Linear Regression

(ver. 6.0)

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We use regression to estimate the unknown effect of changing one variable over another (Stock and Watson, 2003, ch. 4)

When running a regression we are making two assumptions, 1) there is a linear relationship between two variables (i.e. *X* and *Y*) and 2) this relationship is additive (i.e. *Y= x1 + x2 + …+xN*).

Technically, linear regression estimates how much *Y* changes when *X* changes one unit.

In Stata use the command regress, type:

```
regress [dependent variable] [independent variable(s)]
```

```
regress y x
```

In a multivariate setting we type:

```
regress y x1 x2 x3 …
```

Before running a regression it is recommended to have a clear idea of what you are trying to estimate (i.e. which are your outcome and predictor variables).

A regression makes sense only if there is a sound theory behind it.

Example: *Are SAT scores higher in states that spend more money on education controlling by other factors?**

- Outcome (Y) variable – SAT scores, variable `csat` in dataset
- Predictor (X) variables
  - Per pupil expenditures primary & secondary (`expense`)
  - % HS graduates taking SAT (`percent`)
  - Median household income (`income`)
  - % adults with HS diploma (`high`)
  - % adults with college degree (`college`)
  - Region (`region`)

*Source: Data and examples come from the book *Statistics with Stata (updated for version 9)* by Lawrence C. Hamilton (chapter 6). Click here to download the data or search for it at http://www.duxbury.com/highered/.
Use the file `states.dta` (educational data for the U.S.).

Regression: variables

It is recommended first to examine the variables in the model to check for possible errors, type:

```
use http://dss.princeton.edu/training/states.dta
describe csat expense percent income high college region
summarize csat expense percent income high college region
```

```
. describe  csat expense percent income high college region

              storage  display     value
variable name   type   format      label      variable label
------------------------------------------------------------------------------
csat            int    %9.0g                  Mean composite SAT score
expense         int    %9.0g                  Per pupil expenditures prim&sec
percent         byte   %9.0g                  % HS graduates taking SAT
income          double %10.0g                 Median household income, $1,000
high            float  %9.0g                  % adults HS diploma
college         float  %9.0g                  % adults college degree
region          byte   %9.0g       region     Geographical region
```

```
. summarize  csat expense percent income high college region
```

Variable	Obs	Mean	Std. Dev.	Min	Max
csat	51	944.098	66.93497	832	1093
expense	51	5235.961	1401.155	2960	9259
percent	51	35.76471	26.19281	4	81
income	51	33.95657	6.423134	23.465	48.618
high	51	76.26078	5.588741	64.3	86.6
college	51	20.02157	4.16578	12.3	33.3
region	50	2.54	1.128662	1	4

Regression: what to look for

Lets run the regression:

`regress csat expense, robust`

Outcome variable (Y)

Predictor variable (X)

Robust standard errors (to control for heteroskedasticity)

```
. regress  csat expense, robust

Linear regression                               Number of obs =        51
                                                F(  1,    49) =     36.80
                                                Prob > F      =    0.0000
                                                R-squared     =    0.2174
                                                Root MSE      =    59.814
```

csat	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
expense	-.0222756	.0036719	-6.07	0.000	-.0296547	-.0148966
_cons	1060.732	24.35468	43.55	0.000	1011.79	1109.675

1 This is the p-value of the model. It tests whether R^2 is different from 0. Usually we need a p-value lower than 0.05 to show a statistically significant relationship between X and Y.

2 R-square shows the amount of variance of Y explained by X. In this case expense explains 22% of the variance in SAT scores.

3 Adj R^2 (not shown here) shows the same as R^2 but adjusted by the # of cases and # of variables. When the # of variables is small and the # of cases is very large then *Adj* R^2 is closer to R^2. This provides a more honest association between X and Y.

4 Two-tail p-values test the hypothesis that each coefficient is different from 0. To reject this, the p-value has to be lower than 0.05 (you could choose also an alpha of 0.10). In this case, expense is statistically significant in explaining SAT.

5 The t-values test the hypothesis that the coefficient is different from 0. To reject this, you need a t-value greater than 1.96 (for 95% confidence). You can get the t-values by dividing the coefficient by its standard error. The t-values also show the importance of a variable in the model.

6 csat = 1061 - 0.022*expense
For each one-point increase in expense, SAT scores decrease by 0.022 points.

7 Root MSE: root mean squared error, is the sd of the regression. The closer to zero better the fit.

Regression: what to look for

Adding the rest of predictor variables:

`regress csat expense percent income high college, robust`

Robust standard errors (to control for heteroskedasticity)

Output variable (Y)

Predictor variables (X)

```
. regress csat expense percent income high college, robust

Linear regression                               Number of obs =      51
                                                F(  5,    45) =   50.90
                                                Prob > F      =  0.0000
                                                R-squared     =  0.8243
                                                Root MSE      =  29.571

------------------------------------------------------------------------------
             |               Robust
        csat |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     expense |   .0033528    .004781     0.70   0.487    -.0062766    .0129823
     percent |  -2.618177   .2288594   -11.44   0.000    -3.079123   -2.15723
      income |   .1055853   1.207246     0.09   0.931    -2.325933   2.537104
        high |   1.630841    .943318     1.73   0.091    -.2690989   3.530781
     college |   2.030894   2.113792     0.96   0.342    -2.226502    6.28829
       _cons |   851.5649   57.28743    14.86   0.000     736.1821   966.9477
------------------------------------------------------------------------------
```

1 This is the p-value of the model. It indicates the reliability of X to predict Y. Usually we need a p-value lower than 0.05 to show a statistically significant relationship between X and Y.

2 R-square shows the amount of variance of Y explained by X. In this case the model explains 82.43% of the variance in SAT scores.

3 Adj R^2 (not shown here) shows the same as R^2 but adjusted by the # of cases and # of variables. When the # of variables is small and the # of cases is very large then Adj R^2 is closer to R^2. This provides a more honest association between X and Y.

4 Two-tail p-values test the hypothesis that each coefficient is different from 0. To reject this, the p-value has to be lower than 0.05 (you could choose also an alpha of 0.10). In this case, `expense`, `income`, and `college` are not statistically significant in explaining SAT; `high` is almost significant at 0.10. `Percent` is the only variable that has some significant impact on SAT (its coefficient is different from 0)

5 The t-values test the hypothesis that the coefficient is different from 0. To reject this, you need a t-value greater than 1.96 (at 0.05 confidence). You can get the t-values by dividing the coefficient by its standard error. The t-values also show the importance of a variable in the model. In this case, `percent` is the most important.

