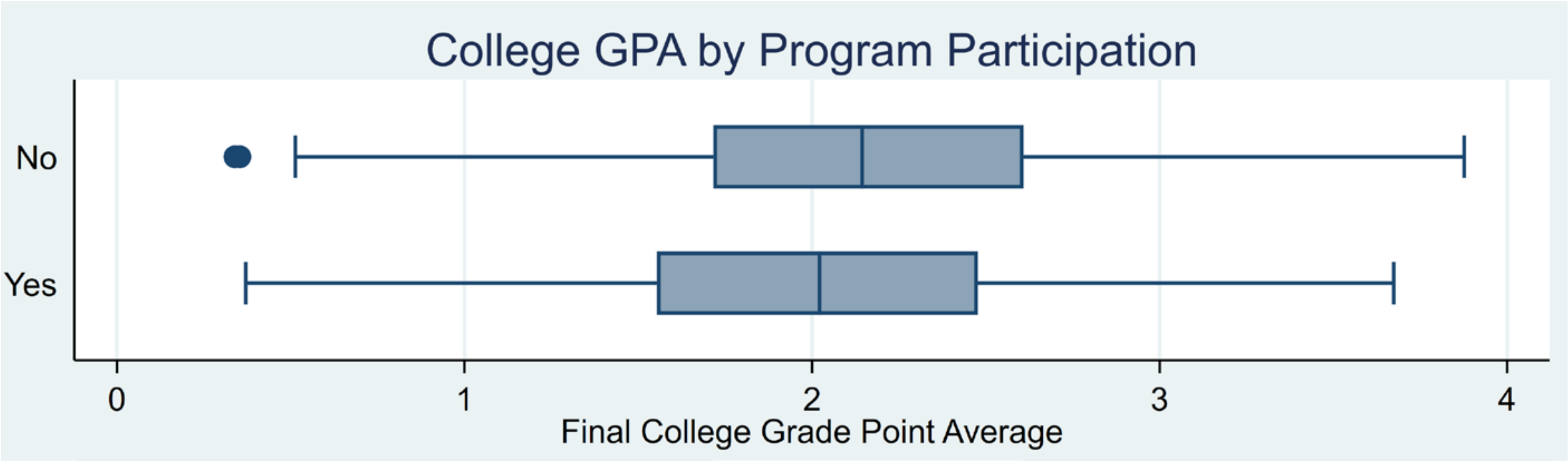
The Data


Final College Grade Point Average
High School Grade Point Average
Parent's Income (x $100,000)
0
2
4
0
.5
1

The Data



The Data

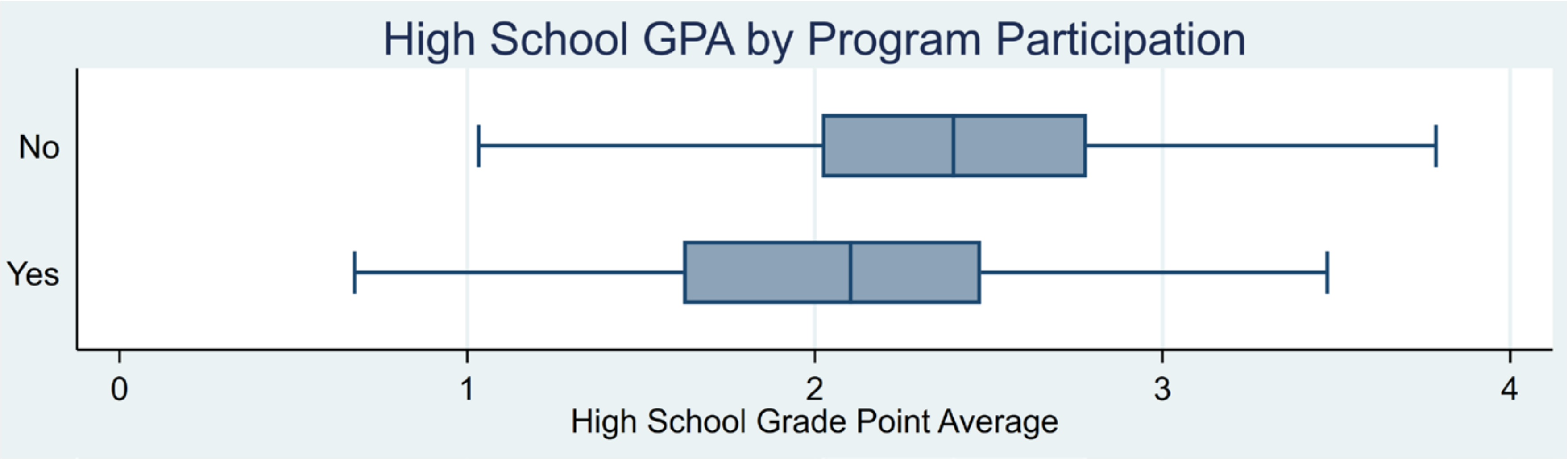

College GPA by Program Participation
No
Yes
0
1
2
3
4
Final College Grade Point Average

The Data

```
. regress gpa i.program

      Source |       SS           df       MS      Number of obs   =       792
-------------+----------------------------------   F(1, 790)       =      5.74
       Model |  2.43242384         1  2.43242384   Prob > F        =    0.0168
    Residual |  334.853048       790  .423864618   R-squared       =    0.0072
-------------+----------------------------------   Adj R-squared   =    0.0060
       Total |  337.285472       791  .426403884   Root MSE        =    .65105

------------------------------------------------------------------------------
         gpa |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     program |
        Yes  |  -.1259343     .05257    -2.40   0.017    -.2291278   -.0227409
       _cons |   2.149036   .0269406    79.77   0.000     2.096152    2.201919
------------------------------------------------------------------------------

. estimates store univar
```

Students who participated in the program had **lower** GPAs?!?!?

