

Categorical Outcomes

Statistical Modelling in Stata: Categorical Outcomes

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- Nominal
- Ordinal

Nominal Outcomes

R by C Table: Example

- Categorical, more than two outcomes
- No ordering on outcomes

	Females		Males		Total	
Indemnity	234	(51%)	60	(40%)	294	(48%)
Prepaid	196	(42%)	81	(53%)	277	(45%)
No Insurance	32	(7%)	13	(8%)	45	(7%)
Total	462	(100%)	154	(100%)	616	(100%)

$$\chi^2 = 6.32, p = 0.04$$

```
tab insure male, co chi2
```

Analysing an R by C Table

- χ^2 -test: says if there is an association
- Need to assess what that association is
- Can calculate odds ratios for each row compared to a baseline row

Odds Ratios from Tables

- Prepaid vs Indemnity
 - OR for males = $\frac{81 \times 234}{60 \times 196} = 1.61$
- No Insurance vs Indemnity
 - OR for males = $\frac{13 \times 234}{60 \times 32} = 1.58$

Multiple Logistic Regression Models

- Previous results can be duplicated with 2 logistic regression models
 - Prepaid vs Indemnity
 - No Insurance vs Indemnity
- Logistic regression model can be extended to more predictors
- Logistic regression model can include continuous variables

Multiple Logistic Regression Models: Example

```
. logistic insure1 male
-----+-----
insure1 | Odds Ratio   Std. Err.      z    P>|z|    [95% Conf. Interval]
-----+-----
male   |   1.611735    .3157844    2.44  0.015    1.09779    2.36629
-----+-----

. logistic insure2 male
-----+-----
insure2 | Odds Ratio   Std. Err.      z    P>|z|    [95% Conf. Interval]
-----+-----
male   |   1.584375    .5693029    1.28  0.200    .7834322    3.204163
-----+-----
```

Multinomial Regression

- It would be convenient to have a single analysis give all the information
- Can be done with multinomial logistic regression
- Also provides more efficient estimates (narrower confidence intervals) in most cases.

Multinomial Regression Example

```
. mlogit insure male, rrr

Multinomial logistic regression      Number of obs   =      616
LR chi2(2)                          =      6.38
Prob > chi2                          =      0.0413
Log likelihood = -553.40712          Pseudo R2       =      0.0057
```

insure		RRR	Std. Err.	z	P> z	[95% Conf. Interval]	
Prepaid							
	male	1.611735	.3157844	2.44	0.015	1.09779	2.36629
Uninsure							
	male	1.584375	.5693021	1.28	0.200	.7834329	3.20416

(Outcome insure==Indemnity is the comparison group)

Multinomial Regression in Stata

- Command `mlogit`
- Option `rrr` (Relative risk ratio) gives odds ratios, rather than coefficients
- Option `basecategory` sets the baseline or reference category

Using `predict` after `mlogit`

- Can predict probability of each outcome
 - Need to give k variables
 - `predict p1-p3, p`
- Can predict probability of one particular outcome
 - Need to specify which with `outcome` option
 - `predict p2, p outcome(2)`

Using `predict` after `mlogit`: Example

```
. by male: summ p1-p3
```

```
-> male = 0
```

Variable	Obs	Mean	Std. Dev.	Min	Max
p1	477	.5064935	0	.5064935	.5064935
p2	477	.4242424	0	.4242424	.4242424
p3	477	.0692641	0	.0692641	.0692641

```
-> male = 1
```

Variable	Obs	Mean	Std. Dev.	Min	Max
p1	167	.3896104	0	.3896104	.3896104
p2	167	.525974	0	.525974	.525974
p3	167	.0844156	0	.0844156	.0844156

Using `lincom` after `mlogit`

- Can use `lincom` to
 - test if coefficients are different
 - calculate odds of being in a given outcome category
- Need to specify which outcome category we are interested in
- Normally, use the option `eform` to get odds ratios, rather than coefficients

