Problem Set 6 (SOLUTIONS)

The purpose of the first part of this problem set is to estimate, interpret the results, and compare the results across different binary dependent variable models. In the second part you will estimate and compare different specifications of an endogenous selection model.

First part will be discussed in week 9 and the second part in week 10 of this term.

The data file for this exercise is on Moodle: `mus16data.dta`. It is a subset of the data used by P. Deb, M. Munkin and P.K. Trivedi (2006): "Bayesian Analysis of Two-Part Model with Endogeneity", Journal of Applied Econometrics, 21, 1081-1100. Data is for 2001 and comes from the Medical Expenditure Survey. Sample has 3,328 observations.

The main outcome variable of interest is ambulatory expenditure (`ambexp`) and the regressors are given below.

Since the expenditure data is skewed, we will be using the logged expenditure variable as our dependent variable. You should read Cameron A.C. and Trivedi, P.K. Micro-econometrics using Stata to see the pros and cons regarding whether to log the dependent variable or not.

Note, there is one individual who has an `expenditure`=1 and this will get coded as 0 when variable is logged. Since it is only one individual, we will ignore the problem by not doing anything. If there are many individuals like this, you will need to see whether you can say why this might be the case.

Dependent variable

- `ambexp`: Ambulatory medical expenditures (excluding dental and outpatient mental). There are 526 individuals with zero expenditure. There is one individual who has expenditure=$1. I am going to assume that this individual did not spend any money.
- `lambexp`: ln(`ambexp`) given `ambexp` > 0 ; missing otherwise
- `dambexp`: 1 if `ambexp` > 0 and 0 otherwise (binary indicator)

Regressors

- `ins`: health insurance measures, either PPO or HMO type insurance
- `totchr`: health status measures: number of chronic diseases
- `age`: age age in years/10
- `female`: 1 for females, zero otherwise
- `educ`: years of schooling of decision maker
- `blhisp`: either black or Hispanic
- `income`: income in USD/1000

Preamble

```
<IPython.core.display.HTML object>
```

Create a do-file for this problem set and include a preamble that sets the directory and opens the data. For example,

```
clear
//or, to remove all stored values (including macros, matrices, scalars, etc.)
*clear all

* Replace $rootdir with the relevant path to on your local harddrive.
cd "$rootdir/problem-sets/ps-6"

cap log close
log using problem-set-6-log.txt, replace

use mus16data.dta, clear
```

```
C:\Users\neil_\OneDrive - University of Warwick\Documents\EC910\website\warwick
> -ec910\problem-sets\ps-6
--------------------------------------------------------------------------------
      name:  <unnamed>
       log:  C:\Users\neil_\OneDrive - University of Warwick\Documents\EC910\we
> bsite\warwick-ec910\problem-sets\ps-6\problem-set-6-log.txt
  log type:  smcl
 opened on:  19 Nov 2024, 16:48:49
```

Questions

Part 1

1.1. Obtain and comment on the descriptive statistics for ambexp, lambexp, age, female, educ, blhisp, totchr, ins, income.

```
su dambexp ambexp lambexp age female educ blhisp totchr ins income
```

```
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
```

```
     dambexp |      3,328    .8419471    .3648454          0          1
      ambexp |      3,328    1386.519    2530.406          0      49960
     lambexp |      2,802    6.555066     1.41073          0   10.81898
         age |      3,328    4.056881    1.121212        2.1        6.4
      female |      3,328    .5084135    .5000043          0          1
-------------+---------------------------------------------------------
        educ |      3,328    13.40565    2.574199          0         17
      blhisp |      3,328    .3085938    .4619824          0          1
      totchr |      3,328    .4831731    .7720426          0          5
         ins |      3,328    .3650841    .4815261          0          1
      income |      3,328    36.80485    26.70121     -90.05    237.301
```