The Data

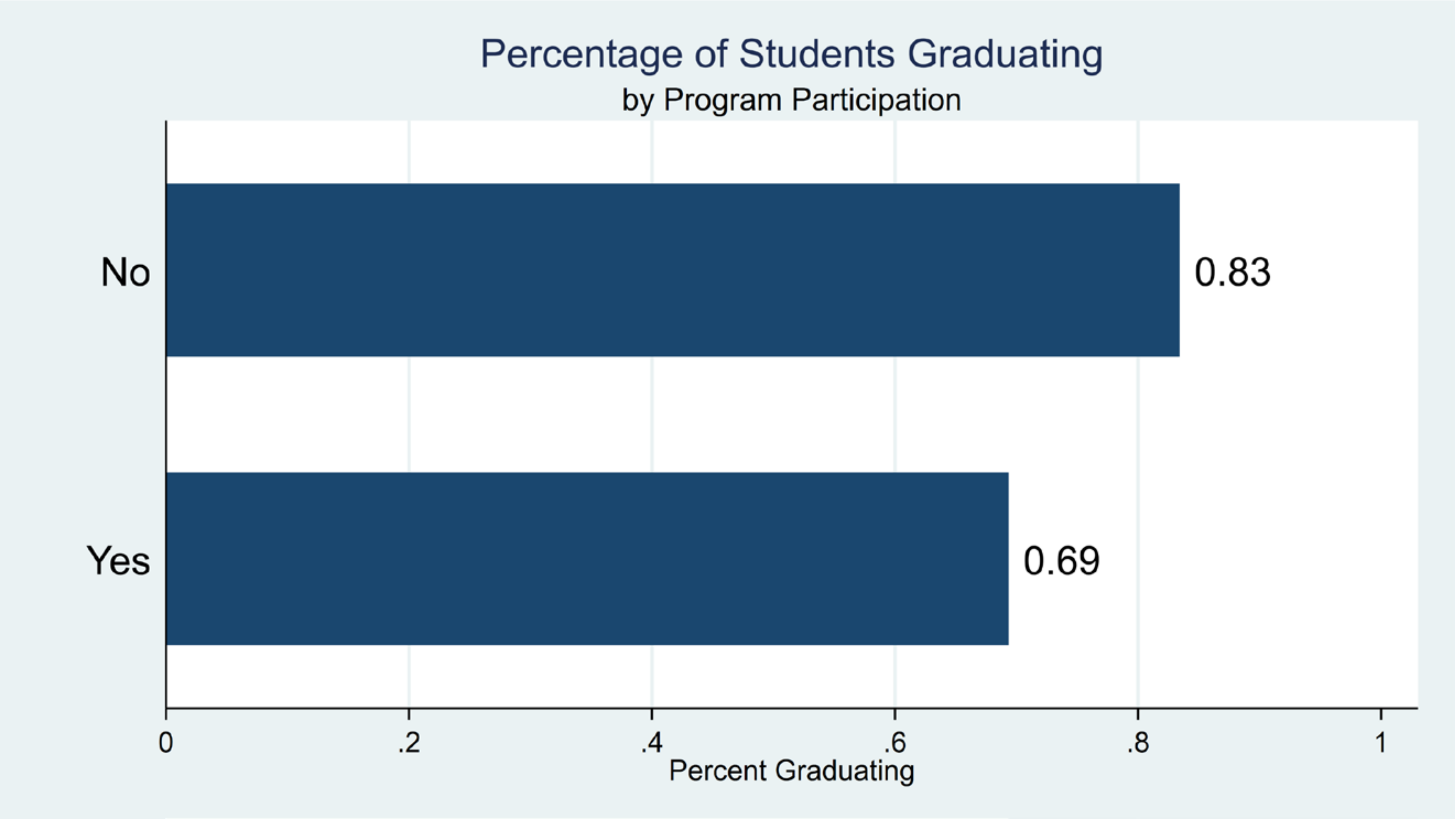

High School GPA by Program Participation
No
Yes
0
1
2
3
4
High School Grade Point Average

The Data

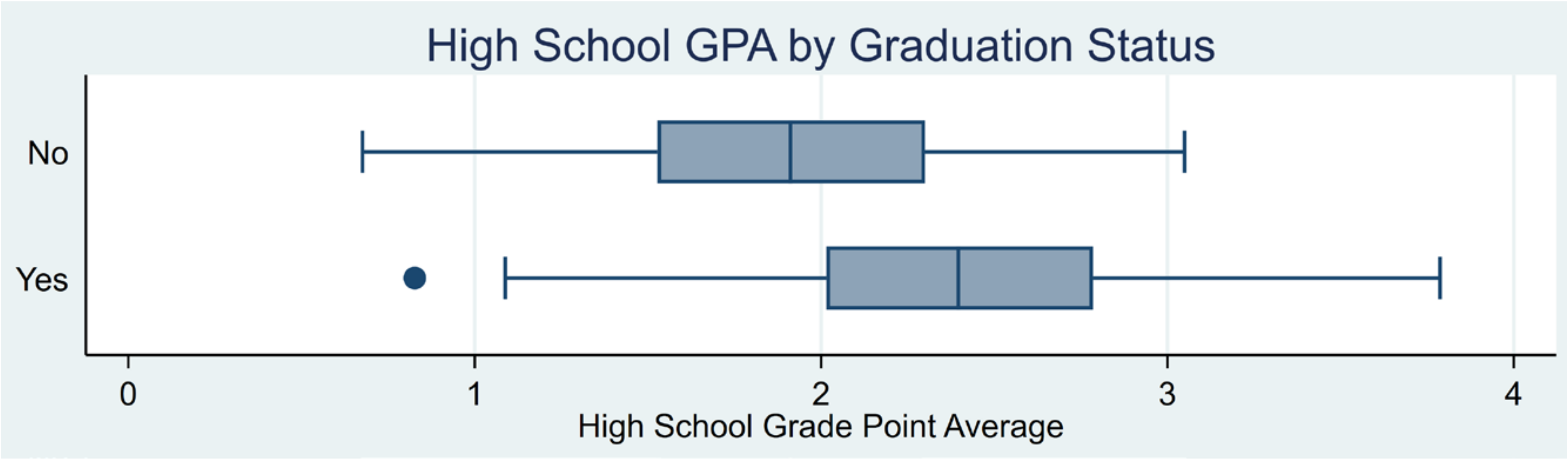
```
. regress gpa i.program hsgpa

      Source |       SS           df       MS      Number of obs   =       792
-------------+----------------------------------   F(2, 789)       =   3350.31
       Model |  301.753841         2  150.876921   Prob > F        =    0.0000
    Residual |  35.5316304       789  .045033752   R-squared       =    0.8947
-------------+----------------------------------   Adj R-squared   =    0.8944
       Total |  337.285472       791  .426403884   Root MSE        =    .21221

------------------------------------------------------------------------------
         gpa |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     program |
         Yes |   .2002776   .0175963    11.38   0.000     .1657364    .2348187
       hsgpa |   1.144457   .0140378    81.53   0.000     1.116901    1.172013
       _cons |  -.6744815    .035729   -18.88   0.000    -.7446166   -.6043464
------------------------------------------------------------------------------

. estimates store hsgpa
```

Students who participated in the program had higher GPAs when we account for high school GPA.

The Data


Percentage of Students Graduating
by Program Participation
No
0.83
Yes
0.69
0
.2
.4
.6
.8
1
Percent Graduating

The Data


High School GPA by Graduation Status
No
Yes
0
1
2
3
4
High School Grade Point Average

The Data

What was the effect of the study program on students GPAs?

Outline

- ✓ Description of the dataset
- Unobserved confounding and endogeneity
- Nonrandom treatment assignment
- Missing not at random (MNAR) and selection bias
- Treatment effects

Observed and Unobserved Factors

$$y = all\ factors\ that\ influence\ y$$

$$y = observed\ factors + unobserved\ factors$$

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \varepsilon$$

Endogeneity

“An explanatory variable in a multiple regression model that is correlated with the error term…” (Wooldridge*, pg 838).

$$y = \beta_0 + \beta_1 x + \beta_2 z + \varepsilon$$

$$\rho_{z\varepsilon} \neq 0$$

*Jeffrey M. Wooldridge (2009) Introductory Econometrics: A Modern Approach, 4th ed.

Omitted Variable Bias

$$y = \beta_0 + \beta_1 x + \beta_2 z + \varepsilon$$

$$\rho_{xz} \neq 0$$

$$y = \beta_0 + \beta_1 x + \varepsilon^{*} \qquad \varepsilon^{*} = z + \varepsilon$$

$$y = \beta_0 + \beta_1 x + \varepsilon^{*}$$

$$\rho_{x\varepsilon^{*}} \neq 0$$

Confounding

"…X and Y are confounded when there is a third variable Z that influences both X and Y…" (Pearl*, pg 193).

$$y = \beta_0 + \beta_1 x + \beta_2 z + \varepsilon$$

*Judea Pearl (2009) Causality: Models, Reasoning, and Inference, 2nd ed.

