Model with Discrete Dependent Variables

Probit & Logit Model

The Model

$$I_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \varepsilon_i$$

$$P(y_i = 1 | X) = G(I_i)$$

where

Y_i = 1 for the firm that paid dividend and Y_i =0 otherwise

x_{1i} = Retained earning to total equity

x_{2i} = Total equity to total asset

x_{3i} = Return on asset

x_{4i} = Ratio of change in revenue last year to last year total revenue

x_{5i} = Percentile of firm in full distribution of market cap in each year

MLE Estimation

```
. logit y x1 x2 x3 x4 x5

Iteration 0:   log likelihood = -1291.7938
Iteration 1:   log likelihood = -1081.5633
...
Iteration 7:   log likelihood = -757.49946

Logistic regression                                     Number of obs   =       1888
                                                        LR chi2(5)      =    1068.59
                                                        Prob > chi2     =     0.0000
Log likelihood = -757.49946                             Pseudo R2       =     0.4136

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          x1 |   5.621999   .3310812    16.98   0.000     4.973092    6.270907
          x2 |   1.251322   .3039485     4.12   0.000     .6555939     1.84705
          x3 |   4.945624    1.12468     4.40   0.000     2.741291    7.149957
          x4 |   .3587824   .1571327     2.28   0.022     .0508079     .666757
          x5 |   .7966562    .239171     3.33   0.001     .3278896    1.265423
       _cons |  -1.796861   .2263828    -7.94   0.000    -2.240563   -1.353159
------------------------------------------------------------------------------
Note: 69 failures and 0 successes completely determined.
```

Change Convergence value

```
. logit y x1 x2 x3 x4 x5, tol(1e-1)

Iteration 0:   log likelihood = -1291.7938
Iteration 1:   log likelihood = -1081.5633
...
Iteration 6:   log likelihood = -757.49946

Logistic regression                                     Number of obs     =      1,888
                                                        LR chi2(5)        =    1068.59
                                                        Prob > chi2       =     0.0000
Log likelihood = -757.49946                             Pseudo R2         =     0.4136

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
```

```
          x1 |   5.621981   .3310802    16.98   0.000     4.973075    6.270886
          x2 |   1.251315    .303948     4.12   0.000     .6555878    1.847042
          x3 |   4.945601   1.124678     4.40   0.000     2.741273    7.149929
          x4 |    .358763   .1571285     2.28   0.022     .0507968    .6667292
          x5 |   .7966555   .2391708     3.33   0.001     .3278895    1.265422
       _cons |  -1.796851   .2263824    -7.94   0.000    -2.240553   -1.35315
------------------------------------------------------------------------------
Note: 69 failures and 0 successes completely determined.
```

Change algorithm from Newton-Raphson to BHHH

```
. logit y x1 x2 x3 x4 x5, tech(bhhh)

Iteration 0:   log likelihood = -1291.7938
Iteration 1:   log likelihood = -1083.2491
...
Iteration 18:  log likelihood = -757.49947

Logistic regression                                     Number of obs     =      1,888
                                                        LR chi2(5)        =    1068.59
                                                        Prob > chi2       =     0.0000
Log likelihood = -757.49947                             Pseudo R2         =     0.4136

------------------------------------------------------------------------------
             |                 OPG
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          x1 |   5.622184   .2989004    18.81   0.000      5.03635    6.208018
          x2 |    1.25141    .306284     4.09   0.000     .6511048    1.851716
          x3 |   4.944747   1.011296     4.89   0.000     2.962643    6.926851
          x4 |   .3594456   .0789519     4.55   0.000     .2047027    .5141885
          x5 |   .7965609   .2415642     3.30   0.001     .3231037    1.270018
       _cons |  -1.796996   .2192842    -8.19   0.000    -2.226785   -1.367207
------------------------------------------------------------------------------
Note: 69 failures and 0 successes completely determined.
```

