6204640178
Mai Surintraboon

From the given data set (`assig8-2.dta`):

a. Estimate the above models using MLE with Newton-Ralphson algorithm.
b. Perform hypothesis testing whether $\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$ using LR-test and Wald test.
c. Estimate the above models using MLE with BHHH algorithm, make comparison of the estimated result with the result from (1), and give explanation why are they different?

a) Estimate model using MLE with Newton-Ralphson algorithm:

$$\hat{z}_i = -1.4004 + 0.4835\hat{x}_1 + 1.454\hat{x}_2 + 2.1732\hat{x}_3 + 1.8555\hat{x}_4$$

b) LR test result

Prob > chi2 = 0.000, thus we can reject the null hypothesis.
All explanatory variables are significant under the LR test.

Wald test result

Prob > chi2 = 0.001, thus we can reject the null hypothesis
All explanatory variables are significant under the wald test.

c) Estimate model using MLE with BHHH algorithm:

$$\hat{z}_i = -1.4 + 0.4833\hat{x}_1 + 1.4533\hat{x}_2 + 2.1726\hat{x}_3 + 1.855\hat{x}_4$$

The estimated result differs from (a) a little bit — all the coefficient values when using BHHH are smaller than using Newton-Ralphson.

This difference is caused by the usage of different algorithm. MLE is sensitive to this.

Let $\Phi(.)$ = Cumulation standard normal probability distribution function and

$$z_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} \quad (3)$$

d. Estimate the models using MLE with Newton-Ralphson algorithm.

$$\hat{z}_i = -0.7729 + 0.3592\hat{x}_1 + 1.1396\hat{x}_2$$

Assume that there exists heteroskedasticity in the model as: $\sigma_i^2 = \exp(\gamma x_{4i})^2$, then,
$\Phi(.)$ = Cumulation standard normal probability distribution function $\Phi\ z_i/\exp(\gamma x_{4i})$

e. Estimate the models with heteroskedasticity using MLE with Newton-Ralphson algorithm. Perform LR-test whether there exists significant heteroskedasticity.