Unobserved Confounding

$$y = \beta_0 + \beta_1 x + (z + \varepsilon)$$

Observed and Unobserved Factors

$$gpa = all\ factors\ that\ influence\ gpa$$

$$gpa = observed\ factors + unobserved\ factors$$

$$gpa = \left\{\begin{bmatrix} \text{High school GPA} \\ \text{SAT Scores} \\ \text{Parents Income} \\ \text{Sex} \\ \text{etc...} \end{bmatrix}\right\} + \left\{\begin{bmatrix} \text{Ability} \\ \text{Motivation} \\ \text{Sleep} \\ \text{Support} \\ \text{etc...} \end{bmatrix}\right\}$$

$$gpa = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \varepsilon$$

Unobserved Confounding

$$gpa = \beta_0 + \beta_1 income + \beta_2 hsgpa + \varepsilon_{total}$$

$$gpa = \beta_0 + \beta_1 income + \beta_2 hsgpa + (Ability + \varepsilon)$$

Unobserved Confounding and Endogeneity

$$gpa = \beta_0 + \beta_1 income + \beta_2(hsgpa) + (Ability + \varepsilon_1)$$

$$hsgpa = \pi_0 + \pi_1 hs\_comp + (Ability + \varepsilon_2)^*$$

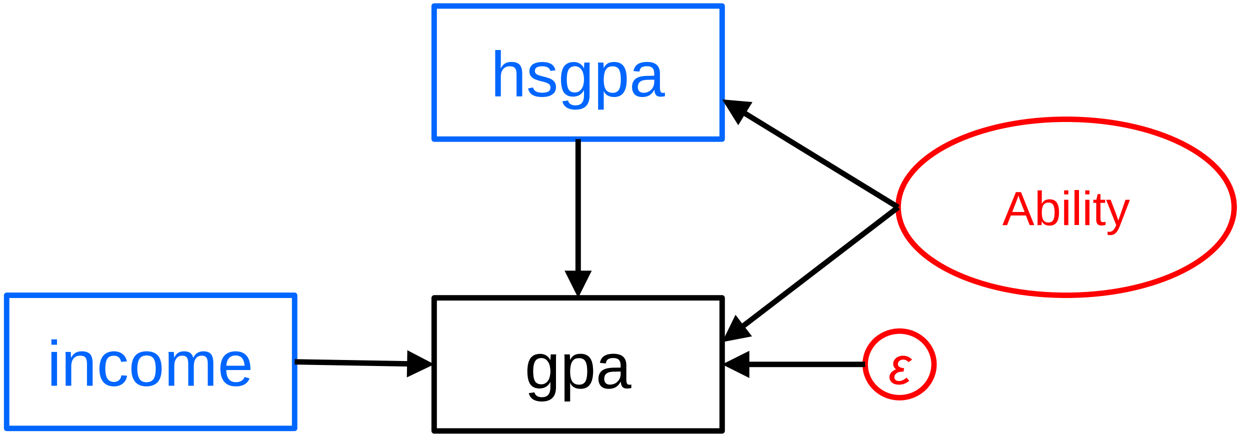
$$gpa = \beta_0 + \beta_1 income + \beta_2(\pi_0 + \pi_1 hs\_comp) + (Ability + \varepsilon_1)^*$$

$$where\ \rho_{\varepsilon_1^* \varepsilon_2^*} \neq 0$$

hsgpa = (factors NOT related to Ability) + (Ability + error)

Unobserved Confounding and Endogeneity

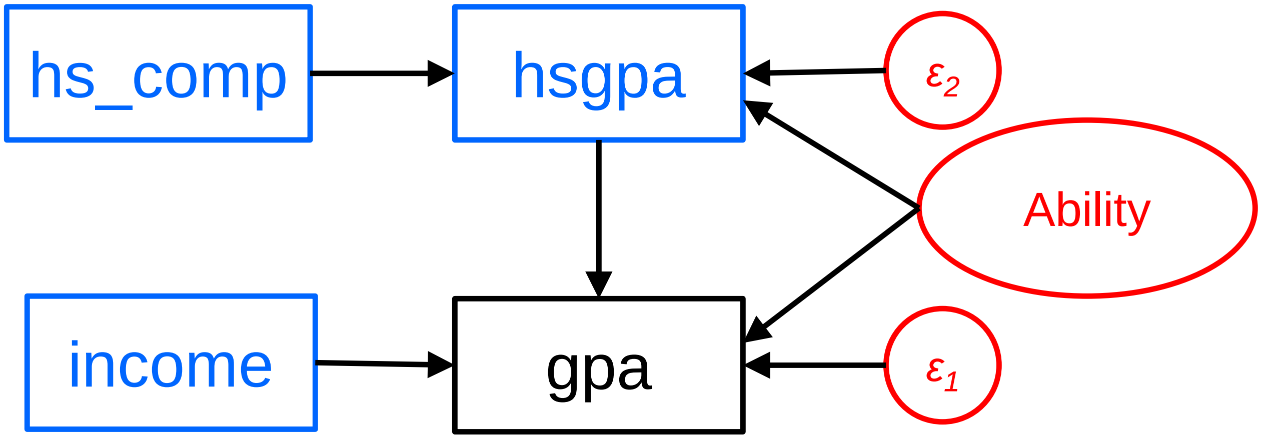
$$gpa = \beta_0 + \beta_1 income + \beta_2 hsgpa + (Ability + \varepsilon)$$



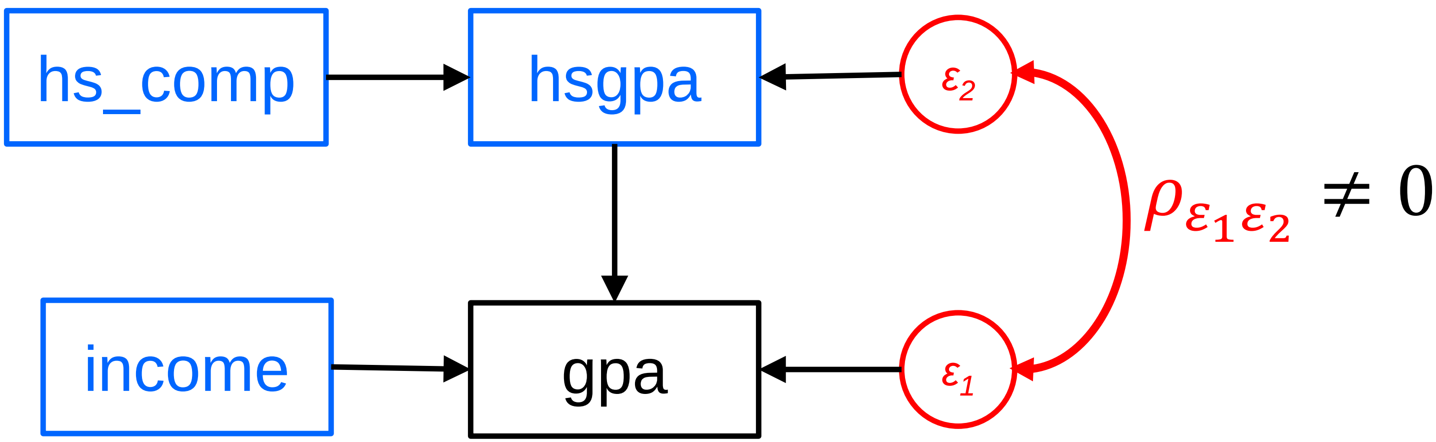
Unobserved Confounding and Endogeneity

$$hsgpa = \pi_0 + \pi_1 hs\_comp + (Ability + \varepsilon_2)^*$$

$$gpa = \beta_0 + \beta_1 income + \beta_2(\pi_0 + \pi_1 hs\_comp) + (Ability + \varepsilon_1)^*$$



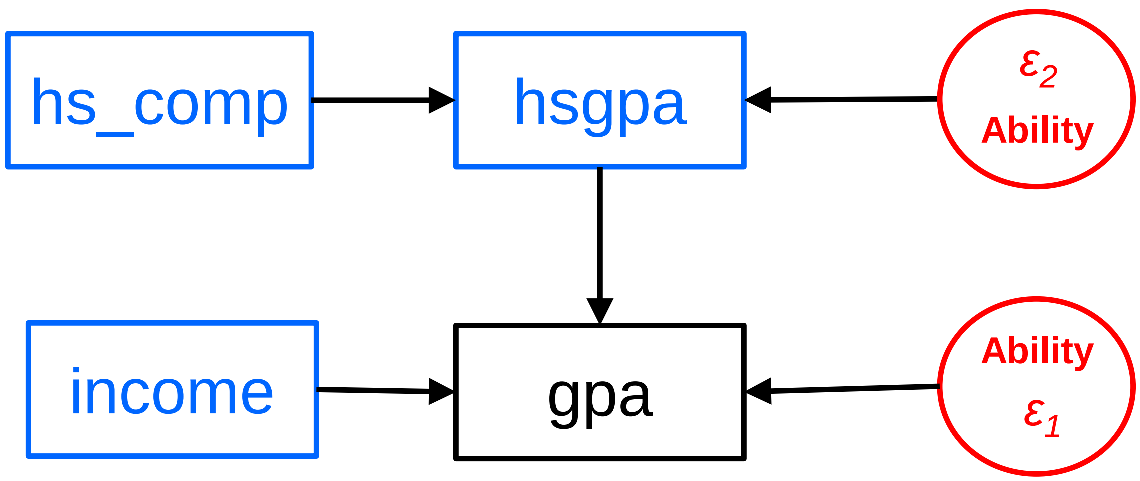
Unobserved Confounding and Endogeneity



Unobserved Confounding and Endogeneity

$$hsgpa = \pi_0 + \pi_1 hs\_comp + (Ability + \varepsilon_2)^*$$

$$gpa = \beta_0 + \beta_1 income + \beta_2(\pi_0 + \pi_1 hs\_comp) + (Ability + \varepsilon_1)^*$$