Change max-iterative time & algorithm from Newton-Raphson to BHHH

```
. logit y x1 x2 x3 x4 x5, iter(5) tech(bhhh)

Iteration 0:   log likelihood = -1291.7938
Iteration 1:   log likelihood = -1083.2491
Iteration 2:   log likelihood = -943.13915
Iteration 3:   log likelihood = -776.29824
Iteration 4:   log likelihood = -759.40564
Iteration 5:   log likelihood =  -757.7448
convergence not achieved

Logistic regression                                     Number of obs     =      1,888
                                                        LR chi2(5)        =    1068.10
                                                        Prob > chi2       =     0.0000
Log likelihood =  -757.7448                             Pseudo R2         =     0.4134

------------------------------------------------------------------------------
             |                 OPG
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          x1 |   5.596123   .2979084    18.78   0.000     5.012233    6.180013
          x2 |   1.316101   .3068283     4.29   0.000     .7147286    1.917473
          x3 |   5.169074   1.008042     5.13   0.000     3.193348      7.1448
          x4 |    .435926   .0771529     5.65   0.000     .2847091     .587143
          x5 |   .7936992   .2415596     3.29   0.001     .3202511    1.267147
       _cons |  -1.816599   .2194466    -8.28   0.000    -2.246706   -1.386492
------------------------------------------------------------------------------
Note: 69 failures and 0 successes completely determined.
Warning: convergence not achieved
```

Overall Test

```
. logit y x1 x2 x3 x4 x5

Iteration 0:   log likelihood = -1291.7938
Iteration 1:   log likelihood = -1081.5633
...
Iteration 7:   log likelihood = -757.49946

Logistic regression                                     Number of obs   =       1888
                                                        LR chi2(5)      =    1068.59
                                                        Prob > chi2     =     0.0000
Log likelihood = -757.49946                             Pseudo R2       =     0.4136

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          x1 |   5.621999   .3310812    16.98   0.000     4.973092    6.270907
          x2 |   1.251322   .3039485     4.12   0.000     .6555939     1.84705
          x3 |   4.945624    1.12468     4.40   0.000     2.741291    7.149957
          x4 |   .3587824   .1571327     2.28   0.022     .0508079     .666757
          x5 |   .7966562    .239171     3.33   0.001     .3278896    1.265423
       _cons |  -1.796861   .2263828    -7.94   0.000    -2.240563   -1.353159
------------------------------------------------------------------------------
Note: 69 failures and 0 successes completely determined.

. logit y, nolog

Logistic regression                                     Number of obs   =       1888
                                                        LR chi2(0)      =      -0.00
                                                        Prob > chi2     =          .
Log likelihood = -1291.7938                             Pseudo R2       =    -0.0000

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       _cons |   .2685516   .0464443     5.78   0.000     .1775224    .3595808
------------------------------------------------------------------------------
```

