

Using Stata 11 & higher for Logistic Regression

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Last revised March 28, 2015

NOTE: The routines `spost13`, `lrdrop1`, and `extremes` are used in this handout. Use the `findit` command to locate and install them. See related handouts for the statistical theory underlying logistic regression and for SPSS examples. Most but not all of the commands shown in this handout will also work in earlier versions of Stata, but the syntax is sometimes a little different. The output may also look a little different in different versions of Stata.

Commands. Stata and SPSS differ a bit in their approach, but both are quite competent at handling logistic regression. With large data sets, I find that Stata tends to be far faster than SPSS, which is one of the many reasons I prefer it.

Stata has various commands for doing logistic regression. They differ in their default output and in some of the options they provide. My personal favorite is `logit`.

```
. use "https://academicweb.nd.edu/~rwilliam/statafiles/logist.dta", clear
. logit grade gpa tuce psi
```

```
Iteration 0:   log likelihood =  -20.59173
Iteration 1:   log likelihood = -13.496795
Iteration 2:   log likelihood = -12.929188
Iteration 3:   log likelihood = -12.889941
Iteration 4:   log likelihood = -12.889633
Iteration 5:   log likelihood = -12.889633
```

```
Logit estimates                                     Number of obs   =          32
                                                    LR chi2(3)      =          15.40
                                                    Prob > chi2     =          0.0015
Log likelihood = -12.889633                        Pseudo R2       =          0.3740
```

grade	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
gpa	2.826113	1.262941	2.24	0.025	.3507938 5.301432
tuce	.0951577	.1415542	0.67	0.501	-.1822835 .3725988
psi	2.378688	1.064564	2.23	0.025	.29218 4.465195
_cons	-13.02135	4.931325	-2.64	0.008	-22.68657 -3.35613

Note that the log likelihood for iteration 0 is LL_0 , i.e. it is the log likelihood when there are no explanatory variables in the model - only the constant term is included. The last log likelihood reported is LL_M . From these we easily compute

$$DEV_0 = -2LL_0 = -2 * -20.59173 = 41.18$$

$$DEV_M = -2LL_M = -2 * -12.889633 = 25.78$$

Also note that the default output does not include $\exp(b)$. To get that, include the `or` parameter (or = odds ratios = $\exp(b)$).

```
. logit grade gpa tuce psi, or nolog
```

```
Logistic regression               Number of obs   =          32
                                LR chi2(3)        =          15.40
                                Prob > chi2       =          0.0015
Log likelihood = -12.889633       Pseudo R2    =          0.3740
```

```
-----+-----
      grade | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----+-----
      gpa |   16.87972   21.31809     2.24   0.025     1.420194    200.6239
      tuce |    1.099832   .1556859     0.67   0.501     .8333651    1.451502
      psi |   10.79073   11.48743     2.23   0.025     1.339344     86.93802
      _cons |   2.21e-06   .0000109    -2.64   0.008     1.40e-10     .03487
-----+-----
```

Or, you can use the `logistic` command, which reports `exp(b)` (odds ratios) by default:

```
. logistic grade gpa tuce psi
```

```
Logistic regression               Number of obs   =          32
                                LR chi2(3)        =          15.40
                                Prob > chi2       =          0.0015
Log likelihood = -12.889633       Pseudo R2    =          0.3740
```

```
-----+-----
      grade | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----+-----
      gpa |   16.87972   21.31809     2.24   0.025     1.420194    200.6239
      tuce |    1.099832   .1556859     0.67   0.501     .8333651    1.451502
      psi |   10.79073   11.48743     2.23   0.025     1.339344     86.93802
      _cons |   2.21e-06   .0000109    -2.64   0.008     1.40e-10     .03487
-----+-----
```