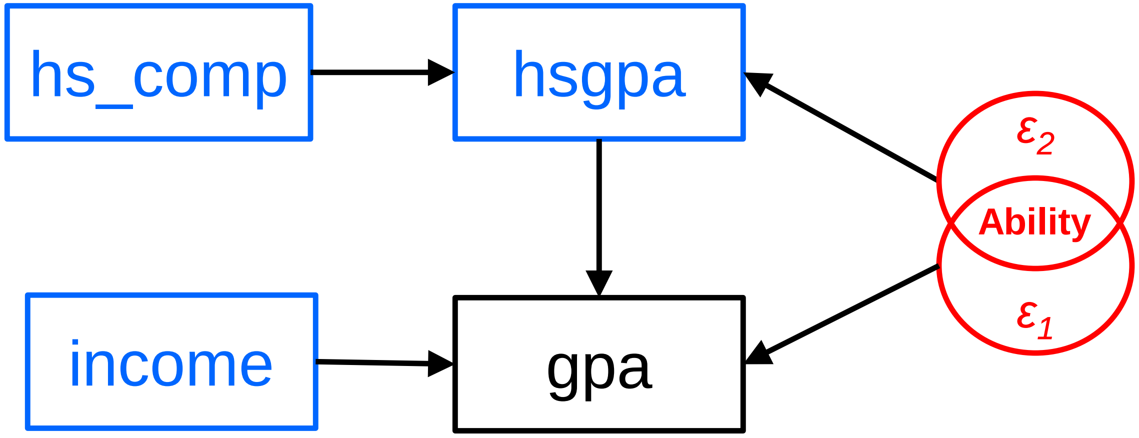


Unobserved Confounding and Endogeneity

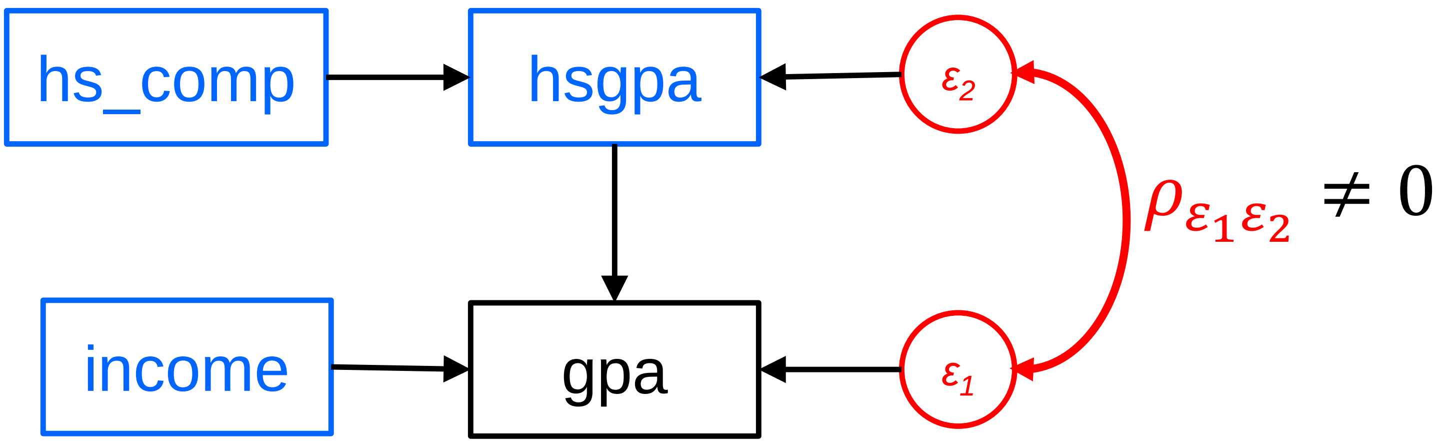
$$hsgpa = \pi_0 + \pi_1 hs\_comp + (Ability + \varepsilon_2)^*$$

$$gpa = \beta_0 + \beta_1 income + \beta_2(\pi_0 + \pi_1 hs\_comp) + (Ability + \varepsilon_1)^*$$

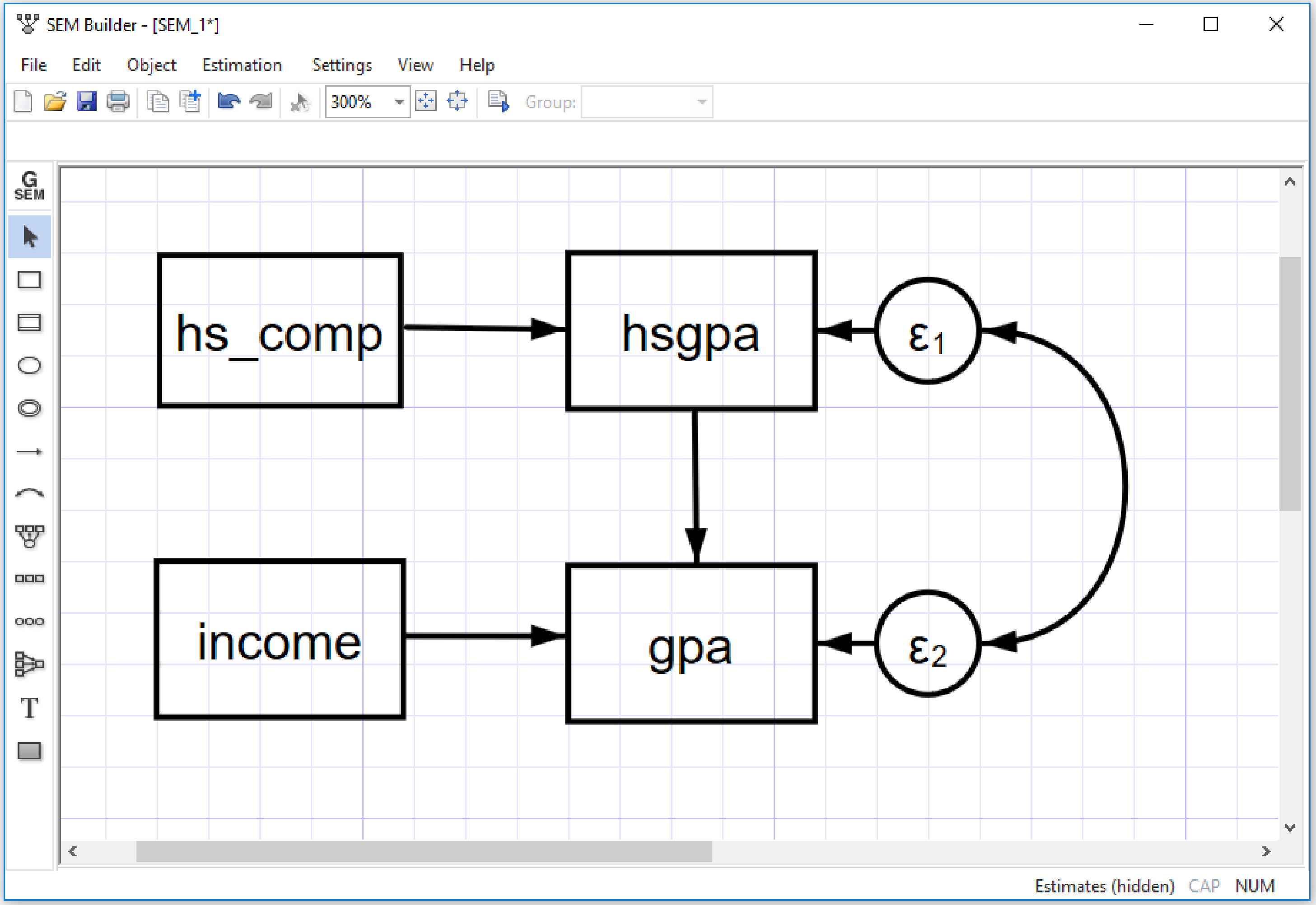
$$where\ \rho_{\varepsilon_1^*\varepsilon_2^*} \neq 0$$