6 csat = 851.56 + 0.003*expense – 2.62*percent + 0.11*income + 1.63*high + 2.03*college

7 Root MSE: root mean squared error, is the sd of the regression. The closer to zero better the fit.

`Region` is entered here as dummy variable. The easy way to add dummy variables to a regression is using "`xi`" and the prefix "`i.`" (interpretation is the same as before). The first category is always the reference:

`xi:` `regress` *`csat expense percent income high college`* ***`i.region`***`,` `robust`

```
. xi: regress  csat expense percent income high college i.region, robust
i.region          _Iregion_1-4        (naturally coded; _Iregion_1 omitted)

Linear regression                               Number of obs =      50
                                                F(  8,    41) =   69.82
                                                Prob > F      =  0.0000
                                                R-squared     =  0.9111
                                                Root MSE      =  21.492

------------------------------------------------------------------------------
             |               Robust
        csat |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     expense |   -.002021   .0035883    -0.56   0.576    -.0092676    .0052256
     percent |  -3.007647   .2358047   -12.75   0.000    -3.483864   -2.53143
      income |  -.1674421   1.196409    -0.14   0.889    -2.583638    2.248754
        high |   1.814731    1.02694     1.77   0.085    -.2592168    3.888679
     college |   4.670564   1.599798     2.92   0.006     1.439705    7.901422
  _Iregion_2 |   69.45333   17.99933     3.86   0.000     33.10295    105.8037
  _Iregion_3 |   25.39701   12.52558     2.03   0.049      .101086    50.69293
  _Iregion_4 |   34.57704   9.44989      3.66   0.001      15.4926    53.66149
       _cons |   808.0206   67.86418    11.91   0.000     670.9661    945.0751
------------------------------------------------------------------------------
```

Regions:
1 West
2 N. East
3 South
4 Midwest

NOTE: By default `xi` excludes the first value, to select a different value, before running the regression type:

```
char region[omit] 4
xi: regress csat expense percent income high college i.region, robust
```

This will select Midwest (4) as the reference category for the dummy variables.

NOTE: Another way to create dummy variables is to type:

```
tab region, gen(region)
```

This will create four new variables (or a many a categories in the variable), one for each region in this case.

If you run the regression without the '`robust`' option you get the ANOVA table

`xi: regress csat expense percent income high college i.region`

Source	SS	df	MS	
Model	(A) **200269.84**	**9**	**22252.2045**	(D)
Residual	(B) **12691.5396**	**40**	**317.28849**	(E)
Total	(C) **212961.38**	**49**	**4346.15061**	(F)

```
Number of obs =      50
F(  9,    40) =   70.13
Prob > F      =  0.0000
R-squared     =  0.9404
Adj R-squared =  0.9270
Root MSE      =  17.813
```

$$F = \frac{\frac{MSS}{(k-1)}}{\frac{RSS}{n-k}} = \frac{\frac{200269.84}{9}}{\frac{12691.5396}{40}} = \frac{22252.2045}{317.28849} = \frac{D}{E} = 70.13$$

$$AdjR^2 = 1 - \frac{n-1}{n-k}(1-R^2) = 1 - \frac{49}{40}(1-0.9404) = 1 - \frac{E}{F} = 1 - \frac{317.28849}{4346.15061} = 0.9270$$

$$R^2 = \frac{MSS}{TSS} = 1 - \frac{\sum e_i^2}{\sum (y_i - \bar{y})^2} = \frac{200269.84}{12691.5396} = \frac{A}{C} = 0.9404$$

$$RootMSE = \sqrt{\frac{RSS}{(n-k)}} = \sqrt{\frac{12691.5396}{40}} = \sqrt{\frac{B}{40}} = 17.813$$

A = Model Sum of Squares (MSS). The closer to TSS the better fit.
B = Residual Sum of Squares (RSS)
C = Total Sum of Squares (TSS)
D = Average Model Sum of Squares = MSS/(*k*-1) where *k* = # predictors
E = Average Residual Sum of Squares = RSS/(*n* – *k*) where *n* = # of observations
F = Average Total Sum of Squares = TSS/(*n* – 1)
R^2 shows the amount of observed variance explained by the model, in this case 94%.
The *F-statistic*, F(9,40), tests whether R^2 is different from zero.
Root MSE shows the average distance of the estimator from the mean, in this case 18 points in estimating SAT scores.

Source: Kohler, Ulrich, Frauke Kreuter, *Data Analysis Using Stata*, 2009

Regression: estto/esttab

To show the models side-by-side you can use the commands `estto` and `esttab`:

```
regress  csat expense, robust
eststo model1
regress csat expense percent income high college, robust
eststo model2
xi: regress  csat expense percent income high college i.region, robust
eststo model3
esttab, r2 ar2 se scalar(rmse)
```

```
. esttab, r2 ar2 se scalar(rmse)
```

	(1) csat	(2) csat	(3) csat
expense	-0.0223***	0.00335	-0.00202
	(0.00367)	(0.00478)	(0.00359)
percent		-2.618***	-3.008***
		(0.229)	(0.236)
income		0.106	-0.167
		(1.207)	(1.196)
high		1.631	1.815
		(0.943)	(1.027)
college		2.031	4.671**
		(2.114)	(1.600)
_Iregion_2			69.45***
			(18.00)
_Iregion_3			25.40*
			(12.53)
_Iregion_4			34.58***
			(9.450)
percent2			
_cons	1060.7***	851.6***	808.0***
	(24.35)	(57.29)	(67.86)
N	51	51	50
R-sq	0.217	0.824	0.911
adj. R-sq	0.201	0.805	0.894
rmse	59.81	29.57	21.49

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

Type `help eststo` and `help esttab` for more options.

Regression: correlation matrix

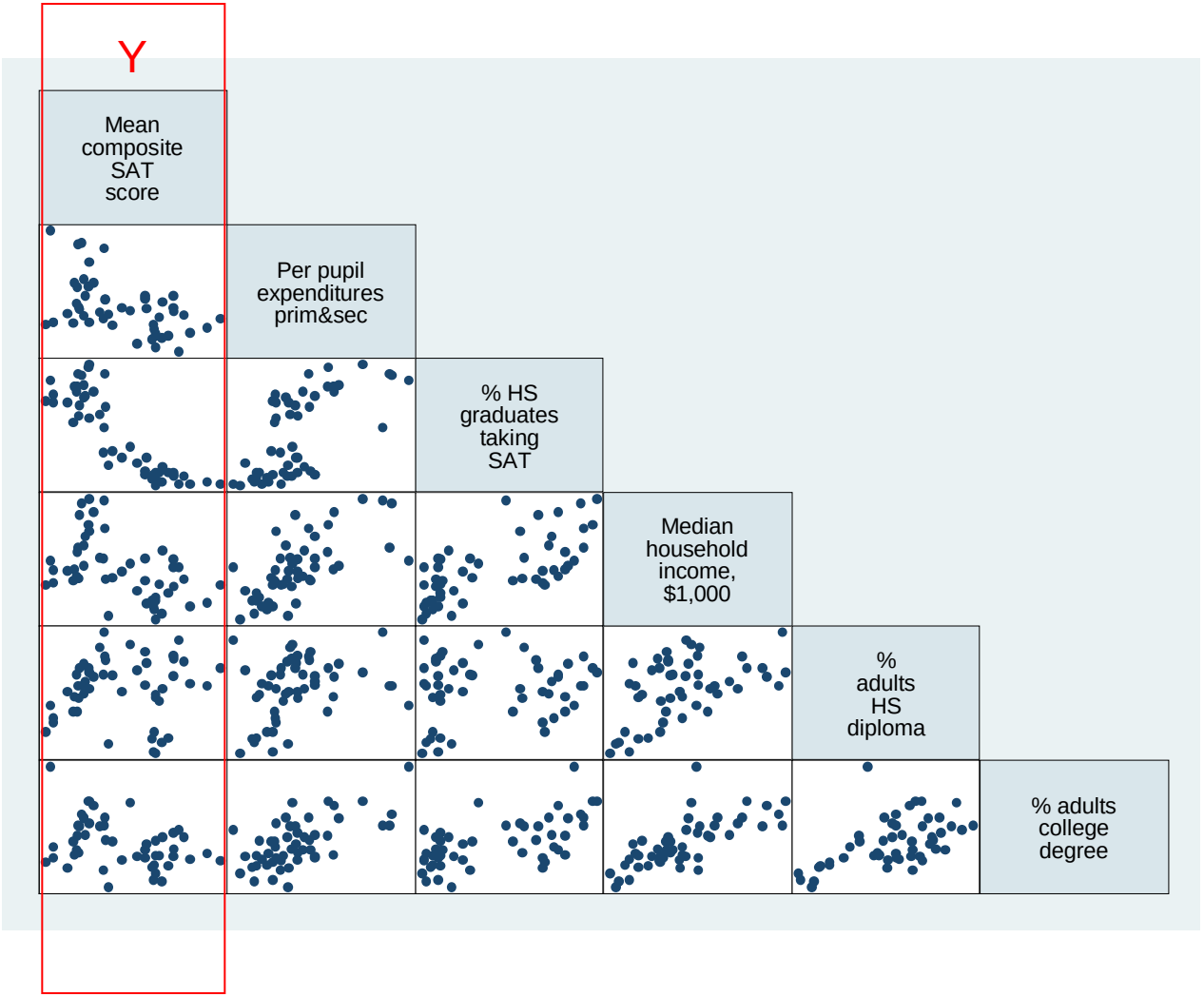
Below is a correlation matrix for all variables in the model. Numbers are Pearson correlation coefficients, go from -1 to 1. Closer to 1 means strong correlation. A negative value indicates an inverse relationship (roughly, when one goes up the other goes down).

```
. pwcorr csat expense percent income high college, star(0.05) sig
```