[Note: Starting with Stata 12, the exponentiated constant is also reported]. To have `logistic` instead give you the coefficients,

```
. logistic grade gpa tuce psi, coef
```

```
Logistic regression               Number of obs   =          32
                                LR chi2(3)        =          15.40
                                Prob > chi2       =          0.0015
Log likelihood = -12.889633       Pseudo R2    =          0.3740
```

```
-----+-----
      grade |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----+-----
      gpa |   2.826113   1.262941     2.24   0.025     .3507938    5.301432
      tuce |   .0951577   .1415542     0.67   0.501    -1.1822835   .3725988
      psi |   2.378688   1.064564     2.23   0.025     .29218     4.465195
      _cons | -13.02135   4.931325    -2.64   0.008    -22.68657   -3.35613
-----+-----
```

There are various other options of possible interest, e.g. just as with OLS regression you can specify robust standard errors, change the confidence interval and do stepwise logistic regression.

You can further enhance the functionality of Stata by downloading and installing `spost13` (which includes several post-estimation commands) and `lrdrop1`. Use the `findit` command to get these. The rest of this handout assumes these routines are installed, so if a command isn't working, it is probably because you have not installed it.

Hypothesis testing. Stata makes you go to a little more work than SPSS does to make contrasts between nested models. You need to use the `estimates store` and `lrtest` commands. Basically, you estimate your models, store the results under some arbitrarily chosen name, and then use the `lrtest` command to contrast models. Let's run through a sequence of models:

```
. * Model 0: Intercept only
. quietly logit grade
. est store M0

. * Model 1: GPA added
. quietly logit grade gpa
. est store M1

. * Model 2: GPA + TUCE
. quietly logit grade gpa tuce
. est store M2

. * Model 3: GPA + TUCE + PSI
. quietly logit grade gpa tuce psi
. est store M3

. * Model 1 versus Model 0
. lrtest M1 M0
```

likelihood-ratio test	LR chi2(1) =	8.77
(Assumption: M0 nested in M1)	Prob > chi2 =	0.0031

```
. * Model 2 versus Model 1
. lrtest M2 M1
```

likelihood-ratio test	LR chi2(1) =	0.43
(Assumption: M1 nested in M2)	Prob > chi2 =	0.5096

```
. * Model 3 versus Model 2
. lrtest M3 M2
```

likelihood-ratio test	LR chi2(1) =	6.20
(Assumption: M2 nested in M3)	Prob > chi2 =	0.0127

```
. * Model 3 versus Model 0
. lrtest M3 M0
```

likelihood-ratio test	LR chi2(3) =	15.40
(Assumption: M0 nested in M3)	Prob > chi2 =	0.0015

Also note that the output includes z values for each coefficient (where $z = \text{coefficient} / \text{standard error}$). SPSS reports these values squared and calls them Wald statistics.

Technically, Wald statistics are not considered 100% optimal; it is better to do likelihood ratio tests, where you estimate the constrained model without the parameter and contrast it with the unconstrained model that includes the parameter. The `lrdrop1` command makes this easy (also see the similar `bicdrop1` command if you want BIC tests instead):

```
. logit grade gpa tuce psi
```

```
Iteration 0:   log likelihood = -20.59173
[Intermediate iterations deleted]
Iteration 5:   log likelihood = -12.889633
```

```
Logit estimates                                     Number of obs   =          32
                                                    LR chi2(3)      =          15.40
                                                    Prob > chi2     =          0.0015
Log likelihood = -12.889633                        Pseudo R2      =          0.3740
```

grade	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gpa	2.826113	1.262941	2.24	0.025	.3507938	5.301432
tuce	.0951577	.1415542	0.67	0.501	-.1822835	.3725988
psi	2.378688	1.064564	2.23	0.025	.29218	4.465195
_cons	-13.02135	4.931325	-2.64	0.008	-22.68657	-3.35613

```
. lrdrop1
```

```
Likelihood Ratio Tests: drop 1 term
logit regression
number of obs = 32
```

grade	Df	Chi2	P>Chi2	-2*log ll	Res. Df	AIC
Original Model				25.78	28	33.78
-gpa	1	6.78	0.0092	32.56	27	38.56
-tuce	1	0.47	0.4912	26.25	27	32.25
-psi	1	6.20	0.0127	31.98	27	37.98

```
Terms dropped one at a time in turn.
```