Using `lincom` after `mlogit`

```
. lincom [Prepaid]male - [Uninsure]male
```

```
( 1) [Prepaid]male - [Uninsure]male = 0
```

insure	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
(1)	.017121	.3544299	0.05	0.961	-.6775487 .7117908

Ordinal Outcomes

- Can ignore ordering, use multinomial model
- Can use a test for trend
- Can use an ordered logistic regression model

Test for Trend

- χ^2 -test tests for any differences between columns (or rows)
- Not very powerful against a linear change in proportions
- Can divide the χ^2 -statistic into two parts: linear trend and variations around the linear trend.
- Test for trend more powerful against a trend
- Has no power to detect other differences
- Often used for ordinal *predictors*

Test for Trend: Example

	Treatment A		Treatment B		Total	
Healed	12	(38%)	5	(16%)	17	(27%)
Improved	10	(31%)	8	(25%)	18	(28%)
No Change	4	(13%)	8	(25%)	12	(19%)
Worse	6	(19%)	11	(34%)	17	(27%)
Total	32	(100%)	32	(100%)	34	(100%)

Test for Trend: Results

```
. ptrendi 12 5 1 \ 10 8 2 \ 4 8 3 \ 6 11 4
```

	r	nr	_prop	x
1.	12	5	0.706	1.00
2.	10	8	0.556	2.00
3.	4	8	0.333	3.00
4.	6	11	0.353	4.00

Trend analysis for proportions

Regression of p = r/(r+nr) on x:
Slope = -.12521, std. error = .0546, Z = 2.293

Overall chi2(3) = 5.909, pr>chi2 = 0.1161
Chi2(1) for trend = 5.259, pr>chi2 = 0.0218
Chi2(2) for departure = 0.650, pr>chi2 = 0.7226

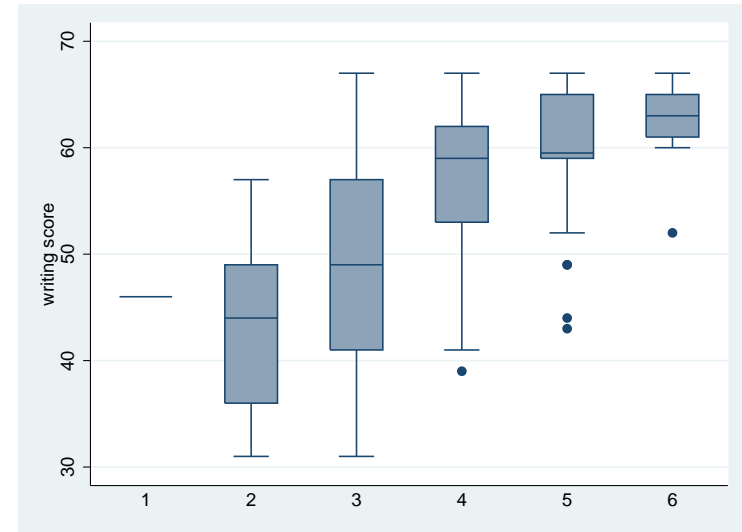
Test for Trend: Caveat

- Test for trend only tests for a linear association between predictors and outcome.
- U-shaped or inverted U-shaped associations will not be detected.

Test for Trend in Stata

- Test for trend often used, should know about it
- Not implemented in base stata:
 - see <http://www.stata.com/support/faqs/stat/trend.html>
- Very rarely the best thing to do:
 - If trend variable is the outcome, use ordinal logistic regression
 - If trend variable is a predictor:
 - fit both categorical & continuous, `testparm` categoricals
 - if non-significant, use continuous variable
 - if significant, use categorical variables