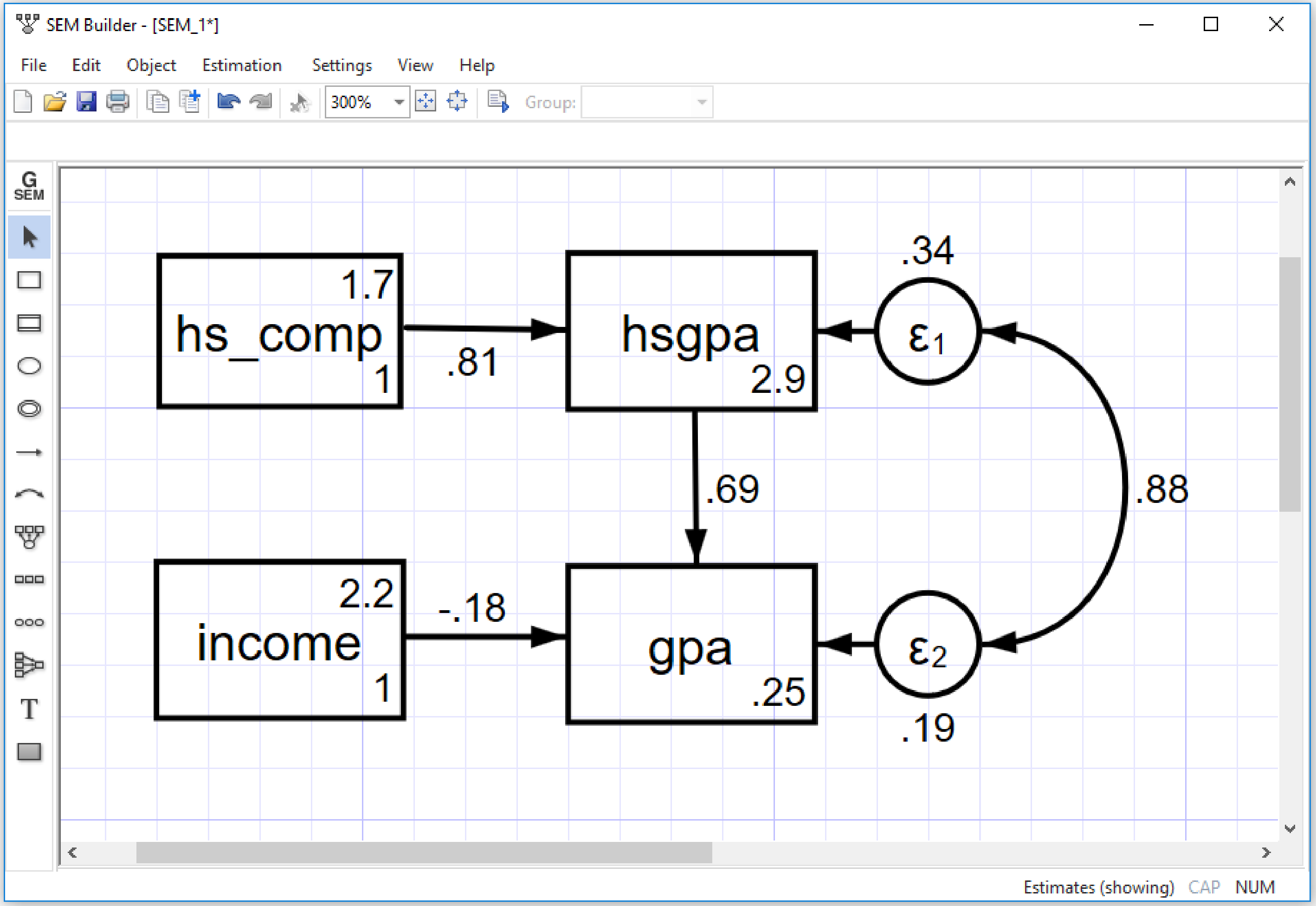
Unobserved Confounding and Endogeneity



Unobserved Confounding and Endogeneity



Unobserved Confounding and Endogeneity



Unobserved Confounding and Endogeneity

Primary model

```
eregress gpa income,                                             ///
             endogenous(hsgpa = hs_comp income)
```

Auxillary model

Unobserved Confounding and Endogeneity

```
. eregress gpa income,                              ///
>              endogenous(hsgpa = hs_comp income) nolog

Extended linear regression                      Number of obs     =        792
                                                Wald chi2(2)      =    3951.76
Log likelihood =  519.11827                     Prob > chi2       =     0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
gpa						
income	.3702125	.0384969	9.62	0.000	.29476	.4456649
hsgpa	.9064316	.0193174	46.92	0.000	.8685702	.944293
_cons	-.2665693	.0397868	-6.70	0.000	-.3445499	-.1885887
hsgpa						
hs_comp	1.524814	.0244398	62.39	0.000	1.476913	1.572715
income	.9898417	.0268549	36.86	0.000	.9372069	1.042476
_cons	1.072201	.0203047	52.81	0.000	1.032404	1.111997
var(e.gpa)	.0554234	.0030877			.0496902	.061818
var(e.hsgpa)	.0381556	.0019174			.0345767	.0421049
corr(e.hsgpa,e.gpa)	.7503328	.0170348	44.05	0.000	.7149879	.7818521

```
. estimates store endog
```

Unobserved Confounding and Endogeneity

var(e.gpa)	.0554234	.0030877			.0496902	.061818
var(e.hsgpa)	.0381556	.0019174			.0345767	.0421049
corr(e.hsgpa,e.gpa)	$\boxed{.7503328}$	.0170348	44.05	0.000	.7149879	.7818521

$$where\ \rho_{\varepsilon_1^* \varepsilon_2^*} \neq 0$$

Unobserved Confounding and Endogeneity