You can also use the `test` command for hypothesis testing, but the Wald tests that are estimated by the `test` command are considered inferior to estimating separate models and then doing LR chi-square contrasts of the results.

```
. test psi
```

```
( 1)  psi = 0
```

```
      chi2( 1) =      4.99
Prob > chi2 =      0.0255
```

Also, Stata 9 added the `nestreg` prefix. This makes it easy to estimate a sequence of nested models and do chi-square contrasts between them. The `lr` option tells `nestreg` to do likelihood ratio tests rather than Wald tests. This can be more time-consuming but is also more accurate. The `store` option is optional but, in this case, will store the results of each model as `m1`, `m2`, etc. This would be handy if, say, you wanted to do a chi-square contrast between model 3 and model 1.

```
. nestreg, lr store(m): logit grade gpa tuce psi
[intermediate output deleted]
```

Block	LL	LR	df	Pr > LR	AIC	BIC
1	-16.2089	8.77	1	0.0031	36.4178	39.34928
2	-15.99148	0.43	1	0.5096	37.98296	42.38017
3	-12.88963	6.20	1	0.0127	33.77927	39.64221

```
. lrtest m3 m1
```

```

Likelihood-ratio test                                LR chi2(2)  =      6.64
(Assumption: m1 nested in m3)                       Prob > chi2 =    0.0362

```

Also, you don't have to enter variables one at a time; by putting parentheses around sets of variables, they will all get entered in the same block.

```
. nestreg, lr: logit grade gpa (tuce psi)
[intermediate output deleted]
```

Block	LL	LR	df	Pr > LR	AIC	BIC
1	-16.2089	8.77	1	0.0031	36.4178	39.34928
2	-12.88963	6.64	2	0.0362	33.77927	39.64221

Note that AIC and BIC are reported. These are also useful statistics for comparing models, but I won't talk about them in this handout. Adding the `stats` option to `lrtest` will also cause these statistics to be reported, e.g.

```
. lrtest m3 m1, stats
```

```

Likelihood-ratio test                                LR chi2(2)  =      6.64
(Assumption: m1 nested in m3)                       Prob > chi2 =    0.0362

```

Model	Obs	ll(null)	ll(model)	df	AIC	BIC
m1	32	-20.59173	-16.2089	2	36.4178	39.34928
m3	32	-20.59173	-12.88963	4	33.77927	39.64221

R² analogs and goodness of fit measures. Although it is not clearly labeled, the Pseudo R² reported by Stata is McFadden's R², which seems to be the most popular of the many alternative measures that are out there. One straightforward formula is

$$Pseudo R^2 = 1 - \frac{LL_M}{LL_0} = 1 - \frac{-12.889633}{-20.59173} = 1 - .625961636 = .374$$

You can also get a bunch of other pseudo R² measures and goodness of fit statistics by typing `fitstat` (part of the `spost13` routines) after you have estimated a logistic regression:

. fitstat

		logit
-----+-----		
Log-likelihood		
Model		-12.890
Intercept-only		-20.592
-----+-----		
Chi-square		
Deviance (df=28)		25.779
LR (df=3)		15.404
p-value		0.002
-----+-----		
R2		
McFadden		0.374
McFadden (adjusted)		0.180
McKelvey & Zavoina		0.544
Cox-Snell/ML		0.382
Cragg-Uhler/Nagelkerke		0.528
Efron		0.426
Tjur's D		0.429
Count		0.813
Count (adjusted)		0.455
-----+-----		
IC		
AIC		33.779
AIC divided by N		1.056
BIC (df=4)		39.642
-----+-----		
Variance of		
e		3.290
y-star		7.210