	csat	expense	percent	income	high	college
csat	1.0000					
expense	-0.4663*	1.0000				
	0.0006					
percent	-0.8758*	0.6509*	1.0000			
	0.0000	0.0000				
income	-0.4713*	0.6784*	0.6733*	1.0000		
	0.0005	0.0000	0.0000			
high	0.0858	0.3133*	0.1413	0.5099*	1.0000	
	0.5495	0.0252	0.3226	0.0001		
college	-0.3729*	0.6400*	0.6091*	0.7234*	0.5319*	1.0000
	0.0070	0.0000	0.0000	0.0000	0.0001	

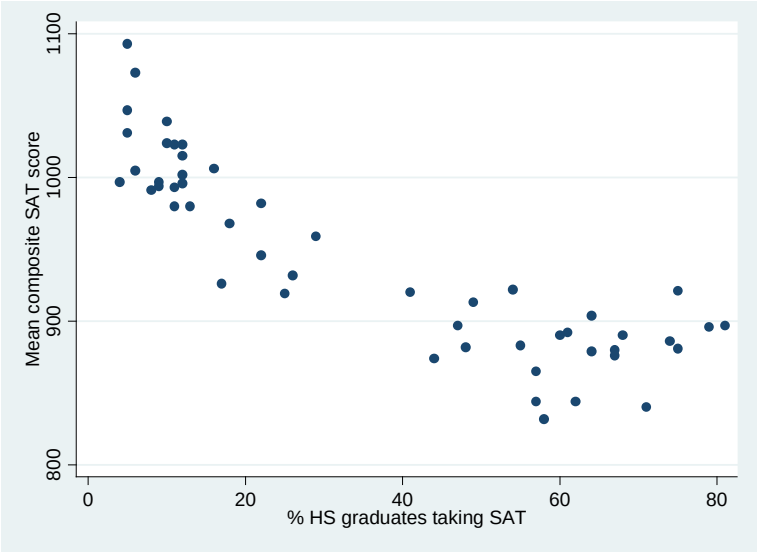
Command `graph matrix` produces a graphical representation of the correlation matrix by presenting a series of scatterplots for all variables. Type:

```
graph matrix csat expense percent income high college, half
maxis(ylabel(none) xlabel(none))
```

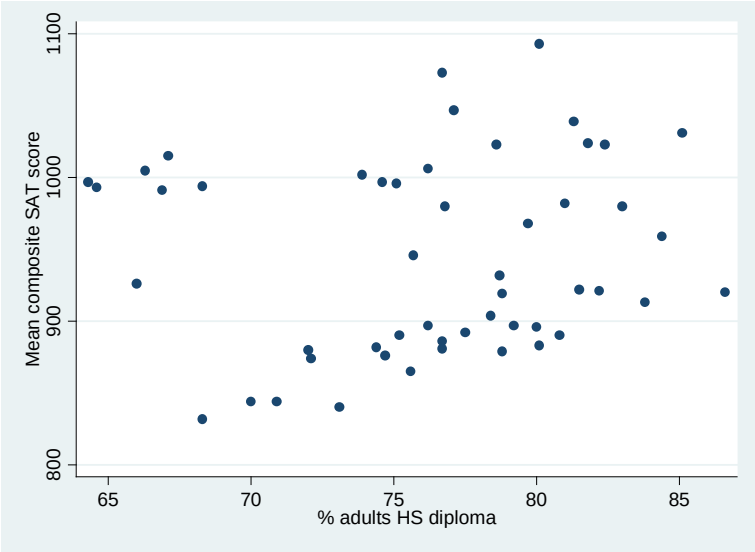


Regression: exploring relationships

```
scatter csat percent
```




```
scatter csat high
```



There seem to be a curvilinear relationship between `csat` and `percent`, and slightly linear between `csat` and `high`. To deal with U-shaped curves we need to add a square version of the variable, in this case `percent square`

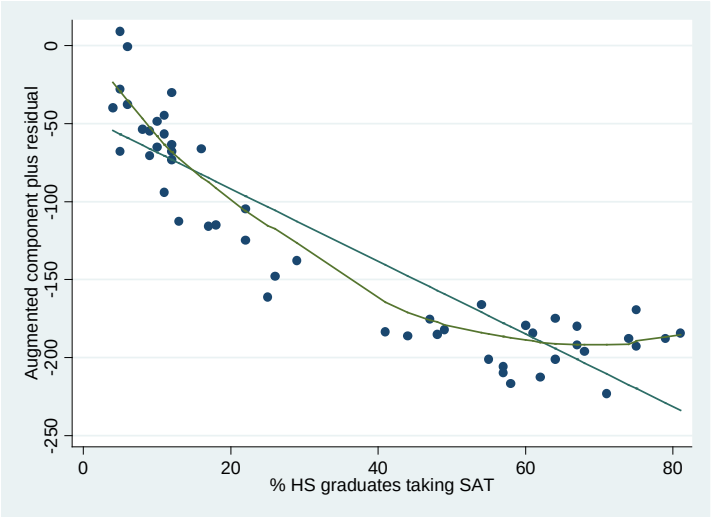
```
generate percent2 = percent^2
```

Regression: functional form/linearity

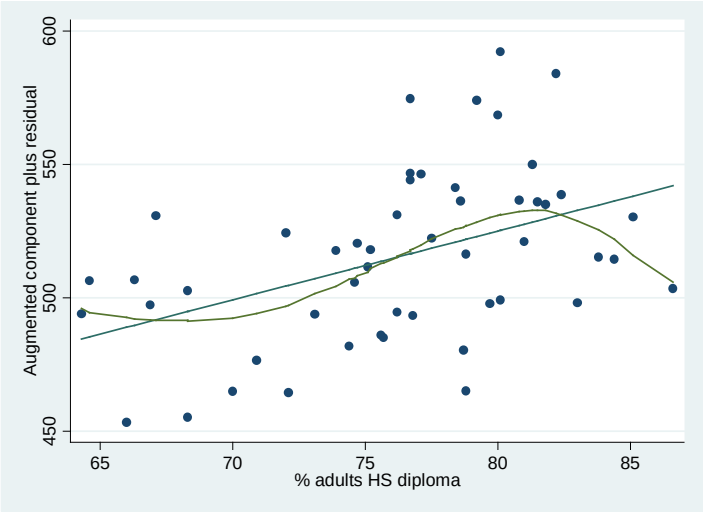
The command `acprplot` (augmented component-plus-residual plot) provides another graphical way to examine the relationship between variables. It does provide a good testing for linearity. Run this command after running a regression

```
regress csat percent high /* Notice we do not include percent2 */
acprplot percent, lowess
acprplot high, lowess
```

`acprplot percent, lowess`



`acprplot high, lowess`



The option `lowess` (locally weighted scatterplot smoothing) draw the observed pattern in the data to help identify nonlinearities. `Percent` shows a quadratic relation, it makes sense to add a square version of it. `High` shows a polynomial pattern as well but goes around the regression line (except on the right). We could keep it as is for now.