```
. estimates table univar hsgpa endog, stats(N) equations(1) keep(#1:)  b(%9.4f)
```

Variable	univar	hsgpa	endog
program			
1	-0.1259	0.2003	
hsgpa		1.1445	0.9064
income			0.3702
_cons	2.1490	-0.6745	-0.2666
N	792	792	792

Outline

- ✓ Description of the dataset
- ✓ Unobserved confounding and endogeneity
- Nonrandom treatment assignment
- Missing not at random (MNAR) and selection bias
- Treatment effects

Random Treatment Assignment

Nonrandom Treatment Assignment

Nonrandom Treatment Assignment

A student's decision to enroll in the study program is based on observed and unobserved factors.

$$P(program = 1) = observed\ factors + unobserved\ factors$$

Unobserved Confounding

$$gpa = \beta_0 + \beta_1 income + \beta_2 program + \varepsilon_{total}$$

$$gpa = \beta_0 + \beta_1 income + \beta_2 program + (Ability + \varepsilon)$$

Endogenous Treatment

$$gpa = \beta_0 + \beta_1 income + \beta_2(program) + (Ability + \varepsilon_1)$$

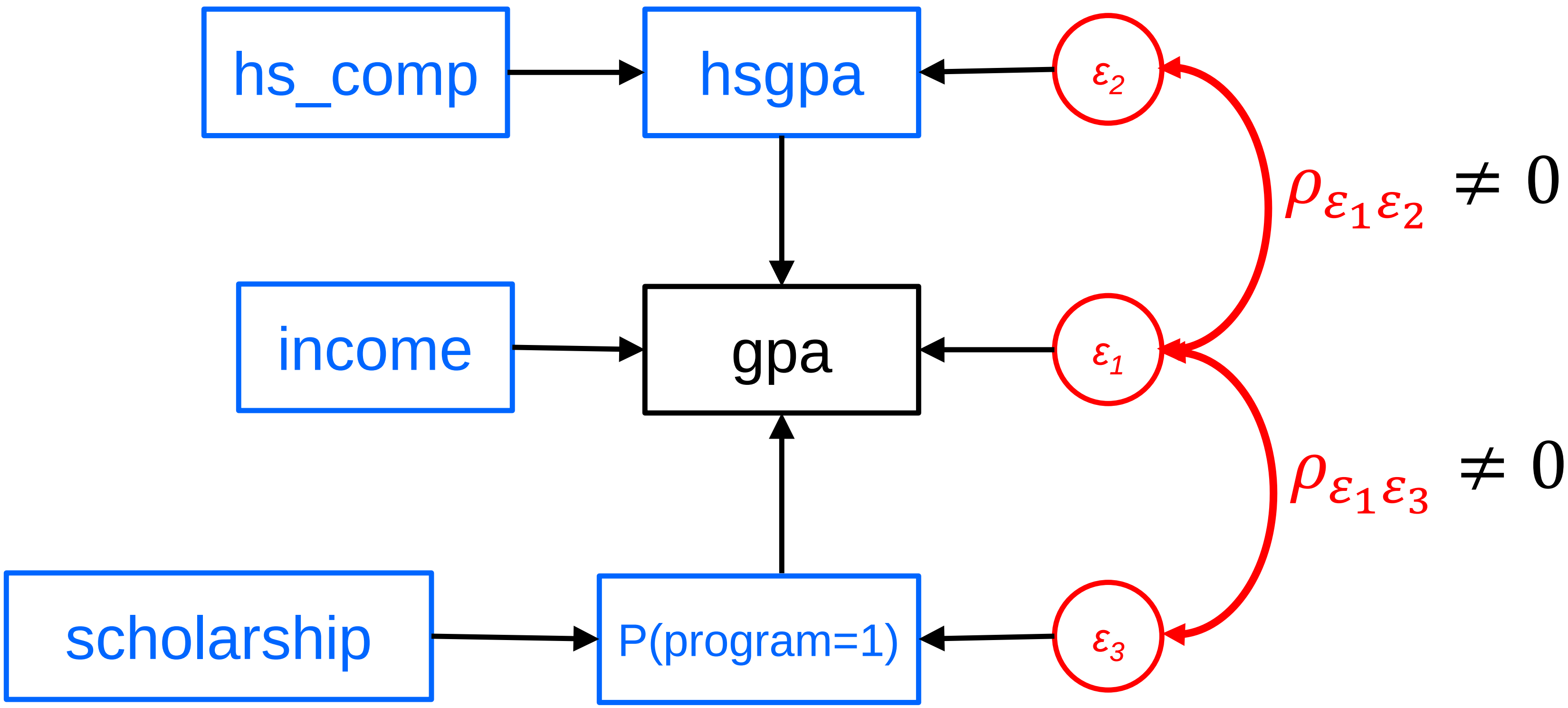
$$P(program = 1) = \pi_0 + \pi_1 scholarship + (Ability + \varepsilon_3)^*$$

$$gpa = \beta_0 + \beta_1 income + \beta_2(\pi_0 + \pi_1 scholarship) + (Ability + \varepsilon_1)^*$$

$$where\ \rho_{\varepsilon_1^* \varepsilon_3^*} \neq 0$$

P(program=1) = (factors NOT related to Ability) + (Ability + error)

Endogenous Treatment



Endogenous Treatment

Primary model

```
eregress gpa income,                                                 ///
            endogenous(hsgpa = hs_comp income)                      ///
            entreat(program = income scholarship, nointeract)
```

Auxillary model

Endogenous Treatment

```
. eregress gpa income,                                              ///
>            endogenous(hsgpa = hs_comp income)                     ///
>            entreat(program = income scholarship, nointeract)  nolog

Extended linear regression                      Number of obs     =        792
                                                Wald chi2(3)      =    6576.43
Log likelihood =  597.15048                     Prob > chi2       =     0.0000

------------------------------------------------------------------------------
                        |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
------------------------+-----------------------------------------------------
gpa                     |
                 income |   .6876358   .0368212    18.67   0.000     .6154676    .7598041
                  hsgpa |   .9021844   .0150525    59.94   0.000      .872682    .9316869
                        |
                program |
                    Yes |   .3040315    .019458    15.62   0.000     .2658944    .3421685
                  _cons |  -.5198319   .0352035   -14.77   0.000    -.5888295   -.4508344
------------------------+-----------------------------------------------------
program                 |
                 income |  -5.868551    .401813   -14.61   0.000     -6.65609   -5.081012
            scholarship |   1.814856   .1636187    11.09   0.000      1.49417    2.135543
                  _cons |   1.503659   .1629857     9.23   0.000     1.184213    1.823106
------------------------+-----------------------------------------------------
hsgpa                   |
                hs_comp |   1.528458   .0236304    64.68   0.000     1.482144    1.574773
                 income |    .989619   .0268526    36.85   0.000     .9369889    1.042249
                  _cons |   1.070543   .0201056    53.25   0.000     1.031136    1.109949
------------------------+-----------------------------------------------------
             var(e.gpa) |   .0358984   .0020787                      .0320469    .0402127
           var(e.hsgpa) |   .0381566   .0019175                      .0345776    .0421062
------------------------+-----------------------------------------------------
   corr(e.program,e.gpa)|   .4511304   .0772058     5.84   0.000     .2877691    .5889813
     corr(e.hsgpa,e.gpa)|   .8093104   .0134908    59.99   0.000     .7811792    .8341618
 corr(e.hsgpa,e.program)|    .480631   .0565509     8.50   0.000     .3624217    .5836218
------------------------------------------------------------------------------

. estimates store entreat
```

Endogenous Treatment

var(e.gpa)	.0358984	.0020787			.0320469	.0402127
var(e.hsgpa)	.0381566	.0019175			.0345776	.0421062
corr(e.program,e.gpa)	.4511304	.0772058	5.84	0.000	.2877691	.5889813
corr(e.hsgpa,e.gpa)	.8093104	.0134908	59.99	0.000	.7811792	.8341618
corr(e.hsgpa,e.program)	.480631	.0565509	8.50	0.000	.3624217	.5836218

$$where\ \rho_{\varepsilon_1^*\varepsilon_3^*} \neq 0$$

Endogenous Treatment

```
. estimates table univar hsgpa endog entreat, stats(N) equations(1) keep(#1:) b(%9.4f)
```

Variable	univar	hsgpa	endog	entreat
program				
Yes	-0.1259	0.2003		0.3040
hsgpa		1.1445	0.9064	0.9022
income			0.3702	0.6876
_cons	2.1490	-0.6745	-0.2666	-0.5198
N	792	792	792	792

Outline

- Description of the dataset
- Unobserved confounding and endogeneity
- Nonrandom treatment assignment
- Missing not at random (MNAR) and selection bias
- Treatment effects

No Missingness

Missing Completely at Random (MCAR)

Missing at Random (MAR)

Missing Not at Random (MNAR)

MNAR and Selection Bias