To get the equivalent of SPSS's classification table, you can use the `estat clas` command (`lstat` also works). This command shows you how many cases were classified correctly and incorrectly, using a cutoff point of 50% for the predicted probability.

```
. lstat
```

Logistic model for grade

		----- True -----		
Classified		D	~D	Total
+		8	3	11
-		3	18	21
Total		11	21	32

Classified + if predicted $\Pr(D) \geq .5$

True D defined as grade $\neq 0$

Sensitivity	Pr(+ D)	72.73%
Specificity	Pr(- ~D)	85.71%
Positive predictive value	Pr(D +)	72.73%
Negative predictive value	Pr(~D -)	85.71%
False + rate for true ~D	Pr(+ ~D)	14.29%
False - rate for true D	Pr(- D)	27.27%
False + rate for classified +	Pr(~D +)	27.27%
False - rate for classified -	Pr(D -)	14.29%
Correctly classified		81.25%

Predicted values. Stata makes it easy to come up with the predicted values for each case. You run the logistic regression, and then use the `predict` command to compute various quantities of interest to you.

```
. quietly logit grade gpa tuce psi

. * get the predicted log odds for each case
. predict logodds, xb

. * get the odds for each case
. gen odds = exp(logodds)

. * get the predicted probability of success
. predict p, p
```

```
. list grade gpa tuce psi logodds odds p
```

	grade	gpa	tuce	psi	logodds	odds	p
1.	0	2.06	22	1	-2.727399	.0653891	.0613758
2.	1	2.39	19	1	-2.080255	.1248984	.1110308
3.	0	2.63	20	0	-3.685518	.0250842	.0244704
4.	0	2.92	12	0	-3.627206	.0265904	.0259016
5.	0	2.76	17	0	-3.603596	.0272256	.026504
6.	0	2.66	20	0	-3.600734	.0273037	.026578
7.	0	2.89	14	1	-1.142986	.3188653	.2417725
8.	0	2.74	19	0	-3.469803	.0311232	.0301837
9.	0	2.86	17	0	-3.320985	.0361172	.0348582
10.	0	2.83	19	0	-3.215453	.0401371	.0385883
11.	0	2.67	24	1	-.8131546	.4434569	.3072187
12.	0	2.87	21	0	-2.912093	.0543618	.051559
13.	0	2.75	25	0	-2.870596	.0566651	.0536264
14.	0	2.89	22	0	-2.760413	.0632657	.0595013
15.	1	2.83	27	1	-.075504	.927276	.481133
16.	0	3.1	21	1	.1166004	1.12367	.5291171
17.	0	3.03	25	0	-2.079284	.1250196	.1111266
18.	0	3.12	23	1	.363438	1.438266	.5898724
19.	1	3.39	17	1	.5555431	1.742887	.6354207
20.	1	3.16	25	1	.6667984	1.947991	.6607859
21.	0	3.28	24	0	-1.467914	.2304057	.1872599
22.	0	3.32	23	0	-1.450027	.234564	.1899974
23.	1	3.26	25	0	-1.429278	.2394817	.1932112
24.	0	3.57	23	0	-.7434988	.4754475	.3222395
25.	1	3.54	24	1	1.645563	5.183929	.8382905
26.	1	3.65	21	1	1.670963	5.317286	.8417042
27.	0	3.51	26	1	1.751095	5.760909	.8520909
28.	0	3.53	26	0	-.5710702	.5649205	.3609899
29.	1	3.62	28	1	2.252283	9.509419	.9048473
30.	1	4	21	0	.2814147	1.325003	.569893
31.	1	4	23	1	2.850418	17.295	.9453403
32.	1	3.92	29	0	.8165872	2.262764	.6935114