Marginal Effects

```
. logit y x1 x2 x3 x4 x5, nolog

Logistic regression                                     Number of obs   =       1888
                                                        LR chi2(5)      =    1068.59
                                                        Prob > chi2     =     0.0000
Log likelihood = -757.49946                             Pseudo R2       =     0.4136

------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          x1 |   5.621999   .3310812    16.98   0.000     4.973092    6.270907
          x2 |   1.251322   .3039485     4.12   0.000     .6555939     1.84705
          x3 |   4.945624    1.12468     4.40   0.000     2.741291    7.149957
          x4 |   .3587824   .1571327     2.28   0.022     .0508079     .666757
          x5 |   .7966562    .239171     3.33   0.001     .3278896    1.265423
       _cons |  -1.796861   .2263828    -7.94   0.000    -2.240563   -1.353159
------------------------------------------------------------------------------
Note: 69 failures and 0 successes completely determined.

. mfx

Marginal effects after logit
      y  = Pr(y) (predict)
         =  .01656286
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
      x1 |   .0915741      .01924    4.76   0.000   .053867  .129281  -.638752
      x2 |   .0203822      .00739    2.76   0.006   .005895  .034869   .468602
      x3 |    .080557      .02952    2.73   0.006    .02269  .138424   .050715
      x4 |    .005844      .00292    2.00   0.046   .000112  .011576   .140109
      x5 |   .0129764      .00516    2.52   0.012   .002869  .023083   .522908
------------------------------------------------------------------------------
```

```
. sum x1 x2 x3 x4 x5

    Variable |       Obs        Mean    Std. Dev.       Min        Max
-------------+--------------------------------------------------------
          x1 |      1888   -.6387522    10.75936  -335.5922      .9919
          x2 |      1888    .4686022    .2384942      .0008      .9736
          x3 |      1888    .0507147    .0842626   -.838584    .477435
          x4 |      1888     .140109    .7137989    -1.7647    19.1005
          x5 |      1888    .5229084    .2882922       .008          1

. mfx, at(median)

Marginal effects after logit
      y  = Pr(y) (predict)
         =  .62470056
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
      x1 |   1.318076      .07849   16.79   0.000   1.16424  1.47191    .19165
      x2 |   .2933722      .07218    4.06   0.000   .151902  .434842    .45625
      x3 |     1.1595      .26399    4.39   0.000   .642097   1.6769   .044221
      x4 |   .0841165      .03706    2.27   0.023    .01148  .156753    .06545
      x5 |   .1867759      .05599    3.34   0.001   .077031   .29652      .522
------------------------------------------------------------------------------

. mfx, at(0 0 0 0 0)

Marginal effects after logit
      y  = Pr(y) (predict)
         =  .13984246
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
      x1 |   .6731383      .10311    6.53   0.000   .471045  .875232         0
      x2 |   .1583092      .02497    6.34   0.000   .109369  .207249         0
      x3 |     .62177      .15501    4.01   0.000   .317964  .925577         0
      x4 |    .052436      .01221    4.30   0.000   .028508  .076364         0
      x5 |   .0954713      .02347    4.07   0.000   .049467  .141476         0
------------------------------------------------------------------------------

. mfx, predict(xb)

Marginal effects after logit
      y  = Linear prediction (predict, xb)
         = -4.0838907
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
      x1 |   5.621999      .33108   16.98   0.000   4.97309  6.27091  -.638752
      x2 |   1.251322      .30395    4.12   0.000   .655594  1.84705   .468602
      x3 |   4.945624     1.12468    4.40   0.000   2.74129  7.14996   .050715
      x4 |   .3587824      .15713    2.28   0.022   .050808  .666757   .140109
      x5 |   .7966562      .23917    3.33   0.001    .32789  1.26542   .522908
------------------------------------------------------------------------------
```

Statistical Indices

```
. fitstat

Measures of Fit for logit of y

Log-Lik Intercept Only:      -1291.794   Log-Lik Full Model:           -757.499
D(1882):                      1514.999   LR(5):                       1068.589
                                         Prob > LR:                      0.000
McFadden's R2:                   0.414   McFadden's Adj R2:              0.409
ML (Cox-Snell) R2:               0.432   Cragg-Uhler(Nagelkerke) R2:     0.580
McKelvey & Zavoina's R2:         0.999   Efron's R2:                     0.490
Variance of y*:               3675.508   Variance of error:              3.290
Count R2:                        0.827   Adj Count R2:                   0.600
AIC:                             0.809   AIC*n:                       1526.999
BIC:                        -12681.442   BIC':                       -1030.872
BIC used by Stata:            1560.259   AIC used by Stata:           1526.999
```

```
. predict pr
(option pr assumed; Pr(y))

. g yhat=0 if pr<=0.5
(1185 missing values generated)

. replace yhat=1 if pr>0.5
(1185 real changes made)

. tabulate y yhat

           |         yhat
         y |         0          1 |     Total
-----------+----------------------+----------
         0 |       597        221 |       818
         1 |       106        964 |     1,070
-----------+----------------------+----------
     Total |       703      1,185 |     1,888

. estat clas

Logistic model for y
              -------- True --------
Classified |         D            ~D  |      Total
-----------+--------------------------+-----------
     +     |       964           221  |       1185
     -     |       106           597  |        703
-----------+--------------------------+-----------
   Total   |      1070           818  |       1888

Classified + if predicted Pr(D) >= .5
True D defined as y != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   90.09%
Specificity                     Pr( -|~D)   72.98%
Positive predictive value       Pr( D| +)   81.35%
Negative predictive value       Pr(~D| -)   84.92%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)   27.02%
False - rate for true D         Pr( -| D)    9.91%
False + rate for classified +   Pr(~D| +)   18.65%
False - rate for classified -   Pr( D| -)   15.08%
--------------------------------------------------
Correctly classified                        82.68%
--------------------------------------------------
```