The model is:

```
xi: regress csat expense percent percent2 income high college i.region, robust
```

Form more details see http://www.ats.ucla.edu/stat/stata/webbooks/reg/chapter2/statareg2.htm, and/or type `help acprplot` and `help lowess`.

Regression: models

```
xi: regress csat expense percent percent2 income high college i.region, robust
eststo model4
esttab, r2 ar2 se scalar(rmse)
```

```
. esttab, r2 ar2 se scalar(rmse)
```

	(1) csat	(2) csat	(3) csat	(4) csat
expense	-0.0223***	0.00335	-0.00202	0.00141
	(0.00367)	(0.00478)	(0.00359)	(0.00372)
percent		-2.618***	-3.008***	-5.945***
		(0.229)	(0.236)	(0.641)
income		0.106	-0.167	-0.914
		(1.207)	(1.196)	(0.973)
high		1.631	1.815	1.869
		(0.943)	(1.027)	(0.931)
college		2.031	4.671**	3.418**
		(2.114)	(1.600)	(1.145)
_Iregion_2			69.45***	5.077
			(18.00)	(20.75)
_Iregion_3			25.40*	5.209
			(12.53)	(10.42)
_Iregion_4			34.58***	19.25*
			(9.450)	(8.110)
percent2				0.0460***
				(0.0102)
_cons	1060.7***	851.6***	808.0***	874.0***
	(24.35)	(57.29)	(67.86)	(58.13)
N	51	51	50	50
R-sq	0.217	0.824	0.911	0.940
adj. R-sq	0.201	0.805	0.894	0.927
rmse	59.81	29.57	21.49	17.81

Standard errors in parentheses
* p<0.05, ** p<0.01, *** p<0.001

How good the model is will depend on how well it predicts *Y*, the linearity of the model and the behavior of the residuals.

There are two ways to generate the *predicted values of Y* (usually called *Yhat*) given the model:

Option A, using `generate` after running the regression:

```
xi: regress csat expense percent percent2 income high college i.region, robust
generate csat_predict = _b[_cons] + _b[percent]*percent + _b[percent]*percent + _b[percent2]*percent2
+ _b[high]*high + …
```

Option B, using `predict` immediately after running the regression:

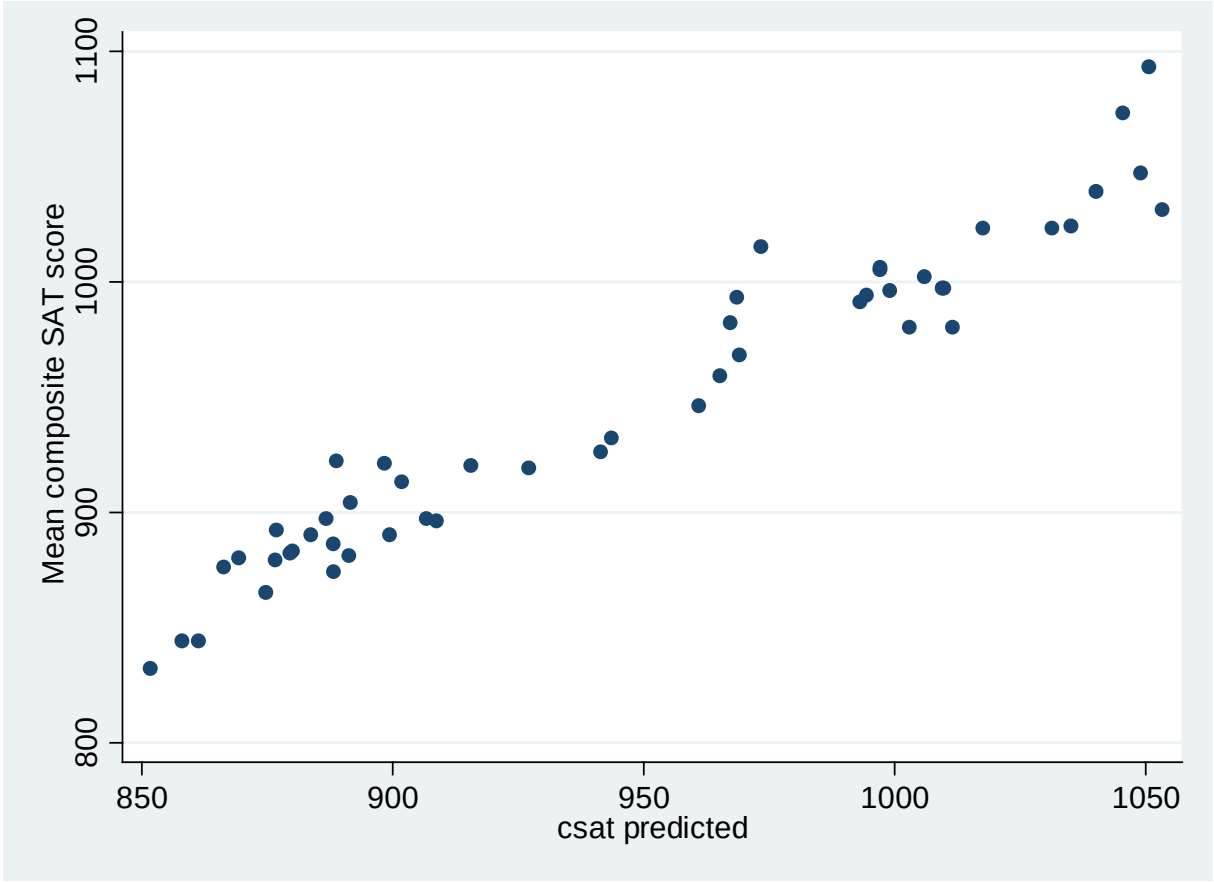
```
xi: regress csat expense percent percent2 income high college i.region, robust
predict csat_predict
label variable csat_predict "csat predicted"
```

```
. predict csat_predict
(option xb assumed; fitted values)
(1 missing value generated)

. label variable csat_predict "csat predicted"
```

For a quick assessment of the model run a scatter plot

```
scatter csat csat_predict
```



We should expect a 45 degree pattern in the data. Y-axis is the observed data and x-axis the predicted data (*Yhat*).