1.2. Estimate a LP, Probit and a Logit model to explain dambexp. Store the β coefficients and report them in a table.

```
global xlist age i.female educ i.blhisp totchr i.ins income  //Define regressor list $xlist
bys dambexp: su $xlist

** LPM
eststo LPM: reg dambexp $xlist, robust // heterosk needs to be corrected

** probit
eststo probit: probit dambexp $xlist

** logit
eststo logit: logit dambexp $xlist

esttab LPM probit logit, se scalar(N r2 ll) mtitle("LPM" "Probit" "Logit") title(Estimated Co
```

```
-------------------------------------------------------------------------------
-> dambexp = 0

    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
         age |        526    3.695627    1.076467        2.1        6.4
             |
      female |
          0  |        526    .7338403    .4423695          0          1
          1  |        526    .2661597    .4423695          0          1
             |
        educ |        526    12.48859    2.697241          0         17
```

```
             |
      blhisp |
          0  |        526    .5171103    .5001828          0          1
-------------+---------------------------------------------------------
          1  |        526    .4828897    .5001828          0          1
             |
      totchr |        526    .0912548    .3074311          0          2
             |
         ins |
          0  |        526    .6977186    .4596837          0          1
          1  |        526    .3022814    .4596837          0          1
             |
      income |        526    31.63409    23.17116          0     166.78

-------------------------------------------------------------------------------
-> dambexp = 1

    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
         age |      2,802    4.124697    1.116641        2.1        6.4
             |
      female |
          0  |      2,802    .4461099    .4971761          0          1
          1  |      2,802    .5538901    .4971761          0          1
             |
        educ |      2,802     13.5778    2.513906          0         17
             |
      blhisp |
          0  |      2,802    .7241256    .4470336          0          1
-------------+---------------------------------------------------------
          1  |      2,802    .2758744    .4470336          0          1
             |
      totchr |      2,802    .5567452     .809943          0          5
             |
         ins |
          0  |      2,802    .6231263    .4846893          0          1
          1  |      2,802    .3768737    .4846893          0          1
             |
      income |      2,802    37.77552    27.20742     -90.05    237.301

Linear regression                               Number of obs     =      3,328
                                                F(7, 3320)        =      69.43
```

```
                                                Prob > F          =     0.0000
                                                R-squared         =     0.1276
                                                Root MSE          =     .34114

------------------------------------------------------------------------------
             |               Robust
     dambexp | Coefficient  std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .0216413   .0056048     3.86   0.000     .0106521    .0326304
    1.female |   .1394928   .0119061    11.72   0.000     .1161487    .1628368
        educ |   .0143544   .0025774     5.57   0.000      .009301    .0194078
    1.blhisp |  -.0889738   .0143088    -6.22   0.000    -.1170288   -.0609188
      totchr |   .0830088   .0057913    14.33   0.000     .0716539    .0943637
       1.ins |   .0364663   .0119311     3.06   0.002     .0130733    .0598592
      income |    .000443   .0002215     2.00   0.046     8.70e-06    .0008774
       _cons |   .4485313   .0430509    10.42   0.000     .3641224    .5329402
------------------------------------------------------------------------------

Iteration 0:  Log likelihood = -1452.4289
Iteration 1:  Log likelihood = -1218.0426
Iteration 2:  Log likelihood = -1195.6199
Iteration 3:  Log likelihood = -1195.5158
Iteration 4:  Log likelihood = -1195.5158

Probit regression                                       Number of obs =  3,328
                                                        LR chi2(7)    = 513.83
                                                        Prob > chi2   = 0.0000
Log likelihood = -1195.5158                             Pseudo R2     = 0.1769

------------------------------------------------------------------------------
     dambexp | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .0868152   .0274556     3.16   0.002     .0330032    .1406272
    1.female |   .6635053   .0609648    10.88   0.000     .5440164    .7829941
        educ |    .061884    .012039     5.14   0.000      .038288    .0854801
    1.blhisp |  -.3657835   .0619095    -5.91   0.000    -.4871239   -.2444432
      totchr |   .7957496   .0712174    11.17   0.000      .656166    .9353332
       1.ins |    .169107   .0629296     2.69   0.007     .0457673    .2924467
      income |   .0026773   .0013105     2.04   0.041     .0001088    .0052458
       _cons |  -.6686471   .1941247    -3.44   0.001    -1.049125   -.2881698
------------------------------------------------------------------------------

Iteration 0:  Log likelihood = -1452.4289
```

```
Iteration 1:  Log likelihood =  -1238.914
Iteration 2:  Log likelihood = -1194.7039
Iteration 3:  Log likelihood = -1192.8189
Iteration 4:  Log likelihood = -1192.8089
Iteration 5:  Log likelihood = -1192.8089

Logistic regression                                     Number of obs =  3,328
                                                        LR chi2(7)    = 519.24
                                                        Prob > chi2   = 0.0000
Log likelihood = -1192.8089                             Pseudo R2     = 0.1787

------------------------------------------------------------------------------
     dambexp | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .1618629   .0496641     3.26   0.001     .0645229    .2592028
    1.female |   1.226724   .1130182    10.85   0.000     1.005212    1.448235
        educ |   .1080498   .0210874     5.12   0.000     .0667192    .1493804
    1.blhisp |  -.6666381   .1093362    -6.10   0.000    -.8809332    -.452343
      totchr |   1.554664   .1499606    10.37   0.000     1.260746    1.848581
       1.ins |    .296996   .1133154     2.62   0.009     .0749019    .5190901
      income |     .00462   .0024332     1.90   0.058     -.000149     .009389
       _cons |   -1.26832   .3407805    -3.72   0.000    -1.936237    -.600402
------------------------------------------------------------------------------

Estimated Coefficients
------------------------------------------------------------
                      (1)             (2)             (3)
                      LPM          Probit           Logit
------------------------------------------------------------
main
age             0.0216***       0.0868**         0.162**
                (0.00560)       (0.0275)        (0.0497)

0.female                0              0               0
                      (.)            (.)             (.)

1.female         0.139***       0.664***        1.227***
                 (0.0119)       (0.0610)         (0.113)

educ            0.0144***      0.0619***        0.108***
                (0.00258)       (0.0120)        (0.0211)

0.blhisp                0              0               0
```

```
                    (.)            (.)            (.)

1.blhisp         -0.0890***      -0.366***      -0.667***
                 (0.0143)       (0.0619)       (0.109)

totchr            0.0830***       0.796***       1.555***
                (0.00579)       (0.0712)       (0.150)

0.ins                  0              0              0
                     (.)            (.)            (.)

1.ins             0.0365**        0.169**        0.297**
                 (0.0119)       (0.0629)       (0.113)

income          0.000443*       0.00268*       0.00462
               (0.000222)      (0.00131)      (0.00243)

_cons              0.449***      -0.669***      -1.268***
                 (0.0431)        (0.194)        (0.341)
------------------------------------------------------------
N                    3328           3328           3328
r2                  0.128
ll                -1139.1        -1195.5        -1192.8
------------------------------------------------------------
Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001
```