```
. tab graduate

    Did the |
    student |
   graduate |
   college? |      Freq.     Percent        Cum.
------------+-----------------------------------
         No |        208       20.80       20.80
        Yes |        792       79.20      100.00
------------+-----------------------------------
      Total |      1,000      100.00
```

Endogenous Sample Selection

A student's decision to drop out of school is based on observed and unobserved factors.

$$P(graduate = 1) = {\color{blue}observed\ factors} + {\color{red}unobserved\ factors}$$

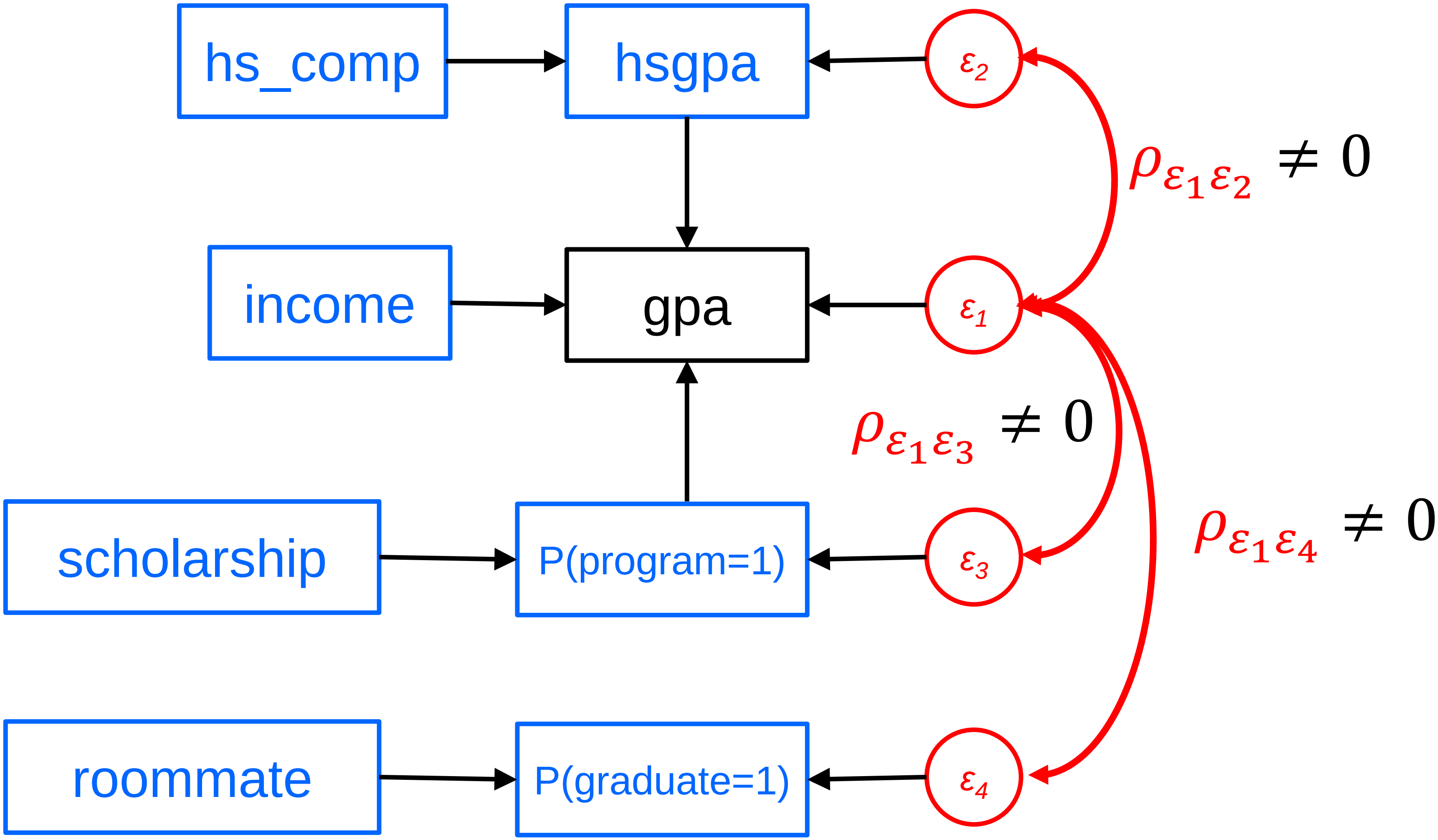
Endogenous Sample Selection

$$gpa = \begin{cases} \beta_0 + \beta_1 income + \beta_2(program) + (Ability + \varepsilon_1)* & \text{if graduate=1} \\ \text{missing} & \text{if graduate=0} \end{cases}$$

$$P(graduate = 1) = \pi_0 + \pi_1 roommate + (Ability + \varepsilon_4)^*$$

$$where\ \rho_{\varepsilon_1^* \varepsilon_4^*} \neq 0$$

Endogenous Sample Selection



Endogenous Sample Selection

Primary model

```
eregress gpa income,                                            ///
            endogenous(hsgpa = hs_comp income)                  ///
            entreat(program = income scholarship, nointeract) ///
            select(graduate = income roommate)
```

Auxillary model

Stata Data Analysis and Statistical Software

Endogenous Sample Selection

```
. eregress gpa income,                                              ///
>             endogenous(hsgpa = hs_comp income)                    ///
>             entreat(program = income scholarship, nointeract) ///
>             select(graduate = income roommate)  nolog
```

Extended linear regression

Number of obs	=	1,000
Selected	=	792
Nonselected	=	208
Wald chi2(3)	=	8866.38
Prob > chi2	=	0.0000

Log likelihood = 323.23691

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
gpa						
income	.8220509	.0333135	24.68	0.000	.7567576	.8873443
hsgpa	.8935782	.0136619	65.41	0.000	.8668013	.9203551
program						
Yes	.2976643	.0168041	17.71	0.000	.2647288	.3305998
_cons	-.6071633	.029947	-20.27	0.000	-.6658583	-.5484682
graduate						
income	4.010154	.2557017	15.68	0.000	3.508988	4.51132
roommate	1.412072	.1320596	10.69	0.000	1.15324	1.670904
_cons	-1.053694	.1059937	-9.94	0.000	-1.261438	-.8459504
program						
income	-4.889741	.2935974	-16.65	0.000	-5.465181	-4.3143
scholarship	1.791084	.1291875	13.86	0.000	1.537881	2.044287
_cons	.8297874	.1047466	7.92	0.000	.6244878	1.035087
hsgpa						
hs_comp	1.512085	.0202588	74.64	0.000	1.472378	1.551791
income	1.0879	.0221946	49.02	0.000	1.044399	1.1314
_cons	.9990863	.0161398	61.90	0.000	.9674529	1.03072
var(e.gpa)	.040487	.0023354			.0361589	.0453332
var(e.hsgpa)	.0399236	.0017858			.0365726	.0435817
corr(e.graduate,e.gpa)	.7609452	.0402982	18.88	0.000	.6700487	.8293596
corr(e.program,e.gpa)	.5402021	.0577087	9.36	0.000	.4175545	.6435181
corr(e.hsgpa,e.gpa)	.8221551	.0119073	69.05	0.000	.797394	.8441524
corr(e.program,e.graduate)	.85115	.0432119	19.70	0.000	.7411121	.9166561
corr(e.hsgpa,e.graduate)	.5633432	.0408602	13.79	0.000	.4780104	.6381415
corr(e.hsgpa,e.program)	.5265467	.0436265	12.07	0.000	.435811	.6066872

```
. estimates store endsel
```

Endogenous Sample Selection

var(e.gpa)	.040487	.0023354			.0361589	.0453332
var(e.hsgpa)	.0399236	.0017858			.0365726	.0435817
corr(e.graduate,e.gpa)	.7609452	.0402982	18.88	0.000	.6700487	.8293596
corr(e.program,e.gpa)	.5402021	.0577087	9.36	0.000	.4175545	.6435181
corr(e.hsgpa,e.gpa)	.8221551	.0119073	69.05	0.000	.797394	.8441524
corr(e.program,e.graduate)	.85115	.0432119	19.70	0.000	.7411121	.9166561
corr(e.hsgpa,e.graduate)	.5633432	.0408602	13.79	0.000	.4780104	.6381415
corr(e.hsgpa,e.program)	.5265467	.0436265	12.07	0.000	.435811	.6066872

Endogenous Sample Selection