In this case the model seems to be doing a good job in predicting `csat`

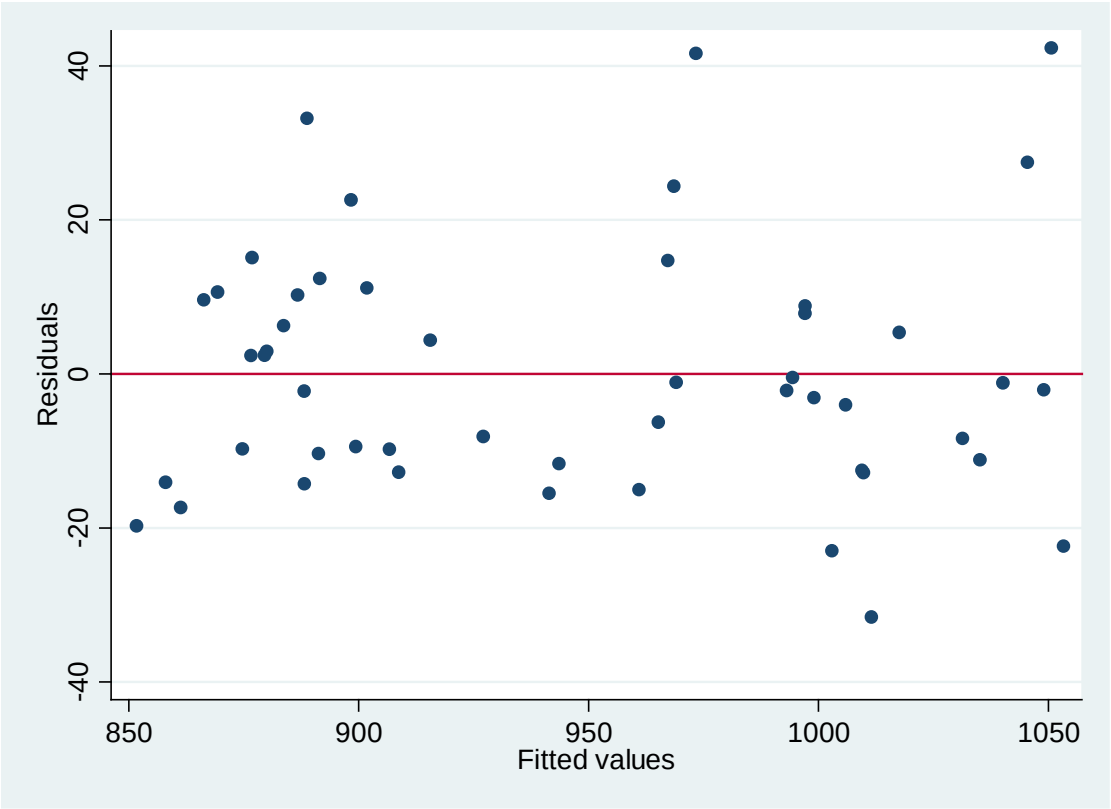
Regression: testing for homoskedasticity

An important assumption is that the variance in the residuals has to be homoskedastic or constant. Residuals cannot varied for lower of higher values of *X* (i.e. fitted values of *Y* since *Y=Xb*). A definition:

> "The error term [e] is homoskedastic if the variance of the conditional distribution of [e_i] given X_i [var(e_i|X_i)], is constant for i=1…n, and in particular does not depend on x; otherwise, the error term is heteroskedastic" (Stock and Watson, 2003, p.126)

When plotting residuals vs. predicted values (*Yhat*) we *should not observe* any pattern at all. In Stata we do this using `rvfplot` right after running the regression, it will automatically draw a scatterplot between residuals and predicted values.

```
rvfplot, yline(0)
```



Residuals seem to slightly expand at higher levels of Yhat.

A non-graphical way to detect heteroskedasticiy is the Breusch-Pagan test. The null hypothesis is that residuals are homoskedastic. In the example below we fail to reject the null at 95% and concluded that residuals are homogeneous. However at 90% we reject the null and conclude that residuals are not homogeneous.

estat hettest

```
. estat hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of csat

         chi2(1)      =     2.72
         Prob > chi2  =   0.0993
```

The graphical and the Breush-Pagan test suggest the possible presence of heteroskedasticity in our model. The problem with this is that we may have the wrong estimates of the standard errors for the coefficients and therefore their t-values.

There are two ways to deal with this problem, one is using heteroskedasticity-robust standard errors, the other one is using weighted least squares (see Stock and Watson, 2003, chapter 15). WLS requires knowledge of the conditional variance on which the weights are based, if this is known (rarely the case) then use WLS. In practice it is recommended to use heteroskedasticity-robust standard errors to deal with heteroskedasticity.

By default Stata assumes homoskedastic standard errors, so we need to adjust our model to account for heteroskedasticity. To do this we use the option `robust` in the `regress` command.

`xi: regress` *`csat expense percent percent2 income high college i.region`*`,` **`robust`**

Following Stock and Watson, as a rule-of-thumb, you should always assume heteroskedasticiy in your model (see Stock and Watson, 2003, chapter 4) .

Regression: omitted-variable test

How do we know we have included all variables we need to explain Y?

Testing for omitted variable bias is important for our model since it is related to the assumption that the error term and the independent variables in the model are not correlated (E(e|X) = 0)

If we are missing variables in our model and

- "is correlated with the included regressor" and,
- " the omitted variable is a determinant of the dependent variable" (Stock and Watson, 2003, p.144),

…then our regression coefficients are inconsistent.

In Stata we test for omitted-variable bias using the `ovtest` command:

```
xi: regress csat expense percent percent2 income high college i.region, robust
ovtest
```

```
. ovtest

Ramsey RESET test using powers of the fitted values of csat
       Ho:  model has no omitted variables
                  F(3, 37) =      1.25
                  Prob > F =      0.3068
```

The null hypothesis is that the model does not have omitted-variables bias, the p-value is higher than the usual threshold of 0.05 (95% significance), so we fail to reject the null and conclude that we do not need more variables.

Another command to test model specification is `linktest`. It basically checks whether we need more variables in our model by running a new regression with the observed *Y* (`csat`) against *Yhat* (`csat_predicted` or $X\beta$) and `Yhat-squared` as independent variables[1].

The thing to look for here is the significance of `_hatsq`. The null hypothesis is that there is no specification error. If the p-value of `_hatsq` is not significant then we fail to reject the null and conclude that our model is correctly specified. Type:

```
xi: regress  csat expense percent percent2 income high college i.region, robust
linktest
```

```
. linktest
```

Source	SS	df	MS
Model	200272.359	2	100136.18
Residual	12689.0209	47	269.979169
Total	212961.38	49	4346.15061

Number of obs	50
F(2, 47)	370.90
Prob > F	0.0000
R-squared	0.9404
Adj R-squared	0.9379
Root MSE	16.431

csat	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
_hat	1.144949	1.50184	0.76	0.450	-1.876362	4.166261
_hatsq	-.0000761	.0007885	-0.10	0.923	-.0016623	.0015101
_cons	-68.69417	712.388	-0.10	0.924	-1501.834	1364.446

[1] For more details see http://www.ats.ucla.edu/stat/stata/webbooks/reg/chapter2/statareg2.htm, and/or type `help linktest`.

Regression: multicollinearity

An important assumption for the multiple regression model is that independent variables are *not perfectly multicolinear*. One regressor should not be a linear function of another.

When multicollinearity is present *standand errors may be inflated*. Stata will drop one of the variables to avoid a division by zero in the OLS procedure (see Stock and Watson, 2003, chapter 5).