1.3. Estimate the Marginal Effect at the Mean for each model, and report them in a table. You will want to use the `estpost margins` post-estimation command, with the relevant option for MEM. Pay special attention to the treatment of discrete regressors. Hint: check to see any differences in the estimated MEs based on whether you use factor notation; for example, `i.female` vs `female`.

```
est clear

** LPM
qui reg dambexp $xlist, robust
estpost margins, dydx(*) atmean
est store LPM

** probit
qui probit dambexp $xlist
```

```
estpost margins, dydx(*) atmean
est store probit

** logit
qui logit dambexp $xlist
estpost margins, dydx(*) atmean
est store logit

esttab LPM probit logit, se scalar(N r2 ll) mtitle("LPM" "Probit" "Logit") title(Marginal Ef
```

```
Conditional marginal effects                              Number of obs = 3,328
Model VCE: Robust

Expression: Linear prediction, predict()
dy/dx wrt:  age 1.female educ 1.blhisp totchr 1.ins income
At: age      = 4.056881 (mean)
    0.female = .4915865 (mean)
    1.female = .5084135 (mean)
    educ     = 13.40565 (mean)
    0.blhisp = .6914063 (mean)
    1.blhisp = .3085938 (mean)
    totchr   = .4831731 (mean)
    0.ins    = .6349159 (mean)
    1.ins    = .3650841 (mean)
    income   = 36.80485 (mean)

------------------------------------------------------------------------------
             |            Delta-method
             |      dy/dx   std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .0216413   .0056048     3.86   0.000     .0106521    .0326304
    1.female |   .1394928   .0119061    11.72   0.000     .1161487    .1628368
        educ |   .0143544   .0025774     5.57   0.000      .009301    .0194078
    1.blhisp |  -.0889738   .0143088    -6.22   0.000    -.1170288   -.0609188
      totchr |   .0830088   .0057913    14.33   0.000     .0716539    .0943637
       1.ins |   .0364663   .0119311     3.06   0.002     .0130733    .0598592
      income |    .000443   .0002215     2.00   0.046     8.70e-06    .0008774
------------------------------------------------------------------------------
Note: dy/dx for factor levels is the discrete change from the base level.

Conditional marginal effects                              Number of obs = 3,328
```

```
Model VCE: OIM

Expression: Pr(dambexp), predict()
dy/dx wrt:  age 1.female educ 1.blhisp totchr 1.ins income
At: age      = 4.056881 (mean)
    0.female = .4915865 (mean)
    1.female = .5084135 (mean)
    educ     = 13.40565 (mean)
    0.blhisp = .6914063 (mean)
    1.blhisp = .3085938 (mean)
    totchr   = .4831731 (mean)
    0.ins    = .6349159 (mean)
    1.ins    = .3650841 (mean)
    income   = 36.80485 (mean)

------------------------------------------------------------------------------
             |            Delta-method
             |      dy/dx   std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .0152201    .004837     3.15   0.002     .0057396    .0247005
    1.female |   .1184629   .0112862    10.50   0.000     .0963423    .1405835
        educ |   .0108492   .0021305     5.09   0.000     .0066736    .0150249
    1.blhisp |  -.0701607   .0130287    -5.39   0.000    -.0956964   -.0446249
      totchr |   .1395073   .0102098    13.66   0.000     .1194966    .1595181
       1.ins |   .0288089   .0104412     2.76   0.006     .0083445    .0492733
      income |   .0004694   .0002295     2.05   0.041     .0000195    .0009192
------------------------------------------------------------------------------
Note: dy/dx for factor levels is the discrete change from the base level.

Conditional marginal effects                             Number of obs = 3,328
Model VCE: OIM

Expression: Pr(dambexp), predict()
dy/dx wrt:  age 1.female educ 1.blhisp totchr 1.ins income
At: age      = 4.056881 (mean)
    0.female = .4915865 (mean)
    1.female = .5084135 (mean)
    educ     = 13.40565 (mean)
    0.blhisp = .6914063 (mean)
    1.blhisp = .3085938 (mean)
    totchr   = .4831731 (mean)
    0.ins    = .6349159 (mean)
    1.ins    = .3650841 (mean)
```

income = 36.80485 (mean)

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf.	interval]
age	.0135771	.0042044	3.23	0.001	.0053365	.0218176
1.female	.1068865	.0107295	9.96	0.000	.085857	.1279159
educ	.0090632	.0018074	5.01	0.000	.0055208	.0126056
1.blhisp	-.062462	.0116115	-5.38	0.000	-.0852201	-.039704
totchr	.1304052	.0093686	13.92	0.000	.112043	.1487674
1.ins	.0241537	.0089994	2.68	0.007	.0065151	.0417922
income	.0003875	.0002043	1.90	0.058	-.0000128	.0007879

Note: dy/dx for factor levels is the discrete change from the base level.

