

## Using Stata 9 & 10 for Logistic Regression

**NOTE:** The routines `spost9`, `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. The `spostado` routines will generally work if you have an earlier version of Stata. Most but not all of the commands shown in this handout will also work in Stata 8, but the syntax is sometimes a little different.

**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 "http://www.nd.edu/~rwilliam/stats2/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
```

```
Logit estimates                               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
-----+-----
```

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
-----+-----
```

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   -.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 `spost9` (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 the same sequence of models we did with SPSS:

```
. * 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

$R^2$  analogs and goodness of fit measures. Although it is not clearly labeled, the Pseudo  $R^2$  reported by Stata is McFadden's  $R^2$ , 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  $R^2$  measures and goodness of fit statistics by typing `fitstat` (part of the `spost9` routines) after you have estimated a logistic regression:

```
. fitstat
```

Measures of Fit for logit of grade

Log-Lik Intercept Only:	-20.592	Log-Lik Full Model:	-12.890
D(28):	25.779	LR(3):	15.404
		Prob > LR:	0.002
McFadden's R2:	0.374	McFadden's Adj R2:	0.180
Maximum Likelihood R2:	0.382	Cragg & Uhler's R2:	0.528
McKelvey and Zavoina's R2:	0.544	Efron's R2:	0.426
Variance of y*:	7.210	Variance of error:	3.290
Count R2:	0.813	Adj Count R2:	0.455
AIC:	1.056	AIC*n:	33.779
BIC:	-71.261	BIC':	-5.007

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

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

Classified + if predicted Pr(D) >= .5  
True D defined as grade != 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 is with the `adjust` command. We previously computed the log odds and 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,

```
* Log odds
. quietly logit grade gpa tuce psi
. adjust gpa=3 tuce=20, by(psi)
```

```
-----
Dependent variable: grade      Command: logit
Covariates set to value: gpa = 3, tuce = 20
-----
```

```
-----
psi |          xb
-----+-----
0 |   -2.63986
1 |   -2.261168
-----
```

```
Key:  xb = Linear Prediction
```

```
* Odds
. adjust gpa=3 tuce=20, by(psi) exp
```

```
-----
Dependent variable: grade      Command: logit
Covariates set to value: gpa = 3, tuce = 20
-----
```

```
-----
psi |      exp(xb)
-----+-----
  0 |      .071372
  1 |      .770151
-----
```

```
Key:  exp(xb) = exp(xb)
```

```
* Probability of getting an A
. adjust gpa=3 tuce=20, by(psi) pr
```

```
-----
Dependent variable: grade      Command: logit
Covariates set to value: gpa = 3, tuce = 20
-----
```

```
-----
psi |      pr
-----+-----
  0 |      .066617
  1 |      .435077
-----
```

```
Key:  pr = Probability
```

These are the same numbers we got before. 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 again the strong student with a 4.0 gpa and a tuce of 25:

```
* Log odds
. adjust gpa=4 tuce=25, by(psi)
```

```
-----
Dependent variable: grade      Command: logit
Covariates set to value: gpa = 4, tuce = 25
-----
```

```
-----
psi |      xb
-----+-----
  0 |      .662045
  1 |      3.04073
-----
```

```
Key:  xb = Linear Prediction
```

```
* Odds
. adjust gpa=4 tuce=25, by(psi) exp
```

```
-----
Dependent variable: grade      Command: logit
Covariates set to value: gpa = 4, tuce = 25
-----
```

```
-----
      psi |      exp(xb)
-----+-----
      0 |      1.93875
      1 |      20.9206
-----
```

```
Key: exp(xb) = exp(xb)
```

```
* Probability of getting an A
. adjust gpa=4 tuce=25, by(psi) pr
```

```
-----
Dependent variable: grade      Command: logit
Covariates set to value: gpa = 4, tuce = 25
-----
```

```
-----
      psi |      pr
-----+-----
      0 |      .65972
      1 |      .954381
-----
```

```
Key: pr = Probability
```

As we saw before, 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.

The `predict` command can also be used to plug in hypothetical values. In general, the `predict` command calculates values for ALL observations currently stored in memory, whether they were used in fitting the model or not. Hence, one of many possible strategies is to run the logistic regression; `preserve` the real data and then temporarily delete it; interactively enter the hypothetical data; use the `predict` and/or `gen` commands to compute the new variables; `list` the results; and finally, `restore` the original data.

```
. quietly logit grade gpa tuce psi

. * Preserve the data so we can restore it later
. preserve

* Temporarily drop all cases - the last character in the next command is
* a lowercase L, which means last case.
. drop in 1/1
(32 observations deleted)

. edit
- preserve
* I interactively entered the values you see below.
```

```
. list
```

```
+-----+
| grade  gpa  tuce  psi |
+-----+
1. |      .    3    20    0 |
2. |      .    3    20    1 |
3. |      .    4    25    0 |
4. |      .    4    25    1 |
+-----+
```

```
. predict logodds, xb
```

```
. gen odds = exp(logodds)
```

```
. predict p, p
```

```
. list
```

```
+-----+
| grade  gpa  tuce  psi  logodds  odds  p |
+-----+
1. |      .    3    20    0  -2.639856  .0713715  .066617 |
2. |      .    3    20    1  -2.2611683  .7701513  .4350765 |
3. |      .    4    25    0  .6620453  1.938754  .6597197 |
4. |      .    4    25    1  3.040733  20.92057  .9543808 |
+-----+
```

```
. * Restore original data
```

```
. restore
```

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

**Stepwise Logistic Regression.** This works pretty much the same way it does with OLS regression. However, by adding the `lr` 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
Log likelihood = -13.126573         Pseudo R2      =          0.3625
```

```
-----+-----+
| 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
```

```
-----+-----
      |               Robust
      |               Coef.   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    -1.1396639     .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 `spost9` 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, Second Edition, by J. Scott Long and Jeremy Freese. 2006.

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

<http://www.nd.edu/~rwilliam/xsoc73994/index.html>