Fitting an ordinal predictor



```
. xi: regress write i.oread oread
i.oread      _Ioread_1-6      (naturally coded; _Ioread_1 omitted)

-----+-----
Source |      SS      df      MS              Number of obs =      200
-----+-----
Model | 6612.82672    5 1322.56534          F( 5, 194) = 22.77
Residual | 11266.0483  194  58.0724138          Prob > F      = 0.0000
-----+-----
Total | 17878.875   199  89.843593          R-squared     = 0.3699
                                          Adj R-squared = 0.3536
                                          Root MSE    = 7.6205

-----+-----
write |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-----+-----
_Ioread_2 | -6.669841   6.339542    -1.05  0.294   -19.17311    5.833432
_Ioread_3 | -3.666385   4.761676    -0.77  0.442   -13.05768    5.724914
_Ioread_4 |  .3641026   3.568089     0.10  0.919    -6.673124    7.401329
_Ioread_5 |  .4233918   2.825015     0.15  0.881    -5.148294    5.995078
_Ioread_6 | (dropped)
oread |  3.288889   1.606548     2.05  0.042    .1203466    6.457431
_cons |  42.71111   9.158732     4.66  0.000    24.64764    60.77458

-----+-----
. testparm _I*

( 1)  _Ioread_2 = 0
( 2)  _Ioread_3 = 0
( 3)  _Ioread_4 = 0
( 4)  _Ioread_5 = 0
( 5)  _Ioread_6 = 0
Constraint 5 dropped

F( 4, 194) = 1.36
Prob > F = 0.2497
```

Dose Response

- Don't confuse trend with dose response
 - All three models may have significant trend test
 - Only first model has a dose-response effect
 - Other models better fitted using categorical variables

Genetic Model	Genotype		
	aa	aA	AA
Additive(dose-response)	0	0.1	0.2
Dominant	0	0.2	0.2
Recessive	0	0	0.2

Ordinal Regression: Example

	Treatment A		Treatment B		Total	
Healed	12	(38%)	5	(16%)	17	(27%)
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Ordinal Regression: Using Tables

- Dichotomise outcome to “Better” or “Worse”
- Can split the table in three places
- This produces 3 odds ratios
- Suppose these three odds ratios are estimates of the same quantity
- Odds of being in a worse group rather than a better one

Ordinal Regression Example: Using Tables

	Treatment A		Treatment B		Total	
Healed	12	(38%)	5	(16%)	17	(27%)
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$$OR1 = \frac{(12+10+4) \times 11}{(5+8+8) \times 6} = 2.3 \quad (1)$$

$$OR2 = \frac{(12+10) \times (8+11)}{(5+8) \times (4+6)} = 3.2 \quad (2)$$

$$OR3 = \frac{(12) \times (8+8+11)}{5 \times (10+4+6)} = 3.2 \quad (3)$$

Ordered Polytomous Logistic Regression

$$\log\left(\frac{p_i}{1 - p_i}\right) = \alpha_i + \beta x$$

Where

- p_i = probability of being in a category up to and including the i th
- α_i = Log-odds of being in a category up to and including the i th if $x = 0$
- β = Log of the odds ratio for being in a category up to and including the i th if $x = 1$, relative to $x = 0$

Ordinal regression in Stata

- `ologit` fits ordinal regression models
- Option `or` gives odds ratios rather than coefficients
- Can compare likelihood to `mlogit` model to see if common odds ratio assumption is valid
- `predict` works as after `mlogit`

Ordinal Regression in Stata: Example

```
. ologit outcome treat, or
Iteration 3:  log likelihood =  -85.2492
Ordered logit estimates      Number of obs =      64
LR chi2(1) =      5.49
Prob > chi2 =      0.0191
Log likelihood =  -85.2492   Pseudo R2 =      0.0312
```

outcome	Odds Ratio	Std. Err.	z	P> z	[95% Conf. Interval]
treat	2.932028	1.367427	2.31	0.021	1.175407 7.31388

Ordinal Regression Caveats

- Assumption that same β fits all outcome categories should be tested
- If inappropriate, can use `mlogit`
- There are a variety of other, less widely used, ordinal regression models: see Sander Greenland: *Alternative Models for Ordinal Logistic Regression*, Statistics in Medicine, 1994, pp1665-1677.