Marginal Effects at the Mean

	(1) LPM	(2) Probit	(3) Logit
age	0.0216***	0.0152**	0.0136**
	(0.00560)	(0.00484)	(0.00420)
0.female	0	0	0
	(.)	(.)	(.)
1.female	0.139***	0.118***	0.107***
	(0.0119)	(0.0113)	(0.0107)
educ	0.0144***	0.0108***	0.00906***
	(0.00258)	(0.00213)	(0.00181)
0.blhisp	0	0	0
	(.)	(.)	(.)
1.blhisp	-0.0890***	-0.0702***	-0.0625***
	(0.0143)	(0.0130)	(0.0116)
totchr	0.0830***	0.140***	0.130***
	(0.00579)	(0.0102)	(0.00937)
0.ins	0	0	0

```
                     (.)             (.)             (.)

1.ins              0.0365**        0.0288**        0.0242**
                  (0.0119)        (0.0104)       (0.00900)

income            0.000443*       0.000469*       0.000388
                (0.000222)      (0.000230)      (0.000204)
------------------------------------------------------------
N                     3328            3328            3328
r2                   0.128
ll                 -1139.1         -1195.5         -1192.8
------------------------------------------------------------
Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001
```

1.4. Estimate the Average Marginal Effect at the Mean for each model, and report them in a table.You will want to use the `estpost margins` post-estimation command, with the relevant option for AME.

```
est clear

** LPM
qui reg dambexp $xlist, robust
estpost margins, dydx(*)
est store LPM

** probit
qui probit dambexp $xlist
estpost margins, dydx(*)
est store probit

** logit
qui logit dambexp $xlist
estpost margins, dydx(*)
est store logit

esttab LPM probit logit, se scalar(N r2 ll) mtitle("LPM" "Probit" "Logit") title(Average Marg
```

```
Average marginal effects                                 Number of obs = 3,328
Model VCE: Robust
```

```
Expression: Linear prediction, predict()
dy/dx wrt:  age 1.female educ 1.blhisp totchr 1.ins income

------------------------------------------------------------------------------
             |            Delta-method
             |      dy/dx   std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .0216413   .0056048     3.86   0.000     .0106521    .0326304
    1.female |   .1394928   .0119061    11.72   0.000     .1161487    .1628368
        educ |   .0143544   .0025774     5.57   0.000      .009301    .0194078
    1.blhisp |  -.0889738   .0143088    -6.22   0.000    -.1170288   -.0609188
      totchr |   .0830088   .0057913    14.33   0.000     .0716539    .0943637
       1.ins |   .0364663   .0119311     3.06   0.002     .0130733    .0598592
      income |    .000443   .0002215     2.00   0.046     8.70e-06    .0008774
------------------------------------------------------------------------------
Note: dy/dx for factor levels is the discrete change from the base level.

Average marginal effects                                 Number of obs = 3,328
Model VCE: OIM

Expression: Pr(dambexp), predict()
dy/dx wrt:  age 1.female educ 1.blhisp totchr 1.ins income

------------------------------------------------------------------------------
             |            Delta-method
             |      dy/dx   std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .0173895   .0054832     3.17   0.002     .0066426    .0281365
    1.female |    .132906   .0118133    11.25   0.000     .1097524    .1560596
        educ |   .0123957   .0023862     5.19   0.000     .0077189    .0170725
    1.blhisp |  -.0777517   .0137954    -5.64   0.000    -.1047901   -.0507133
      totchr |   .1593929   .0139062    11.46   0.000     .1321371    .1866486
       1.ins |    .033324   .0121638     2.74   0.006     .0094834    .0571646
      income |   .0005363   .0002621     2.05   0.041     .0000225    .0010501
------------------------------------------------------------------------------
Note: dy/dx for factor levels is the discrete change from the base level.

Average marginal effects                                 Number of obs = 3,328
Model VCE: OIM

Expression: Pr(dambexp), predict()
dy/dx wrt:  age 1.female educ 1.blhisp totchr 1.ins income
```

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf. interval]	
age	.0181007	.0055261	3.28	0.001	.0072697	.0289317
1.female	.1357958	.0117423	11.56	0.000	.1127813	.1588102
educ	.0120829	.0023248	5.20	0.000	.0075264	.0166394
1.blhisp	-.0795676	.0136638	-5.82	0.000	-.1063481	-.0527871
totchr	.1738536	.0164518	10.57	0.000	.1416087	.2060985
1.ins	.0326182	.0121752	2.68	0.007	.0087552	.0564812
income	.0005166	.0002718	1.90	0.057	-.000016	.0010493

Note: dy/dx for factor levels is the discrete change from the base level.

