

Bivariate Probit Models

Model for Financial Restructuring Strategies

The study focused on answering how Thai distressed firms chose restructuring strategy in recovering their firm performance.

Bivariate Probit Models

The model can be shown as

$$y_1^* = \beta_1'x + \varepsilon_1, \quad y_1 = 1 \text{ if } y_1^* > 0, 0 \text{ otherwise}$$

$$y_2^* = \beta_2'x + \varepsilon_2, \quad y_2 = 1 \text{ if } y_2^* > 0, 0 \text{ otherwise}$$

where:

$$E[\varepsilon_1 | x_1, x_2, x_3, x_4] = E[\varepsilon_2 | x_1, x_2, x_3, x_4] = 0$$

$$\text{Var}[\varepsilon_1 | x_1, x_2, x_3, x_4] = \text{Var}[\varepsilon_2 | x_1, x_2, x_3, x_4] = 1$$

$$\text{Cov}[\varepsilon_1, \varepsilon_2 | x_1, x_2, x_3, x_4] = \rho$$

Data

| | |
|-----------|--|
| y_{1it} | = 1 if firm i choose debt restructuring, 0 otherwise |
| y_{2it} | = 1 if firm i choose asset expansion action, 0 otherwise |
| x_{1it} | = Firm's leverage |
| x_{2it} | = Firm's size |
| x_{3it} | = Proportion of outside directors to total directors |
| x_{4it} | = Country's GDP growth rate |

Two Separate Probit Models

```
. probit y1 x1 x2 x3 x4
```

```
Iteration 0: log likelihood = -1053.0627
Iteration 1: log likelihood = -979.26803
Iteration 2: log likelihood = -978.63736
Iteration 3: log likelihood = -978.63691
Iteration 4: log likelihood = -978.63691
```

| | | | |
|-----------------------------|---------------|---|--------|
| Probit regression | Number of obs | = | 1,543 |
| | LR chi2(4) | = | 148.85 |
| | Prob > chi2 | = | 0.0000 |
| Log likelihood = -978.63691 | Pseudo R2 | = | 0.0707 |

| | y1 | Coef. | Std. Err. | z | P> z | [95% Conf. Interval] |
|-------|----|-----------|-----------|-------|-------|----------------------|
| x1 | | .0010014 | .0001838 | 5.45 | 0.000 | .0006412 .0013615 |
| x2 | | -.0955169 | .0187219 | -5.10 | 0.000 | -.1322112 -.0588226 |
| x3 | | -.008575 | .0026366 | -3.25 | 0.001 | -.0137426 -.0034074 |
| x4 | | .0673559 | .0079195 | 8.51 | 0.000 | .051834 .0828778 |
| _cons | | .3568971 | .1445463 | 2.47 | 0.014 | .0735916 .6402026 |

```
. probit y2 x1 x2 x3 x4
```

```
Iteration 0: log likelihood = -913.94299
Iteration 1: log likelihood = -832.82564
Iteration 2: log likelihood = -830.65401
Iteration 3: log likelihood = -830.56871
Iteration 4: log likelihood = -830.56869
```

| | | | |
|-----------------------------|---------------|---|--------|
| Probit regression | Number of obs | = | 1,543 |
| | LR chi2(4) | = | 166.75 |
| | Prob > chi2 | = | 0.0000 |
| Log likelihood = -830.56869 | Pseudo R2 | = | 0.0912 |

| y2 | Coef. | Std. Err. | z | P> z | [95% Conf. Interval] | |
|-------|-----------|-----------|--------|-------|----------------------|-----------|
| x1 | -.0010529 | .0003819 | -2.76 | 0.006 | -.0018014 | -.0003045 |
| x2 | .1657084 | .0206766 | 8.01 | 0.000 | .125183 | .2062338 |
| x3 | .0125813 | .0027806 | 4.52 | 0.000 | .0071314 | .0180311 |
| x4 | .0170502 | .0087229 | 1.95 | 0.051 | -.0000464 | .0341468 |
| _cons | -1.992698 | .1734121 | -11.49 | 0.000 | -2.332579 | -1.652816 |