$$\hat{z}_i = -0.6388 + 0.2921\hat{x}_1 + 0.9417\hat{x}_2$$

When perform the LR test, Prob > chi2 = 0.000.
Thus, we can reject H_0 — meaning all explanatory variables are significant. Thus, there exists significant heteroskedasticity.

```
  ___  ____  ____  ____  ____ (R)
 /__    /   ____/   /   ____/
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  Notes:
        1.  Unicode is supported; see help unicode advice.
        2.  More than 2 billion observations are allowed; see help obs advice.
        3.  Maximum number of variables is set to 5000; see help set maxvar.
        4.  New update available; type -update all-

1 . log using "C:\Users\user\Documents\BE TU\Year2\EE426\HW4\4.7.smcl"
-------------------------------------------------------------------------------
      name:  <unnamed>
       log:  C:\Users\user\Documents\BE TU\Year2\EE426\HW4\4.7.smcl
  log type:  smcl
 opened on:  17 Feb 2021, 23:23:32

2 . do "C:\Users\user\AppData\Local\Temp\STD41d4_000000.tmp"

3 . program ml_logit
    1.  args lnf theta
    2.  quietly replace `lnf'=ln(1/(1+exp(-`theta'))) if $ML_y1==1
    3.  quietly replace `lnf'=ln(1-(1/(1+exp(-`theta')))) if $ML_y1==0
    4. end

4 .
  end of do-file

5 . use "C:\Users\user\Documents\BE TU\Year2\EE426\HW4\assign4.dta"

6 . ml model lf ml_logit (y= x1 x2 x3 x4)

7 . ml maximize

  initial:       log likelihood = -90.109133
  alternative:   log likelihood = -86.130008
  rescale:       log likelihood = -86.130008
  Iteration 0:   log likelihood = -86.130008
  Iteration 1:   log likelihood = -66.355929
  Iteration 2:   log likelihood = -63.355226
  Iteration 3:   log likelihood = -57.763041
  Iteration 4:   log likelihood = -55.063873
  Iteration 5:   log likelihood = -54.628535
  Iteration 6:   log likelihood = -54.627603
  Iteration 7:   log likelihood = -54.627603

                                                Number of obs     =        130
                                                Wald chi2(4)      =      22.79
  Log likelihood = -54.627603                   Prob > chi2       =     0.0001

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          x1 |   .4835128   .1686119     2.87   0.004     .1530395     .813986
          x2 |   1.454009   .5001373     2.91   0.004     .4737578     2.43426
          x3 |   2.173186   .7757021     2.80   0.005      .652838    3.693535
          x4 |   1.855464   .7138855     2.60   0.009     .4562739    3.254653
       _cons |  -1.400447   .5531237    -2.53   0.011    -2.484549    -.316344
------------------------------------------------------------------------------
```

```
 8 . test x1=x2=x3=x4=0

   ( 1)  [eq1]x1 - [eq1]x2 = 0
   ( 2)  [eq1]x1 - [eq1]x3 = 0
   ( 3)  [eq1]x1 - [eq1]x4 = 0
   ( 4)  [eq1]x1 = 0

           chi2(  4) =   22.79
         Prob > chi2 =    0.0001

 9 . est store unres

10 . ml model lf ml_logit (y= )

11 . ml maximize

   initial:       log likelihood = -90.109133
   alternative:   log likelihood = -86.130008
   rescale:       log likelihood = -86.130008
   Iteration 0:   log likelihood = -86.130008
   Iteration 1:   log likelihood = -86.129902
   Iteration 2:   log likelihood = -86.129902

                                                 Number of obs     =        130
                                                 Wald chi2(0)      =          .
   Log likelihood = -86.129902                   Prob > chi2       =          .

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   .5026289   .1809802     2.78   0.005     .1479141    .8573436
------------------------------------------------------------------------------

12 . est store res

13 . lrtest unres res

   Likelihood-ratio test                                 LR chi2(4)  =     63.00
   (Assumption: res nested in unres)                     Prob > chi2 =    0.0000

14 . ml model lf ml_logit (y= x1 x2 x3 x4), tech (bhhh)

15 . ml maximize

   initial:       log likelihood = -90.109133
   alternative:   log likelihood = -86.130008
   rescale:       log likelihood = -86.130008
   Iteration 0:   log likelihood = -86.130008
   Iteration 1:   log likelihood = -64.805009
   Iteration 2:   log likelihood = -58.076419
   Iteration 3:   log likelihood = -55.104476
   Iteration 4:   log likelihood = -54.737891
   Iteration 5:   log likelihood = -54.673222
   Iteration 6:   log likelihood = -54.653417
   Iteration 7:   log likelihood = -54.641919
   Iteration 8:   log likelihood = -54.636424
   Iteration 9:   log likelihood = -54.632812
   Iteration 10:  log likelihood = -54.630848
   Iteration 11:  log likelihood = -54.629561
   Iteration 12:  log likelihood = -54.628821
   Iteration 13:  log likelihood = -54.628345
   Iteration 14:  log likelihood = -54.628063
   Iteration 15:  log likelihood = -54.627885
   Iteration 16:  log likelihood = -54.627777
   Iteration 17:  log likelihood =  -54.62771
   Iteration 18:  log likelihood = -54.627669
   Iteration 19:  log likelihood = -54.627644
   Iteration 20:  log likelihood = -54.627628
   Iteration 21:  log likelihood = -54.627618
   Iteration 22:  log likelihood = -54.627612
   Iteration 23:  log likelihood = -54.627609
   Iteration 24:  log likelihood = -54.627607
   Iteration 25:  log likelihood = -54.627605
```

```
                                                Number of obs     =        130
                                                Wald chi2(4)      =      16.34
Log likelihood = -54.627605                     Prob > chi2       =     0.0026
```

y	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
x1	.4833318	.1542635	3.13	0.002	.180981	.7856827
x2	1.453275	.597925	2.43	0.015	.2813639	2.625187
x3	2.172641	.8589781	2.53	0.011	.489075	3.856207
x4	1.854961	.7142729	2.60	0.009	.4550117	3.25491
_cons	-1.400063	.5625155	-2.49	0.013	-2.502573	-.2975527

```
16 . do "C:\Users\user\AppData\Local\Temp\STD41d4_000000.tmp"

17 . program ml_probit
     1.  args lnf theta
     2.  tempvar z
     3.  quietly g double `z'=`theta'
     4.  quietly replace `lnf'=ln(normal(`z')) if $ML_y1==1
     5.  quietly replace `lnf'=ln(1-normal(`z')) if $ML_y1==0
     6. end

18 .
   end of do-file

19 . ml model lf ml_probit (y= x1 x2)

20 . ml maximize

   initial:       log likelihood = -90.109133
   alternative:   log likelihood = -87.504336
   rescale:       log likelihood = -86.291737
   Iteration 0:   log likelihood = -86.291737
   Iteration 1:   log likelihood = -78.555778
   Iteration 2:   log likelihood = -65.283096
   Iteration 3:   log likelihood =  -60.75495
   Iteration 4:   log likelihood = -60.695531
   Iteration 5:   log likelihood = -60.695503
   Iteration 6:   log likelihood = -60.695503

                                                Number of obs     =        130
                                                Wald chi2(2)      =      22.61
   Log likelihood = -60.695503                  Prob > chi2       =     0.0000
```