Average Marginal Effects

	(1) LPM	(2) Probit	(3) Logit
age	0.0216***	0.0174**	0.0181**
	(0.00560)	(0.00548)	(0.00553)
0.female	0	0	0
	(.)	(.)	(.)
1.female	0.139***	0.133***	0.136***
	(0.0119)	(0.0118)	(0.0117)
educ	0.0144***	0.0124***	0.0121***
	(0.00258)	(0.00239)	(0.00232)
0.blhisp	0	0	0
	(.)	(.)	(.)
1.blhisp	-0.0890***	-0.0778***	-0.0796***
	(0.0143)	(0.0138)	(0.0137)
totchr	0.0830***	0.159***	0.174***
	(0.00579)	(0.0139)	(0.0165)
0.ins	0	0	0
	(.)	(.)	(.)

```
1.ins              0.0365**        0.0333**        0.0326**
                  (0.0119)        (0.0122)        (0.0122)

income            0.000443*       0.000536*       0.000517
                (0.000222)      (0.000262)      (0.000272)
------------------------------------------------------------
N                     3328            3328            3328
r2                   0.128
ll                 -1139.1         -1195.5         -1192.8
------------------------------------------------------------
Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001
```

1.5. Check to see how well the prodbit model predicts the outcome using the **estat classification** post-estimation command.

```
qui probit dambexp age i.female educ i.blhisp totchr i.ins income
estat classification
```

```
Probit model for dambexp

              -------- True --------
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |      2768           469  |       3237
     -     |        34            57  |         91
-----------+--------------------------+-----------
   Total   |      2802           526  |       3328

Classified + if predicted Pr(D) >= .5
True D defined as dambexp != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   98.79%
Specificity                     Pr( -|~D)   10.84%
Positive predictive value       Pr( D| +)   85.51%
Negative predictive value       Pr(~D| -)   62.64%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)   89.16%
False - rate for true D         Pr( -| D)    1.21%
False + rate for classified +   Pr(~D| +)   14.49%
False - rate for classified -   Pr( D| -)   37.36%
```

```
--------------------------------------------------
Correctly classified                        84.89%
--------------------------------------------------
```

1.6. Construct and interpret the LR test for the omission of income in the probit model. Do this in two ways: (1) using the post estimation `lrtest`; (2) manually recreate (1)'s results (both test-statistic and p-value).

```
est clear

** Remove income from xlist
global xlist age i.female educ i.blhisp totchr i.ins

eststo modU: qui probit dambexp $xlist income
scalar logl_U = e(ll)

eststo modR: qui probit dambexp $xlist
scalar logl_R = e(ll)

lrtest modU modR

** Replicate
scalar stat = 2 * (logl_U - logl_R)
scalar pval = chi2tail(1,stat)
scalar list
```

```
Likelihood-ratio test
Assumption: modR nested within modU

 LR chi2(1) =   4.30
Prob > chi2 = 0.0382
      pval =  .03817363
      stat =   4.297269
    logl_R = -1197.6644
    logl_U = -1195.5158
```

Part 2

Estimate the following models for `lambexp` treating the selection into non-zero `lambexp` value as endogenous using, both Heckman 2-step method and also MLE.

In the main data `lambexp` is missing for values of `ambexp`=0. Before proceeding,

```
replace lambexp = 0 if ambexp==0
```

```
(526 real changes made)
```

This will correction will also treat observations with `ambexp=1` as equivalent to =0; however, this is only a single observation.

```
** Remove income from xlist
global xlist age i.female educ i.blhisp totchr i.ins
```

2.1. Estimate the Heckman 2-step estimator and store the results. In addition, store the Mills ratio as a separate variable. Use `income` as the excluded variable. This means that `income` appears in the selection equation, but NOT the main equation.

```
eststo heck_2sW: heckman lambexp $xlist, select(dambexp = $xlist income) twostep mills(mills_
```

```
Heckman selection model -- two-step estimates   Number of obs     =      3,328
(regression model with sample selection)              Selected    =      2,802
                                                      Nonselected =        526

                                                Wald chi2(6)      =     193.43
                                                Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
lambexp      |
         age |   .2024668   .0242202     8.36   0.000     .1549961    .2499374
    1.female |   .2921341   .0725756     4.03   0.000     .1498886    .4343796
        educ |   .0123889   .0115682     1.07   0.284    -.0102844    .0350622
    1.blhisp |  -.1828659   .0653449    -2.80   0.005    -.3109396   -.0547922
      totchr |   .5006332   .0485548    10.31   0.000     .4054675    .5957988
       1.ins |  -.0465097   .0529742    -0.88   0.380    -.1503373    .0573179
       _cons |   5.288927    .288522    18.33   0.000     4.723435     5.85442
-------------+----------------------------------------------------------------
dambexp      |
         age |   .0868152   .0274556     3.16   0.002     .0330032    .1406272
    1.female |   .6635053   .0609648    10.88   0.000     .5440165    .7829941
```

```
         educ |    .061884     .012039     5.14   0.000      .038288    .0854801
     1.blhisp |  -.3657835    .0619095    -5.91   0.000    -.4871239   -.2444432
       totchr |   .7957496    .0712174    11.17   0.000      .656166    .9353332
        1.ins |    .169107    .0629296     2.69   0.007     .0457673    .2924467
       income |   .0026773    .0013105     2.04   0.041     .0001088    .0052458
        _cons |  -.6686471    .1941247    -3.44   0.001    -1.049125   -.2881698
-------------+----------------------------------------------------------------
/mills        |
       lambda |  -.4637133    .2825997    -1.64   0.101    -1.017598     .090172
-------------+----------------------------------------------------------------
          rho |   -0.35907
        sigma |  1.2914258
------------------------------------------------------------------------------
```