The Stata command to check for multicollinearity is `vif` (variance inflation factor). Right after running the regression type:

```
. vif
```

Variable	VIF	1/VIF
percent2	**70.80**	**0.014124**
percent	**49.52**	**0.020193**
_Iregion_2	**8.47**	**0.118063**
income	**4.97**	**0.201326**
_Iregion_3	**4.89**	**0.204445**
high	**4.71**	**0.212134**
college	**4.52**	**0.221348**
expense	**3.33**	**0.300111**
_Iregion_4	**2.14**	**0.467506**
Mean VIF	**17.04**	

A `vif > 10` or a `1/vif < 0.10` indicates trouble.

We know that `percent` and `percent2` are related since one is the square of the other. They are ok since `percent` has a quadratic relationship with *Y, but this would be an example of multicolinearity.*

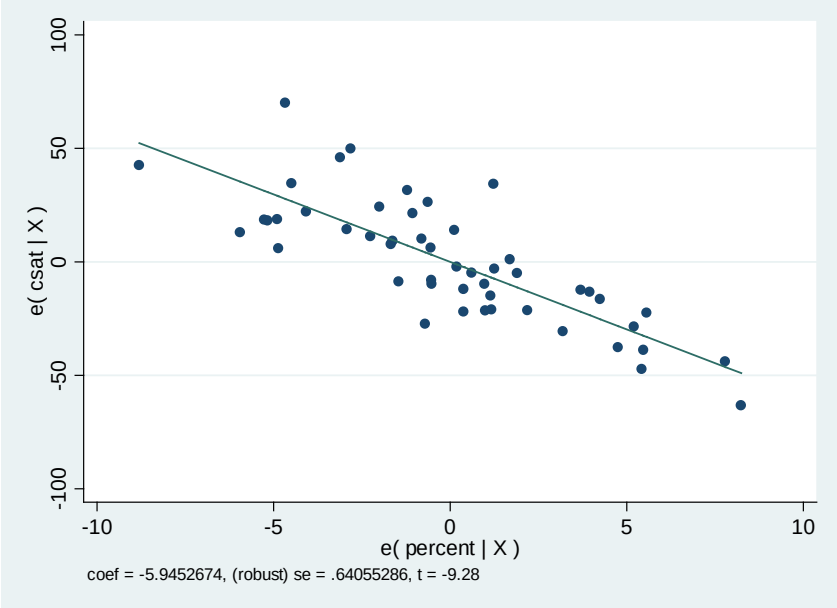
The rest of the variables look ok.

Form more details see http://www.ats.ucla.edu/stat/stata/webbooks/reg/chapter2/statareg2.htm, and/or type `help vif`.

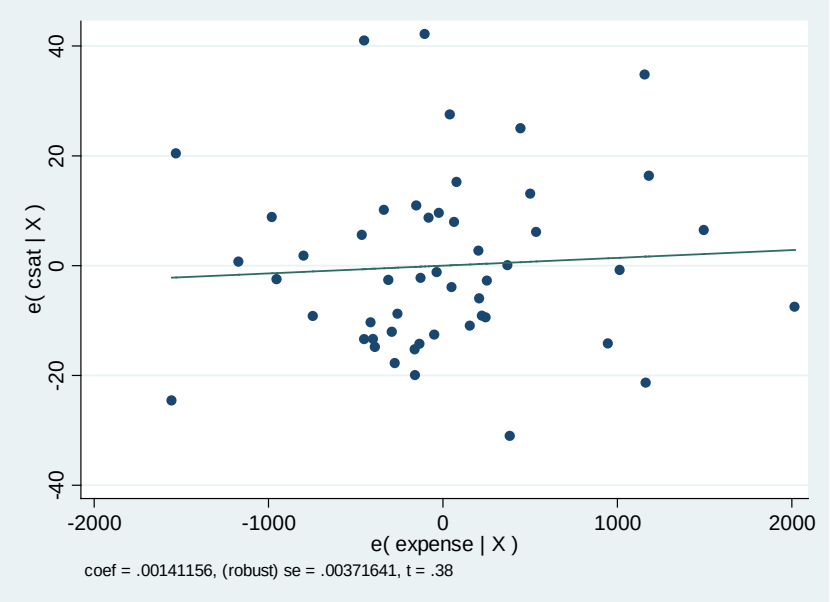
Regression: outliers

To check for outliers we use the `avplots` command (added-variable plots). Outliers are data points with extreme values that could have a negative effect on our estimators. After running the regression type:

`avplot percent`



`avplot expense`



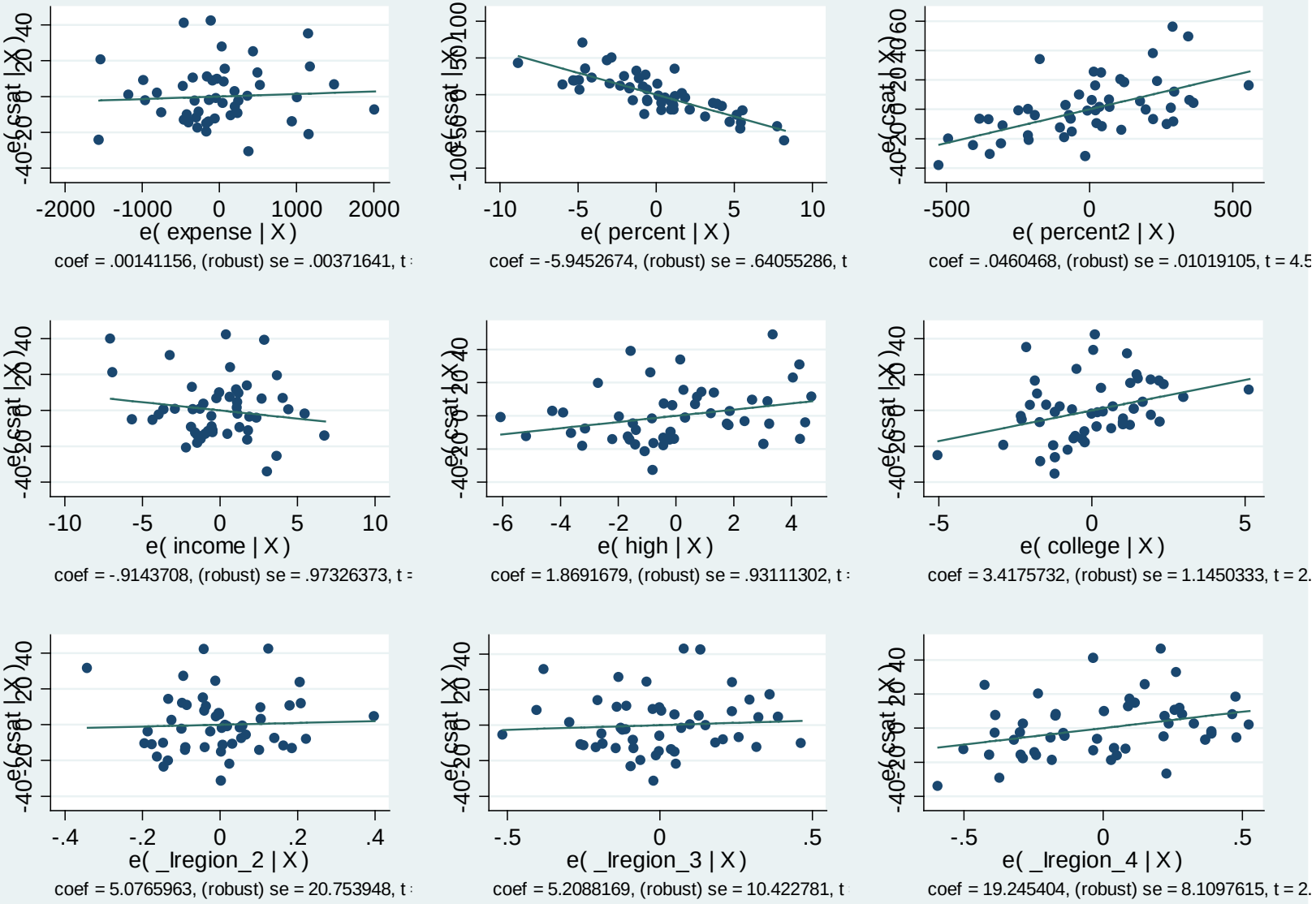
These plots regress each variable against all others, notice the coefficients on each. All data points seem to be in range, no outliers observed.