Probit Model

```
. probit y x1 x2 x3 x4 x5, nolog

Probit regression                                 Number of obs   =       1888
                                                  LR chi2(5)      =    1042.01
                                                  Prob > chi2     =     0.0000
Log likelihood = -770.78852                       Pseudo R2       =     0.4033
------------------------------------------------------------------------------
           y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          x1 |   2.991683   .1628704    18.37   0.000     2.672462    3.310903
          x2 |   .6882851   .1742238     3.95   0.000     .3468128    1.029757
          x3 |   2.600306   .5990625     4.34   0.000     1.426165    3.774446
          x4 |   .1802702   .0649368     2.78   0.006     .0529964     .307544
          x5 |   .4506521   .1374255     3.28   0.001     .1813031    .7200011
       _cons |  -.9700784   .1261652    -7.69   0.000    -1.217358   -.7227991
------------------------------------------------------------------------------
Note: 95 failures and 0 successes completely determined.

. mfx
Marginal effects after probit
      y  = Pr(y) (predict)
         =   .0151667
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
      x1 |   .1143775      .02894    3.95   0.000   .057651  .171104  -.638752
      x2 |   .0263144      .01081    2.43   0.015   .005118  .047511   .468602
      x3 |   .0994144      .04073    2.44   0.015   .019592  .179236   .050715
      x4 |   .0068921      .00313    2.21   0.027   .000766  .013018   .140109
      x5 |   .0172292      .00746    2.31   0.021   .002605  .031854   .522908
------------------------------------------------------------------------------

. fitstat

Measures of Fit for probit of y
Log-Lik Intercept Only:      -1291.794   Log-Lik Full Model:           -770.789
D(1882):                      1541.577   LR(5):                       1042.011
                                         Prob > LR:                      0.000
McFadden's R2:                   0.403   McFadden's Adj R2:              0.399
ML (Cox-Snell) R2:               0.424   Cragg-Uhler(Nagelkerke) R2:     0.569
McKelvey & Zavoina's R2:         0.999   Efron's R2:                     0.483
Variance of y*:               1040.916   Variance of error:              1.000
Count R2:                        0.826   Adj Count R2:                   0.598
AIC:                             0.823   AIC*n:                       1553.577
BIC:                        -12654.863   BIC':                       -1004.294
BIC used by Stata:            1586.837   AIC used by Stata:           1553.577

. estat clas

Probit model for y
              -------- True --------
Classified |         D             ~D  |      Total
-----------+--------------------------+-----------
     +     |       963            222  |       1185
     -     |       107            596  |        703
-----------+--------------------------+-----------
   Total   |      1070            818  |       1888

Classified + if predicted Pr(D) >= .5
True D defined as y != 0
--------------------------------------------------
Sensitivity                     Pr( +| D)   90.00%
Specificity                     Pr( -|~D)   72.86%
Positive predictive value       Pr( D| +)   81.27%
Negative predictive value       Pr(~D| -)   84.78%
--------------------------------------------------
False + rate for true ~D        Pr( +|~D)   27.14%
False - rate for true D         Pr( -| D)   10.00%
False + rate for classified +   Pr(~D| +)   18.73%
False - rate for classified -   Pr( D| -)   15.22%
--------------------------------------------------
Correctly classified                        82.57%
--------------------------------------------------
```