2.2. Replicate these results by applying the following steps: (1) estimate the selection equation using a probit model; (2) create the mills ratio; (3) `compare` your mills ratio with the one stored above; (4) estimate the main equation, including the mills ratio.

```
probit dambexp $xlist income
predict index, xb
gen mills = normalden(index)/normal(index)
compare mills mills_a
reg lambexp $xlist mills
```

```
Iteration 0:  Log likelihood = -1452.4289
Iteration 1:  Log likelihood = -1218.0426
Iteration 2:  Log likelihood = -1195.6199
Iteration 3:  Log likelihood = -1195.5158
Iteration 4:  Log likelihood = -1195.5158

Probit regression                                       Number of obs =  3,328
                                                        LR chi2(7)    = 513.83
                                                        Prob > chi2   = 0.0000
Log likelihood = -1195.5158                             Pseudo R2     = 0.1769

------------------------------------------------------------------------------
     dambexp | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .0868152    .0274556     3.16   0.002     .0330032    .1406272
    1.female |   .6635053    .0609648    10.88   0.000     .5440164    .7829941
        educ |    .061884     .012039     5.14   0.000      .038288    .0854801
```

```
    1.blhisp |  -.3657835   .0619095    -5.91   0.000    -.4871239   -.2444432
      totchr |   .7957496   .0712174    11.17   0.000      .656166    .9353332
       1.ins |    .169107   .0629296     2.69   0.007     .0457673    .2924467
      income |   .0026773   .0013105     2.04   0.041     .0001088    .0052458
       _cons |  -.6686471   .1941247    -3.44   0.001    -1.049125   -.2881698
------------------------------------------------------------------------------
```

```
                                        ---------- Difference ----------
                            Count       Minimum      Average     Maximum
------------------------------------------------------------------------
mills<mills_a                1660     -5.02e-08    -8.91e-09   -1.75e-14
mills>mills_a                1668      7.75e-15     8.64e-09    5.45e-08
                       ----------
Jointly defined              3328     -5.02e-08    -1.10e-10    5.45e-08
                       ----------
Total                        3328
```

```
      Source |       SS           df       MS      Number of obs   =     3,328
-------------+----------------------------------   F(7, 3320)      =    164.14
       Model |  6325.70678         7  903.672398   Prob > F        =    0.0000
    Residual |  18278.1125     3,320  5.50545557   R-squared       =    0.2571
-------------+----------------------------------   Adj R-squared   =    0.2555
       Total |  24603.8193     3,327  7.39519666   Root MSE        =    2.3464

------------------------------------------------------------------------------
     lambexp | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .1628716   .0410937     3.96   0.000     .0823001    .2434431
    1.female |   .1898127   .1257893     1.51   0.131    -.0568198    .4364451
        educ |  -.0016555   .0199775    -0.08   0.934    -.0408251     .037514
    1.blhisp |  -.1086689   .1107824    -0.98   0.327    -.3258776    .1085397
      totchr |   .4202052   .0839337     5.01   0.000     .2556382    .5847723
       1.ins |  -.0686172   .0899672    -0.76   0.446    -.2450141    .1077796
       mills |  -4.592193   .4582359   -10.02   0.000    -5.490646   -3.693739
       _cons |   5.904903   .5004624    11.80   0.000     4.923657    6.886149
------------------------------------------------------------------------------
```

2.3 Estimate the marginal effects of the selection equation. You can do this using the `estpost margins` command. This should correspond to a probit model estimation above.

```
qui heckman lambexp $xlist, select(dambexp = $xlist income) twostep
estpost margins, dydx(*) predict(psel)
```

```
Average marginal effects                                Number of obs = 3,328
Model VCE: Conventional

Expression: Pr(dambexp), predict(psel)
dy/dx wrt:  age 1.female educ 1.blhisp totchr 1.ins income

------------------------------------------------------------------------------
             |            Delta-method
             |      dy/dx   std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
         age |   .0173895   .0054832     3.17   0.002     .0066426    .0281365
    1.female |    .132906   .0118133    11.25   0.000     .1097524    .1560596
        educ |   .0123957   .0023862     5.19   0.000     .0077189    .0170725
    1.blhisp |  -.0777517   .0137954    -5.64   0.000    -.1047901   -.0507133
      totchr |   .1593929   .0139062    11.46   0.000     .1321371    .1866486
       1.ins |    .033324   .0121638     2.74   0.006     .0094834    .0571646
      income |   .0005363   .0002621     2.05   0.041     .0000225    .0010501
------------------------------------------------------------------------------
Note: dy/dx for factor levels is the discrete change from the base level.
```