```
. estimates table univar hsgpa endog entreat endsel, stats(N) equations(1) keep(#1:) b(%9.4f)
```

Variable	univar	hsgpa	endog	entreat	endsel
program					
Yes	-0.1259	0.2003		0.3040	0.2977
hsgpa		1.1445	0.9064	0.9022	0.8936
income			0.3702	0.6876	0.8221
_cons	2.1490	-0.6745	-0.2666	-0.5198	-0.6072
N	792	792	792	792	1000

<u>True Model (simulated)</u>

gpa = -0.6 + 0.3*treatment + 0.9*hsgpa + 0.8*income

Outline

- ✓ Description of the dataset
- ✓ Unobserved confounding and endogeneity
- ✓ Nonrandom treatment assignment
- ✓ Missing not at random (MNAR) and selection bias
- Treatment effects

ERM Postestimation

- **estat teffects**
- **margins**
- **marginsplot**
- **predict**

estat teffects

```
. estat teffects

Predictive margins                          Number of obs     =      1,000
Model VCE    : OIM

------------------------------------------------------------------------------
             |            Delta-method
             |     Margin   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ATE          |
     program |
  (Yes vs No)|   .2976643   .0168041    17.71   0.000     .2647288    .3305998
------------------------------------------------------------------------------

Note: Standard errors treat sample covariate values as fixed and
      not a draw from the population.  If your interest is in
      population rather than sample effects, refit your model
      using vce(robust).
```

estat teffects, atet

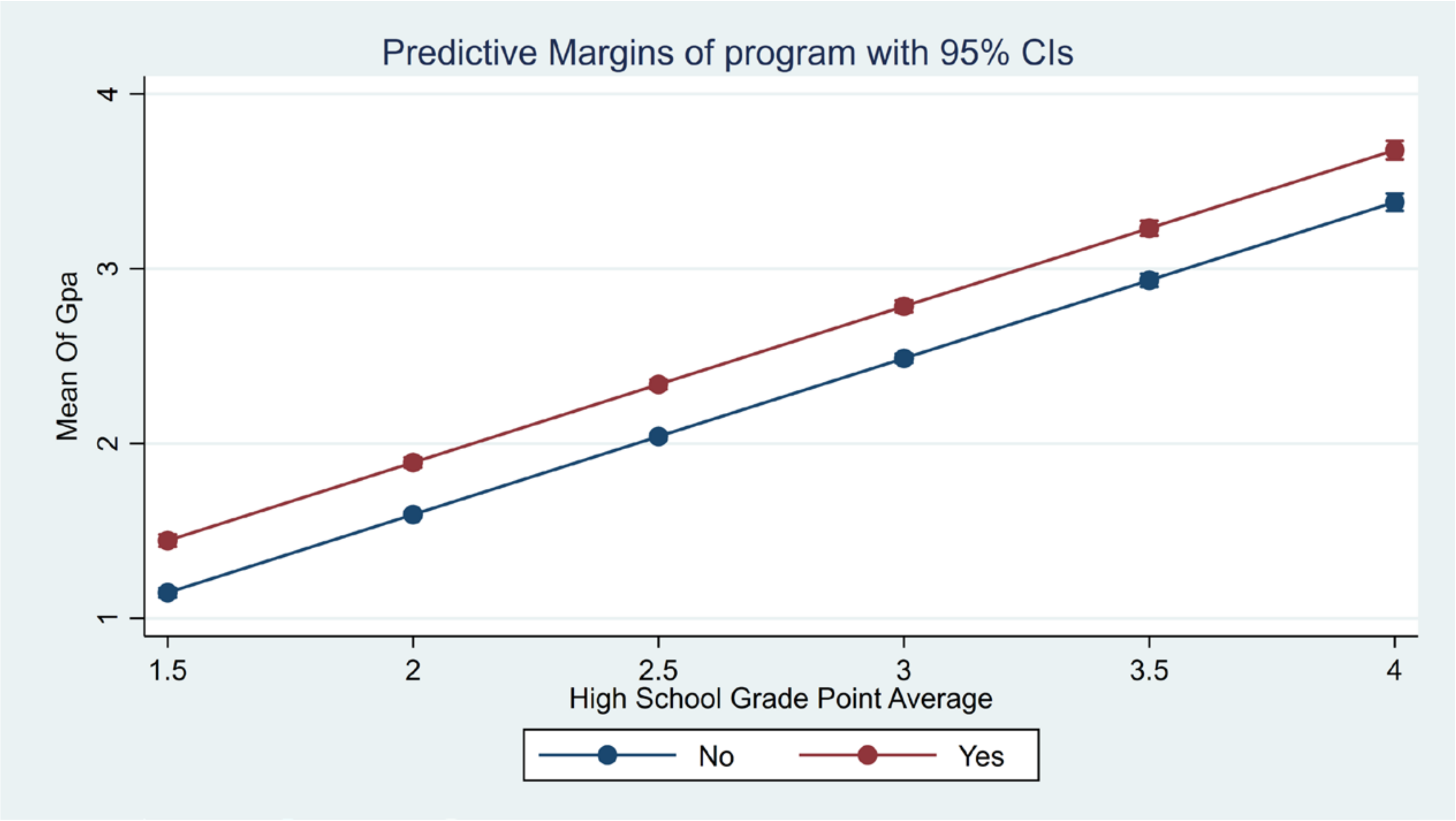
```
. estat teffects, atet

Predictive margins                              Number of obs     =      1,000
                                                Subpop. no. obs   =        300

Model VCE    : OIM

------------------------------------------------------------------------------
             |            Delta-method
             |     Margin   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ATET         |
     program |
 (Yes vs No) |   .2976643   .0168041    17.71   0.000     .2647288    .3305998
------------------------------------------------------------------------------
```

margins

```
. margins i.program, at(hsgpa=(1.5(0.5)4)) predict(fix(hsgpa program)) vsquish

Predictive margins                              Number of obs     =      1,000
Model VCE    : OIM

Expression   : mean of gpa, predict(fix(hsgpa program))
1._at        : hsgpa           =         1.5
2._at        : hsgpa           =           2
3._at        : hsgpa           =         2.5
4._at        : hsgpa           =           3
5._at        : hsgpa           =         3.5
6._at        : hsgpa           =           4

------------------------------------------------------------------------------
             |            Delta-method
             |     Margin   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  _at#program |
        1#No  |   1.146849   .0134979    84.96   0.000     1.120394    1.173305
       1#Yes  |   1.444513   .0178228    81.05   0.000     1.409581    1.479446
        2#No  |   1.593638   .0092729   171.86   0.000     1.575464    1.611813
       2#Yes  |   1.891303   .0146207   129.36   0.000     1.862646    1.919959
        3#No  |   2.040427   .0091161   223.83   0.000      2.02256    2.058294
       3#Yes  |   2.338092   .0142549   164.02   0.000     2.310153    2.366031
        4#No  |   2.487216   .0131736   188.80   0.000     2.461397    2.513036
       4#Yes  |   2.784881   .0169105   164.68   0.000     2.751737    2.818025
        5#No  |   2.934006   .0189026   155.22   0.000     2.896957    2.971054
       5#Yes  |    3.23167   .0214953   150.34   0.000      3.18954      3.2738
        6#No  |   3.380795   .0251872   134.23   0.000     3.331429    3.430161
       6#Yes  |   3.678459   .0270455   136.01   0.000     3.625451    3.731467
------------------------------------------------------------------------------
```

marginsplot

```
. marginsplot
```



More ERMs

- **`eregress`** – continuous outcomes
- **`eintreg`** – interval outcomes
- **`eprobit`** – binary outcomes
- **`eoprobit`** – ordinal outcomes

ERMs For Panel Data

- **`xteregress`** – continuous outcomes
- **`xteintreg`** – interval outcomes
- **`xteprobit`** – binary outcomes
- **`xteoprobit`** – ordinal outcomes

More About ERMs

- ERMs can include:
  - polynomials of endogenous covariates
  - interactions of endogenous covariates
  - interactions of endogenous with exogenous covariates

Cautionary Note

- Nothing about ERMs magically extracts causal relationships.

- As with any regression analysis of observational data, the causal interpretation must be based on a reasonable underlying scientific rationale.

Thanks for coming!

Questions?

chuber@stata.com

You can download the slides, datasets, and do-files here:
https://tinyurl.com/2019CausalInference