y	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
x1	.3592444	.0871351	4.12	0.000	.1884627	.5300262
x2	1.139607	.3224845	3.53	0.000	.5075491	1.771665
_cons	-.7729211	.2765064	-2.80	0.005	-1.314864	-.2309785

```
21 . do "C:\Users\user\AppData\Local\Temp\STD41d4_000000.tmp"

22 . program ml_probit_het
     1.  args lnf theta sigma
     2.  tempvar z s
     3.  quietly g double `s'=exp(`sigma')
     4.  quietly g double `z'=`theta'/`s'
     5.  quietly replace `lnf'=ln(normal(`z')) if $ML_y1==1
     6.  quietly replace `lnf'=ln(1-normal(`z')) if $ML_y1==0
     7. end
```

```
23 .
   end of do-file

24 . ml model lf ml_probit_het (y=x1 x2) (x4, noconstant)

25 . ml maximize

   initial:       log likelihood = -90.109133
   alternative:   log likelihood = -83.932039
   rescale:       log likelihood = -83.932039
   rescale eq:    log likelihood =  -70.42663
   Iteration 0:   log likelihood =  -70.42663
   Iteration 1:   log likelihood = -69.416378
   Iteration 2:   log likelihood = -67.899365
   Iteration 3:   log likelihood = -64.594892
   Iteration 4:   log likelihood = -62.956299
   Iteration 5:   log likelihood = -61.359985
   Iteration 6:   log likelihood = -59.838297
   Iteration 7:   log likelihood = -59.474018
   Iteration 8:   log likelihood = -59.404563
   Iteration 9:   log likelihood = -59.404451
   Iteration 10:  log likelihood = -59.404451

                                                 Number of obs     =        130
                                                 Wald chi2(2)      =      16.42
   Log likelihood = -59.404451                   Prob > chi2       =     0.0003

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
eq1          |
          x1 |   .2921402   .0773776     3.78   0.000      .140483    .4437975
          x2 |   .9417319    .280057     3.36   0.001     .3928302    1.490634
       _cons |  -.6388431   .2144267    -2.98   0.003    -1.059112   -.2185746
-------------+----------------------------------------------------------------
eq2          |
          x4 |   1.183929   .5851991     2.02   0.043     .0369599    2.330898
------------------------------------------------------------------------------

26 . est store unres1

27 . ml model lf ml_probit_het (y= ) (x4, noconstant)

28 . ml maximize

   initial:       log likelihood = -90.109133
   alternative:   log likelihood = -83.932039
   rescale:       log likelihood = -83.932039
   rescale eq:    log likelihood =  -70.42663
   Iteration 0:   log likelihood =  -70.42663
   Iteration 1:   log likelihood = -69.976275
   Iteration 2:   log likelihood = -69.973883
   Iteration 3:   log likelihood = -69.973882

                                                 Number of obs     =        130
                                                 Wald chi2(0)      =          .
   Log likelihood = -69.973882                   Prob > chi2       =          .

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
eq1          |
       _cons |   .6158099   .2005698     3.07   0.002     .2227003    1.008919
-------------+----------------------------------------------------------------
eq2          |
          x4 |  -8.17863   3.212406    -2.55   0.011    -14.47483   -1.882429
------------------------------------------------------------------------------
```

```
29 . est store res1

30 . lrtest unres1 res1

   Likelihood-ratio test                                 LR chi2(2)  =     21.14
   (Assumption: res1 nested in unres1)                   Prob > chi2 =    0.0000

31 . log close
        name:  <unnamed>
         log:  C:\Users\user\Documents\BE TU\Year2\EE426\HW4\4.7.smcl
    log type:  smcl
   closed on:  17 Feb 2021, 23:31:29
-------------------------------------------------------------------------------

32 .
```