2.4. Estimate the Maximum Likelihood version of the Heckmann correction (with an excluded variable) and store the results.

```
eststo heck_mlW: heckman lambexp $xlist, select(dambexp = $xlist income) nolog mills(mills_a
```

```
Heckman selection model                         Number of obs     =      3,328
(regression model with sample selection)              Selected    =      2,802
                                                      Nonselected =        526

                                                Wald chi2(6)      =     288.88
Log likelihood = -5836.219                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
lambexp      |
         age |   .2119749   .0230072     9.21   0.000     .1668816    .2570682
    1.female |   .3481441   .0601142     5.79   0.000     .2303223    .4659658
        educ |    .018716   .0105473     1.77   0.076    -.0019563    .0393883
    1.blhisp |  -.2185714   .0596687    -3.66   0.000    -.3355199    -.101623
```

```
     totchr |     .53992   .0393324    13.73   0.000     .4628299      .61701
      1.ins |  -.0299871   .0510882    -0.59   0.557    -.1301182    .0701439
      _cons |   5.044056   .2281259    22.11   0.000     4.596938    5.491175
-------------+----------------------------------------------------------------
dambexp      |
        age |   .0879359    .027421     3.21   0.001     .0341917      .14168
   1.female |   .6626649   .0609384    10.87   0.000     .5432278    .7821021
       educ |   .0619485   .0120295     5.15   0.000     .0383711    .0855258
   1.blhisp |  -.3639377   .0618734    -5.88   0.000    -.4852073   -.2426682
     totchr |   .7969518   .0711306    11.20   0.000     .6575383    .9363653
      1.ins |   .1701367   .0628711     2.71   0.007     .0469117    .2933618
     income |   .0027078   .0013168     2.06   0.040      .000127    .0052886
      _cons |  -.6760546   .1940288    -3.48   0.000    -1.056344   -.2957652
-------------+----------------------------------------------------------------
    /athrho |  -.1313456   .1496292    -0.88   0.380    -.4246134    .1619222
   /lnsigma |   .2398173   .0144598    16.59   0.000     .2114767     .268158
-------------+----------------------------------------------------------------
        rho |  -.1305955   .1470772                     -.4008098    .1605217
      sigma |   1.271017   .0183786                      1.235501    1.307554
     lambda |  -.1659891   .1878698                     -.5342072    .2022291
------------------------------------------------------------------------------
LR test of indep. eqns. (rho = 0): chi2(1) = 0.91         Prob > chi2 = 0.3406
```

2.5. Now re-estimate the two-step and MLE approach without an excluded variable, storing the results each time. This means that the same set of regressors enter both equations. i.e. include income in the outcome equation.

```
global xlist age i.female educ i.blhisp totchr i.ins income

eststo heck_2sWO: heckman lambexp $xlist, select(dambexp = $xlist) twostep mills(mills_b)

eststo heck_mlWO: heckman lambexp $xlist, select(dambexp = $xlist) nolog mills(mills_b_mle)
```

```
Heckman selection model -- two-step estimates   Number of obs     =      3,328
(regression model with sample selection)              Selected    =      2,802
                                                      Nonselected =        526

                                                Wald chi2(7)      =     192.92
                                                Prob > chi2       =     0.0000

------------------------------------------------------------------------------
```

```
             | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
lambexp      |
         age |   .2043022   .0244086     8.37   0.000     .1564622    .2521422
    1.female |   .2786877   .0750154     3.72   0.000     .1316602    .4257151
        educ |   .0141631   .0118462     1.20   0.232    -.0090551    .0373812
    1.blhisp |  -.1797416   .0656337    -2.74   0.006    -.3083812    -.051102
      totchr |   .4938391    .049539     9.97   0.000     .3967445    .5909337
       1.ins |  -.0461181    .053113    -0.87   0.385    -.1502176    .0579815
      income |  -.0007456   .0010158    -0.73   0.463    -.0027367    .0012454
       _cons |   5.306311   .2901551    18.29   0.000     4.737617    5.875004
-------------+----------------------------------------------------------------
dambexp      |
         age |   .0868152   .0274556     3.16   0.002     .0330032    .1406272
    1.female |   .6635053   .0609648    10.88   0.000     .5440165    .7829941
        educ |    .061884    .012039     5.14   0.000      .038288    .0854801
    1.blhisp |  -.3657835   .0619095    -5.91   0.000    -.4871239   -.2444432
      totchr |   .7957496   .0712174    11.17   0.000      .656166    .9353332
       1.ins |    .169107   .0629296     2.69   0.007     .0457673    .2924467
      income |   .0026773   .0013105     2.04   0.041     .0001088    .0052458
       _cons |  -.6686471   .1941247    -3.44   0.001    -1.049125   -.2881698
-------------+----------------------------------------------------------------
/mills       |
      lambda |  -.5087361   .2894687    -1.76   0.079    -1.076084    .0586121
-------------+----------------------------------------------------------------
         rho |   -0.39250
       sigma |  1.2961455
------------------------------------------------------------------------------

Heckman selection model                         Number of obs     =      3,328
(regression model with sample selection)              Selected    =      2,802
                                                      Nonselected =        526

                                                Wald chi2(7)      =     285.98
Log likelihood =  -5836.09                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
             | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
lambexp      |
         age |   .2137594   .0232969     9.18   0.000     .1680983    .2594205
    1.female |    .342293   .0615522     5.56   0.000     .2216528    .4629332
        educ |   .0202746   .0110032     1.84   0.065    -.0012913    .0418406
```

```
    1.blhisp |  -.2185104   .0598099    -3.65   0.000    -.3357357   -.1012852
      totchr |   .5375964   .0398453    13.49   0.000      .459501    .6156918
       1.ins |  -.0287728   .0511856    -0.56   0.574    -.1290946    .0715491
      income |  -.0005026    .000989    -0.51   0.611    -.0024411    .0014359
       _cons |   5.041712    .229726    21.95   0.000     4.591458    5.491967
-------------+----------------------------------------------------------------
dambexp      |
         age |   .0878613   .0274099     3.21   0.001      .034139    .1415837
    1.female |   .6628035    .060929    10.88   0.000     .5433848    .7822223
        educ |   .0617998   .0120332     5.14   0.000     .0382152    .0853844
    1.blhisp |  -.3636885   .0618724    -5.88   0.000    -.4849562   -.2424207
      totchr |   .7968988   .0711265    11.20   0.000     .6574934    .9363041
       1.ins |   .1699645   .0628669     2.70   0.007     .0467476    .2931815
      income |   .0027483   .0013209     2.08   0.037     .0001595    .0053372
       _cons |   -.675346   .1939739    -3.48   0.000    -1.055528    -.295164
-------------+----------------------------------------------------------------
     /athrho |  -.1419126   .1535634    -0.92   0.355    -.4428913    .1590661
    /lnsigma |    .240186   .0146925    16.35   0.000     .2113892    .2689828
-------------+----------------------------------------------------------------
         rho |  -.1409675   .1505118                     -.4160382     .157738
       sigma |   1.271486   .0186813                      1.235393    1.308633
      lambda |  -.1792382   .1924853                     -.5565025    .1980261
------------------------------------------------------------------------------
LR test of indep. eqns. (rho = 0): chi2(1) = 1.02         Prob > chi2 = 0.3122
```