Hypothetical values. Stata also makes it very easy to plug in hypothetical values. One way to do this in Stata 11 or higher is with the `margins` command (with older versions of Stata you can use `adjust`). We previously computed the probability of success for a hypothetical student with a gpa of 3.0 and a tuce score of 20 who is either in psi or not in psi. To compute these numbers in Stata,


```
. * Probability of getting an A
. quietly logit grade gpa tuce i.psi
. margins psi, at(gpa = 3 tuce = 20)
```

```
Adjusted predictions      Number of obs   =          32
Model VCE      : OIM
```

```
Expression   : Pr(grade), predict()
at           : gpa           =          3
              tuce          =         20
```

		Delta-method				
		Margin	Std. Err.	z	P> z	[95% Conf. Interval]
	psi					
	0	.066617	.0611322	1.09	0.276	-.0531999 .1864339
	1	.4350765	.1812458	2.40	0.016	.0798413 .7903118

This hypothetical, about average student would have less than a 7% chance of getting an A in the traditional classroom, but would have almost a 44% chance of an A in a psi classroom.

Now, consider a strong student with a 4.0 gpa and a tuce of 25:

```
. margins psi, at(gpa = 4 tuce = 25)
```

```
Adjusted predictions      Number of obs   =          32
Model VCE      : OIM
```

```
Expression   : Pr(grade), predict()
at           : gpa           =          4
              tuce          =         25
```

		Delta-method				
		Margin	Std. Err.	z	P> z	[95% Conf. Interval]
	psi					
	0	.6597197	.2329773	2.83	0.005	.2030926 1.116347
	1	.9543808	.0560709	17.02	0.000	.8444837 1.064278

This student has about a 2/3 chance of an A in a traditional classroom, and a better than 95% chance of an A in psi.

If you want the log odds instead of the probabilities, give commands like

```
. margins psi, at(gpa = 4 tuce = 25) predict(xb)
```

```
Adjusted predictions      Number of obs   =          32
Model VCE      : OIM
```

```
Expression      : Linear prediction (log odds), predict(xb)
at              : gpa              =          4
                tuce              =          25
```

		Delta-method				[95% Conf. Interval]	
		Margin	Std. Err.	z	P> z		
	psi						
	0	.6620453	1.037809	0.64	0.524	-1.372022	2.696113
	1	3.040733	1.287859	2.36	0.018	.5165768	5.564889

To get the odds, you need to exponentiate the log odds. You can do that via

```
. margins psi, at(gpa = 4 tuce = 25) expression(exp(predict(xb)))
```

```
Adjusted predictions      Number of obs   =          32
Model VCE      : OIM
```

```
Expression      : exp(predict(xb))
at              : gpa              =          4
                tuce              =          25
```

		Delta-method				[95% Conf. Interval]	
		Margin	Std. Err.	z	P> z		
	psi						
	0	1.938754	2.012055	0.96	0.335	-2.004802	5.88231
	1	20.92057	26.94274	0.78	0.437	-31.88622	73.72737

Long & Freese's `spost` commands provide several other good ways of performing these sorts of tasks; see, for example, the `mtable` and `mchange` commands.

Stepwise Logistic Regression. This works pretty much the same way it does with OLS regression. However, by adding the `lrr` parameter, we force Stata to use the more accurate (and more time-consuming) Likelihood Ratio tests rather than Wald tests when deciding which variables to include. (Note: stepwise is available in earlier versions of Stata but the syntax is a little different.)

```
. sw, pe(.05) lr: logit grade gpa tuce psi
```

```
LR test              begin with empty model
p = 0.0031 < 0.0500  adding  gpa
p = 0.0130 < 0.0500  adding  psi
```

```
Logistic regression      Number of obs   =          32
                          LR chi2(2)      =          14.93
                          Prob > chi2     =          0.0006
                          Pseudo R2      =          0.3625

Log likelihood = -13.126573
```

grade	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]	
gpa	3.063368	1.22285	2.51	0.012	.6666251	5.46011
psi	2.337776	1.040784	2.25	0.025	.2978755	4.377676
_cons	-11.60157	4.212904	-2.75	0.006	-19.85871	-3.344425