For more details and tests on this and influential and leverage variables please check
http://www.ats.ucla.edu/stat/stata/webbooks/reg/chapter2/statareg2.htm

Also type `help diagplots` in the Stata command window.

Regression: outliers

```
avplots
```



Regression: summary of *influence* indicators

DfBeta	Measures the influence of each observation on the *coefficient* of a particular independent variable (for example, x1). This is in standard errors terms.
	
	An observation is influential if it has a significant effect on the coefficient.
		A case is an influential outlier if
		
		|DfBeta|> 2/SQRT(N)
		
		Where N is the sample size.
		
		Note: Stata estimates standardized DfBetas.
			In Stata type:
			
			`reg y x1 x2 x3`
			
			`dfbeta x1`
			
			Note: you could also type:
			
			`predict DFx1, dfbeta(x1)`
			
			To estimate the dfbetas for all predictors just type:
			
			`dfbeta`
			
			To flag the cutoff
			
			`gen cutoffdfbeta = abs(DFx1) > 2/sqrt(e(N)) & e(sample)`
				In SPSS: Analyze-Regression-Linear; click Save. Select under "Influence Statistics" to add as a new variable (DFB1_1) or in syntax type
				`REGRESSION`
				`  /MISSING LISTWISE`
				`  /STATISTICS COEFF OUTS R ANOVA`
				`  /CRITERIA=PIN(.05) POUT(.10)`
				`  /NOORIGIN`
				`  /DEPENDENT  Y`
				`  /METHOD=ENTER X1 X2 X3`
				`  /CASEWISE PLOT(ZRESID) OUTLIERS(3) DEFAULTS DFBETA`
				`  /SAVE MAHAL COOK LEVER DFBETA SDBETA DFFIT SDFIT COVRATIO .`

DfFit	Indicator of leverage and high residuals.
	
	Measures how much an observation influences the regression model as a whole.
	
	How much the predicted values change as a result of including and excluding a particular observation.
		High influence if
		
		|DfFIT| >2*SQRT(k/N)
		
		Where k is the number of parameters (including the intercept) and N is the sample size.
			After running the regression type:
			
			`predict dfits if e(sample), dfits`
			
			To generate the flag for the cutoff type:
			
			`gen cutoffdfit= abs(dfits)>2*sqrt((e(df_m) +1)/e(N)) & e(sample)`
				Same as DfBeta above (DFF_1)

Covariance ratio	Measures the impact of an observation on the standard errors	High impact if |COVRATIO-1| ≥ 3*k/N Where k is the number of parameters (including the intercept) and N is the sample size.	In Stata after running the regression type `predict covratio if e(sample), covratio`	Same as DfBeta above (COV_1)

Regression: summary of *distance* measures

Cook's distance	Measures how much an observation influences the overall model or predicted values. It is a summary measure of leverage and high residuals. .	High influence if D > 4/N Where N is the sample size. A D>1 indicates big outlier problem	In Stata after running the regression type: `predict D, cooksd`	In SPSS: Analyze-Regression-Linear; click Save. Select under "Distances" to add as a new variable (COO_1) or in syntax type REGRESSION /MISSING LISTWISE /STATISTICS COEFF OUTS R ANOVA /CRITERIA=PIN(.05) POUT(.10) /NOORIGIN /DEPENDENT Y /METHOD=ENTER X1 X2 X3 /CASEWISE PLOT(ZRESID) OUTLIERS(3) DEFAULTS DFBETA /SAVE MAHAL COOK LEVER DFBETA SDBETA DFFIT SDFIT COVRATIO.
Leverage	Measures how much an observation influences regression coefficients.	High influence if leverage h > 2*k/N Where k is the number of parameters (including the intercept) and N is the sample size. A rule-of-thumb: Leverage goes from 0 to 1. A value closer to 1 or over 0.5 may indicate problems.	In Stata after running the regression type: `predict lev, leverage`	Same as above (LEV_1)
Mahalanobis distance	It is rescaled measure of leverage. M = leverage*(N-1) Where N is sample size.	Higher levels indicate higher distance from average values. The M-distance follows a Chi-square distribution with k-1 df and alpha=0.001 (where k is the number of independent variables). Any value over this Chi-square value may indicate problems.	Not available	Same as above (MAH_1)

Sources for the summary tables: influence indicators and distance measures

- Statnotes: http://faculty.chass.ncsu.edu/garson/PA765/regress.htm#outlier2
- *An Introduction to Econometrics Using Stata*/Christopher F. Baum, Stata Press, 2006
- *Statistics with Stata (updated for version 9) /* Lawrence Hamilton, Thomson Books/Cole, 2006
- UCLA http://www.ats.ucla.edu/stat/stata/webbooks/reg/chapter2/statareg2.htm

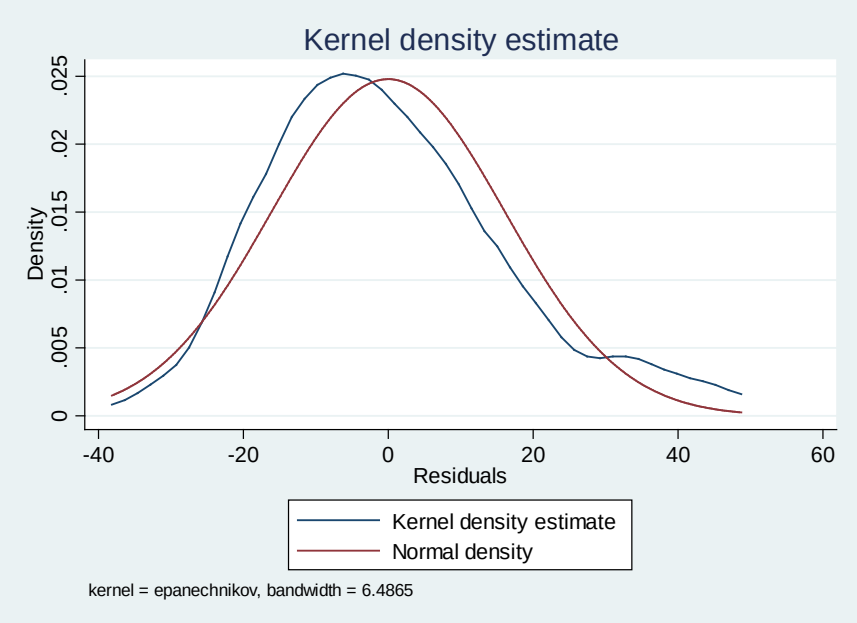
Regression: testing for normality

Another assumption of the regression model (OLS) that impact the validity of all tests (p, t and F) is that residuals behave 'normal'. Residuals (here indicated by the letter "e") are the difference between the observed values (Y) and the predicted values (Yhat): `e = Y – Yhat`.

In Stata you type: `predict e, resid.` It will generate a variable called "e" (residuals).