Bivariate Probit Models

```
. biprobit y1 y2 x1 x2 x3 x4
```

Fitting comparison equation 1:

```
Iteration 0: log likelihood = -1053.0627
Iteration 1: log likelihood = -979.26803
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Iteration 3: log likelihood = -978.63691
Iteration 4: log likelihood = -978.63691
```

Fitting comparison equation 2:

```
Iteration 0: log likelihood = -913.94299
Iteration 1: log likelihood = -832.82564
Iteration 2: log likelihood = -830.65401
Iteration 3: log likelihood = -830.56871
Iteration 4: log likelihood = -830.56869
```

Comparison: log likelihood = -1809.2056

Fitting full model:

```
Iteration 0: log likelihood = -1809.2056
Iteration 1: log likelihood = -1802.6093
Iteration 2: log likelihood = -1802.6028
Iteration 3: log likelihood = -1802.6028
```

Bivariate probit regression

```
Number of obs = 1,543
Wald chi2(8) = 269.26
Prob > chi2 = 0.0000
```

Log likelihood = -1802.6028

| | Coef. | Std. Err. | z | P> z | [95% Conf. Interval] | |
|---------|-----------|-----------|--------|-------|----------------------|-----------|
| y1 | | | | | | |
| x1 | .0009977 | .0001835 | 5.44 | 0.000 | .000638 | .0013574 |
| x2 | -.0955578 | .0187098 | -5.11 | 0.000 | -.1322282 | -.0588873 |
| x3 | -.0084887 | .0026315 | -3.23 | 0.001 | -.0136464 | -.003331 |
| x4 | .0668233 | .0078856 | 8.47 | 0.000 | .0513678 | .0822787 |
| _cons | .3563222 | .144177 | 2.47 | 0.013 | .0737404 | .638904 |
| y2 | | | | | | |
| x1 | -.000827 | .0003474 | -2.38 | 0.017 | -.0015079 | -.0001461 |
| x2 | .1695905 | .0206041 | 8.23 | 0.000 | .1292071 | .2099739 |
| x3 | .0124783 | .0027839 | 4.48 | 0.000 | .0070219 | .0179347 |
| x4 | .016554 | .0087379 | 1.89 | 0.058 | -.0005721 | .03368 |
| _cons | -2.032975 | .1706191 | -11.92 | 0.000 | -2.367383 | -1.698568 |
| /athrho | -.1712861 | .0471648 | -3.63 | 0.000 | -.2637273 | -.0788449 |
| rho | -.1696304 | .0458076 | | | -.2577785 | -.0786819 |

LR test of rho=0: chi2(1) = 13.2057

Prob > chi2 = 0.0003

```
. margins, dydx(*) predict(p11)
```

Average marginal effects
Model VCE : OIM

Number of obs = 1,543

Expression : Pr(y1=1,y2=1), predict(p11)
dy/dx w.r.t. : x1 x2 x3 x4

Multivariate Probit Models

Model for Financial Restructuring Strategies

Multivariate Probit Models

The model can be shown as

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$$y_2^* = \beta_2'x + \varepsilon_2, \quad y_2 = 1 \text{ if } y_2^* > 0, 0 \text{ otherwise}$$

$$y_3^* = \beta_3'x + \varepsilon_3, \quad y_3 = 1 \text{ if } y_3^* > 0, 0 \text{ otherwise}$$

$$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix} \sim N \left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & & \\ \rho_{21} & 1 & \\ \rho_{31} & \rho_{32} & 1 \end{bmatrix} \right)$$