2.6. Create a table that reports the four models alongside one another and compare the results.

```
esttab heck_2sW heck_2sWO heck_mlW heck_mlWO, se scalar(N) mtitle("2-step,w/" "2-step,w/o" "I
```

```
Heckman Selection Models
----------------------------------------------------------------------------
                      (1)             (2)             (3)             (4)   
                2-step,w/      2-step,w/o           ML,w/          ML,w/o   
----------------------------------------------------------------------------
lambexp
age                 0.202***        0.204***        0.212***        0.214***
                 (0.0242)        (0.0244)        (0.0230)        (0.0233)   

1.female            0.292***        0.279***        0.348***        0.342***
                 (0.0726)        (0.0750)        (0.0601)        (0.0616)   
```

educ	0.0124	0.0142	0.0187	0.0203
	(0.0116)	(0.0118)	(0.0105)	(0.0110)
1.blhisp	-0.183**	-0.180**	-0.219***	-0.219***
	(0.0653)	(0.0656)	(0.0597)	(0.0598)
totchr	0.501***	0.494***	0.540***	0.538***
	(0.0486)	(0.0495)	(0.0393)	(0.0398)
1.ins	-0.0465	-0.0461	-0.0300	-0.0288
	(0.0530)	(0.0531)	(0.0511)	(0.0512)
income		-0.000746		-0.000503
		(0.00102)		(0.000989)
_cons	5.289***	5.306***	5.044***	5.042***
	(0.289)	(0.290)	(0.228)	(0.230)
dambexp				
age	0.0868**	0.0868**	0.0879**	0.0879**
	(0.0275)	(0.0275)	(0.0274)	(0.0274)
1.female	0.664***	0.664***	0.663***	0.663***
	(0.0610)	(0.0610)	(0.0609)	(0.0609)
educ	0.0619***	0.0619***	0.0619***	0.0618***
	(0.0120)	(0.0120)	(0.0120)	(0.0120)
1.blhisp	-0.366***	-0.366***	-0.364***	-0.364***
	(0.0619)	(0.0619)	(0.0619)	(0.0619)
totchr	0.796***	0.796***	0.797***	0.797***
	(0.0712)	(0.0712)	(0.0711)	(0.0711)
1.ins	0.169**	0.169**	0.170**	0.170**
	(0.0629)	(0.0629)	(0.0629)	(0.0629)
income	0.00268*	0.00268*	0.00271*	0.00275*
	(0.00131)	(0.00131)	(0.00132)	(0.00132)
_cons	-0.669***	-0.669***	-0.676***	-0.675***
	(0.194)	(0.194)	(0.194)	(0.194)

```
----------------------------------------------------------------------------
/mills
lambda                -0.464          -0.509                                
                     (0.283)         (0.289)                                
----------------------------------------------------------------------------
/
athrho                                                -0.131          -0.142
                                                     (0.150)         (0.154)

lnsigma                                                0.240***        0.240***
                                                    (0.0145)        (0.0147)
----------------------------------------------------------------------------
N                       3328            3328            3328            3328
----------------------------------------------------------------------------
Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001
```

Postamble

```
log close
```

```
      name:  <unnamed>
       log:  C:\Users\neil_\OneDrive - University of Warwick\Documents\EC910\we
> bsite\warwick-ec910\problem-sets\ps-6\problem-set-6-log.txt
  log type:  smcl
 closed on:  19 Nov 2024, 16:48:57
-------------------------------------------------------------------------------
```