Diagnostics. The `predict` command lets you compute various diagnostic measures, just like it did with OLS. For example, the `predict` command can generate a standardized residual. It can also generate a deviance residual (the deviance residuals identify those cases that contribute the most to the overall deviance of the model.) [WARNING: SPSS and Stata sometimes use different formulas and procedures for computing residuals, so results are not always identical across programs.]

```
. * Generate predicted probability of success
. predict p, p

. * Generate standardized residuals
. predict rstandard, rstandard

. * Generate the deviance residual
. predict dev, deviance

. * Use the extremes command to identify large residuals
. extremes rstandard dev p grade gpa tuce psi
```

obs:	rstandard	dev	p	grade	gpa	tuce	psi
27.	-2.541286	-1.955074	.8520909	0	3.51	26	1
18.	-1.270176	-1.335131	.5898724	0	3.12	23	1
16.	-1.128117	-1.227311	.5291171	0	3.1	21	1
28.	-.817158	-.9463985	.3609899	0	3.53	26	0
24.	-.7397601	-.8819993	.3222395	0	3.57	23	0
19.	.8948758	.9523319	.6354207	1	3.39	17	1
30.	1.060433	1.060478	.569893	1	4	21	0
15.	1.222325	1.209638	.481133	1	2.83	27	1
23.	2.154218	1.813269	.1932112	1	3.26	25	0
2.	3.033444	2.096639	.1110308	1	2.39	19	1

The above results suggest that cases 2 and 27 may be problematic. Several other diagnostic measures can also be computed.

Multicollinearity. Multicollinearity is a problem of the X variables, and you can often diagnose it the same ways you would for OLS. Phil Ender's `collin` command is very useful for this:

```
. collin gpa tuce psi if !missing(grade)
```

Robust standard errors. If you fear that the error terms may not be independent and identically distributed, e.g. heteroscedasticity may be a problem, you can add the `robust` parameter just like you did with the `regress` command.

```
. logit grade gpa tuce psi, robust
```

```
Iteration 0:  log pseudo-likelihood = -20.59173
Iteration 1:  log pseudo-likelihood = -13.496795
Iteration 2:  log pseudo-likelihood = -12.929188
Iteration 3:  log pseudo-likelihood = -12.889941
Iteration 4:  log pseudo-likelihood = -12.889633
Iteration 5:  log pseudo-likelihood = -12.889633
```

```
Logit estimates                                     Number of obs   =          32
                                                    Wald chi2(3)    =           9.36
                                                    Prob > chi2     =          0.0249
Log pseudo-likelihood = -12.889633                Pseudo R2       =          0.3740
```

grade	Coef.	Robust Std. Err.	z	P> z	[95% Conf. Interval]	

gpa	2.826113	1.287828	2.19	0.028	.3020164	5.35021
tuce	.0951577	.1198091	0.79	0.427	-.1396639	.3299793
psi	2.378688	.9798509	2.43	0.015	.4582152	4.29916
_cons	-13.02135	5.280752	-2.47	0.014	-23.37143	-2.671264

Note that the standard errors have changed very little. However, Stata now reports “pseudo-likelihoods” and a Wald chi-square instead of a likelihood ratio chi-square for the model. I won't try to explain why. Stata will surprise you some times with the statistics it reports, but it generally seems to have a good reason for them (although you may have to spend a lot of time reading through the manuals or the online FAQs to figure out what it is.)

Additional Information. Long and Freese's `spost13` routines include several other commands that help make the results from logistic regression more interpretable. Their book is very good:

Regression Models for Categorical Dependent Variables Using Stata, Third Edition, by J. Scott Long and Jeremy Freese. 2014.

The notes for my Soc 73994 class, Categorical Data Analysis, contain a lot of additional information on using Stata for logistic regression and other categorical data techniques. See

<https://academicweb.nd.edu/~rwilliam/xsoc73994/index.html>