Data

y_{1it} = 1 if firm i choose debt restructuring, 0 otherwise
 y_{2it} = 1 if firm i choose asset expansion action, 0 otherwise
 y_{3it} = 1 if firm i choose equity issues, 0 otherwise
 x_{1it} = Firm's leverage
 x_{2it} = Firm's size
 x_{3it} = Proportion of outside directors to total directors
 x_{4it} = Country's GDP growth rate

Three Separate Probit

```
. probit y1 x1 x2 x3 x4
```

```
Iteration 0: log likelihood = -1053.0627
Iteration 1: log likelihood = -979.26803
Iteration 2: log likelihood = -978.63736
Iteration 3: log likelihood = -978.63691
Iteration 4: log likelihood = -978.63691
```

```
Probit regression                               Number of obs   =       1,543
                                                LR chi2(4)      =       148.85
                                                Prob > chi2     =       0.0000
Log likelihood = -978.63691                    Pseudo R2       =       0.0707
```

```
-----+-----
      y1 |          Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----+-----
      x1 |   .0010014   .0001838     5.45  0.000   .0006412   .0013615
      x2 |  -.0955169   .0187219    -5.10  0.000  -.1322112  -.0588226
      x3 |  -.008575   .0026366    -3.25  0.001  -.0137426  -.0034074
      x4 |   .0673559   .0079195     8.51  0.000   .051834   .0828778
     _cons |   .3568971   .1445463     2.47  0.014   .0735916   .6402026
-----+-----
```

```
. probit y2 x1 x2 x3 x4
```

```
Iteration 0: log likelihood = -913.94299
Iteration 1: log likelihood = -832.82564
Iteration 2: log likelihood = -830.65401
Iteration 3: log likelihood = -830.56871
Iteration 4: log likelihood = -830.56869
```

```
Probit regression                               Number of obs   =       1,543
                                                LR chi2(4)      =       166.75
                                                Prob > chi2     =       0.0000
Log likelihood = -830.56869                    Pseudo R2       =       0.0912
```


| | | | | | | | |
|-------|--|-----------|----------|-------|-------|-----------|-----------|
| rho21 | | -.137539 | .0436719 | -3.15 | 0.002 | -.221908 | -.0511257 |
| rho31 | | .3654461 | .0408466 | 8.95 | 0.000 | .2828338 | .4426765 |
| rho32 | | -.0450386 | .0455762 | -0.99 | 0.323 | -.1337717 | .0444109 |

Likelihood ratio test of rho21 = rho31 = rho32 = 0:
chi2(3) = 80.1221 Prob > chi2 = 0.0000

. mvppred pmarg, pmarg
(pmarg will be stored in variables pmargi, i = 1,...,#eqs)

. sum pmarg1 pmarg2 pmarg3

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|----------|-------|----------|-----------|----------|----------|
| pmarg1 | 1,543 | .4270183 | .1378704 | .0809701 | .9999002 |
| pmarg2 | 1,543 | .2795515 | .140703 | 7.42e-06 | .7976359 |
| pmarg3 | 1,543 | .1919922 | .0444743 | .0365036 | .3873732 |

. mvppred pall, pall
(Pr(all zeros), Pr(all ones) will be stored in variables pall0s, pall1s)

. sum pall0s pall1s

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|----------|-------|----------|-----------|----------|----------|
| pall0s | 1,543 | .3426681 | .1123748 | .0000965 | .6709439 |
| pall1s | 1,543 | .0284488 | .0169754 | 2.48e-06 | .0963519 |

Bivariate Ordered Probit Models

Two Separate Ordered Probit

. oprobit y1 x1 x2 x3, nolog

| | | | |
|-----------------------------|---------------|---|--------|
| Ordered probit regression | Number of obs | = | 500 |
| | LR chi2(3) | = | 195.39 |
| | Prob > chi2 | = | 0.0000 |
| Log likelihood = -341.53944 | Pseudo R2 | = | 0.2224 |

| y1 | Coef. | Std. Err. | z | P> z | [95% Conf. Interval] |
|-------|-----------|-----------|-------|-------|----------------------|
| x1 | .0008314 | .0000654 | 12.71 | 0.000 | .0007032 .0009596 |
| x2 | .0003181 | .0003541 | 0.90 | 0.369 | -.0003759 .0010121 |
| x3 | -.012998 | .0058886 | -2.21 | 0.027 | -.0245394 -.0014567 |
| /cut1 | -.2279898 | .1007339 | | | -.4254247 -.0305549 |
| /cut2 | 1.910848 | .1222889 | | | 1.671166 2.150529 |

. oprobit y2 x1 x2 x3, nolog

| | | | |
|----------------------------|---------------|---|--------|
| Ordered probit regression | Number of obs | = | 500 |
| | LR chi2(3) | = | 184.51 |
| | Prob > chi2 | = | 0.0000 |
| Log likelihood = -319.8527 | Pseudo R2 | = | 0.2239 |

| y2 | Coef. | Std. Err. | z | P> z | [95% Conf. Interval] |
|-------|-----------|-----------|-------|-------|----------------------|
| x1 | .0007755 | .0000631 | 12.30 | 0.000 | .0006519 .0008991 |
| x2 | .0010777 | .0003602 | 2.99 | 0.003 | .0003718 .0017836 |
| x3 | -.0003529 | .0060018 | -0.06 | 0.953 | -.0121162 .0114104 |
| /cut1 | -.2703532 | .1006197 | | | -.4675641 -.0731423 |
| /cut2 | 2.186934 | .1309391 | | | 1.930298 2.44357 |

Bivariate Ordered Probit

```
. bioprobit (y1 x1 x2 x3) (y2 x1 x2 x3)
```

| group(y2) | Freq. | Percent | Cum. |
|-----------|-------|---------|--------|
| 1 | 171 | 34.20 | 34.20 |
| 2 | 303 | 60.60 | 94.80 |
| 3 | 26 | 5.20 | 100.00 |
| Total | 500 | 100.00 | |

```
initial:      log likelihood = -579.27593
```

```
Iteration 3:  log likelihood = -549.08381
```

```
Seemingly unrelated bivariate ordered probit regression
```

```

                                Number of obs   =      500
                                Wald chi2(3)     =     152.90
                                Prob > chi2     =      0.0000
Log likelihood = -549.08381
```

| | | Coef. | Std. Err. | z | P> z | [95% Conf. Interval] | |
|--------|--------|-----------|-----------|-------|-------|----------------------|-----------|
| y1 | | | | | | | |
| | x1 | .000781 | .0000634 | 12.32 | 0.000 | .0006567 | .0009052 |
| | x2 | .0003603 | .0003477 | 1.04 | 0.300 | -.0003212 | .0010418 |
| | x3 | -.0129852 | .0058692 | -2.21 | 0.027 | -.0244886 | -.0014817 |
| y2 | | | | | | | |
| | x1 | .0007884 | .0000648 | 12.16 | 0.000 | .0006614 | .0009154 |
| | x2 | .0009916 | .0003585 | 2.77 | 0.006 | .0002891 | .0016942 |
| | x3 | .002355 | .0060989 | 0.39 | 0.699 | -.0095985 | .0143086 |
| athrho | | | | | | | |
| | _cons | 1.034165 | .0715436 | 14.46 | 0.000 | .8939422 | 1.174388 |
| | /cut11 | -.1872815 | .1011869 | | | -.3856042 | .0110411 |
| | /cut12 | 1.829454 | .1206768 | | | 1.592931 | 2.065976 |
| | /cut21 | -.2373209 | .1035177 | | | -.4402118 | -.03443 |
| | /cut22 | 2.179327 | .1332206 | | | 1.91822 | 2.440435 |
| | rho | .7755734 | .0285091 | | | .7133354 | .8256738 |

```
LR test of indep. eqns. :          chi2(1) = 224.62   Prob > chi2 = 0.0000
```