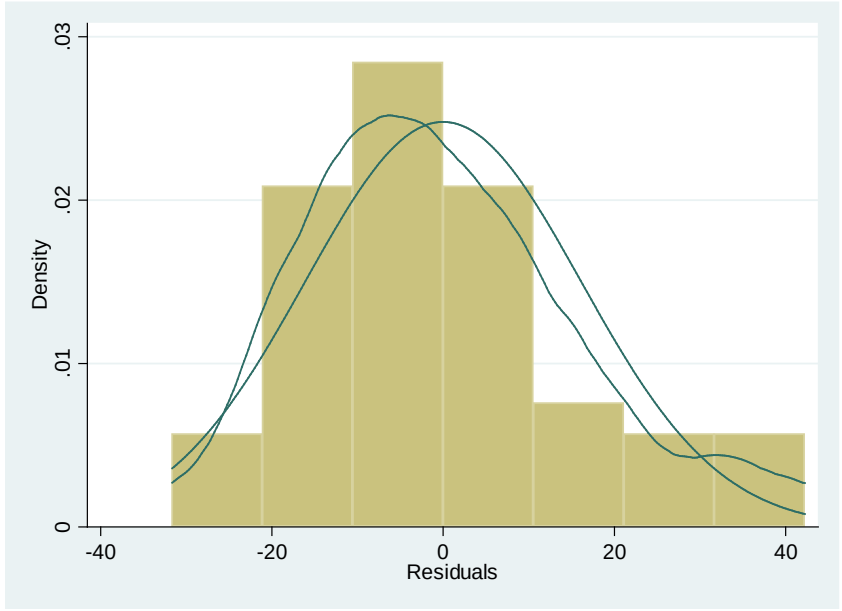
Three graphs will help us check for normality in the residuals: `kdensity, pnorm` and `qnorm`.

`kdensity e, normal`



A kernel density plot produces a kind of histogram for the residuals, the option `normal` overlays a normal distribution to compare. Here residuals seem to follow a normal distribution. Below is an example using `histogram`.

`histogram e, kdensity normal`

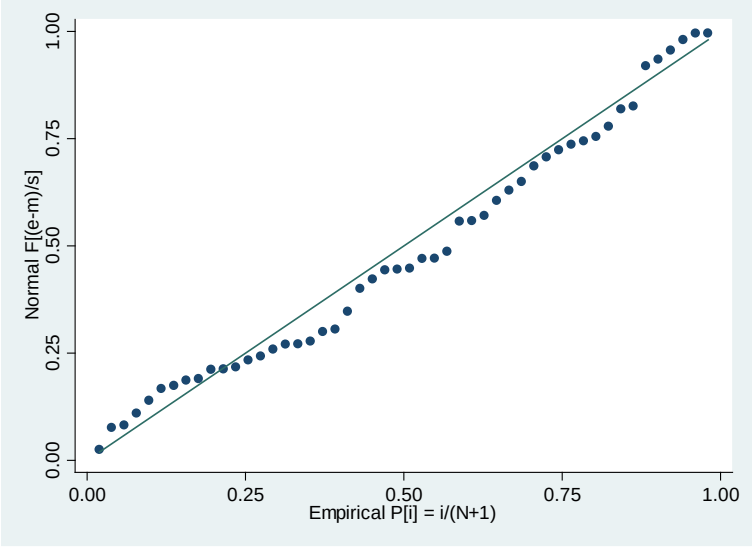


If residuals do not follow a 'normal' pattern then you should check for omitted variables, model specification, linearity, functional forms. In sum, you may need to reassess your model/theory. In practice normality does not represent much of a problem when dealing with really big samples.

Regression: testing for normality

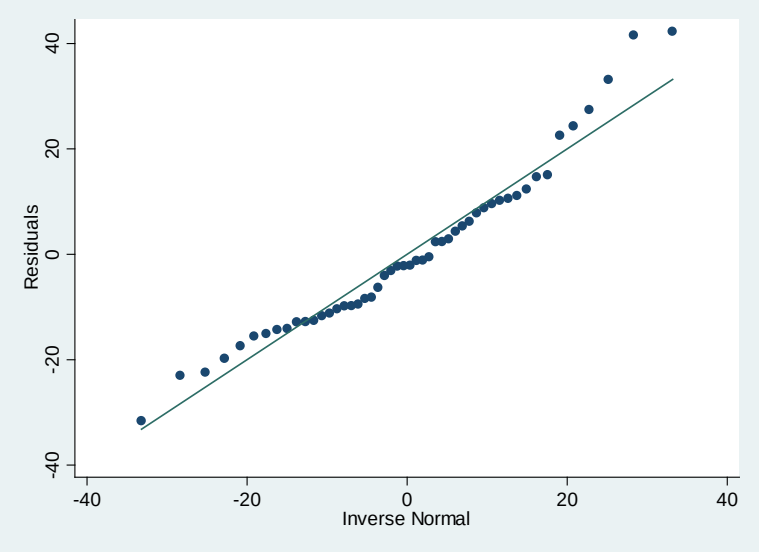
Standardize normal probability plot (`pnorm`) checks for non-normality in the middle range of residuals. Again, slightly off the line but looks ok.

`pnorm e`



Quintile-normal plots (`qnorm`) check for non-non-normality in the extremes of the data (tails). It plots quintiles of residuals vs quintiles of a normal distribution. Tails are a bit off the normal.

`qnorm e`



A non-graphical test is the Shapiro-Wilk test for normality. It tests the hypothesis that the distribution is normal, in this case the null hypothesis is that the distribution of the residuals is normal. Type

`swilk e`

```
. swilk e

                    Shapiro-Wilk W test for normal data

    Variable |   Obs        W           V        z       Prob>z
-------------+--------------------------------------------------
           e |    50     0.95566      2.085    1.567     0.05855
```

The null hypothesis is that the distribution of the residuals is normal, here the p-value is 0.06 we failed to reject the null (at 95%). We conclude then that residuals are normally distributed, with the caveat that they are not at 90%.

Regression: joint test (*F-test*)

To test whether two coefficients are jointly different from 0 use the command `test` (see Hamilton, 2006, p.175).

```
xi: quietly regress csat expense percent percent2 income high college i.region, robust
```
Note 'quietly' suppress the regression output

To test the null hypothesis that *both* coefficients do not have any effect on `csat` ($\beta_{high} = 0$ and $\beta_{college} = 0$), type:

```
test high college
```

```
. test high college

 ( 1)  high = 0
 ( 2)  college = 0

       F(  2,    40) =   17.12
            Prob > F =    0.0000
```

The p-value is 0.0000, we reject the null and conclude that *both* variables have indeed a significant effect on SAT.

Some other possible tests are (see Hamilton, 2006, p.176):

```
test income = 1
test high = college
test income = (high + college)/100
```

Note: Not to be confused with `ttest`. Type `help test` and `help ttest` for more details

Stata temporarily stores the coefficients as _b[varname], so if you type:

```
gen percent_b = _b[percent]
gen constant_b = _b[_cons]
```

You can also save the standard errors of the variables _se[varname]

```
gen percent_se = _se[percent]
gen constant_se = _se[_cons]
```

```
. summarize  percent_b percent_se constant_b constant_se
```

Variable	Obs	Mean	Std. Dev.	Min	Max
percent_b	51	-5.945267	0	-5.945267	-5.945267
percent_se	51	.6405529	0	.6405529	.6405529
constant_b	51	873.9537	0	873.9537	873.9537
constant_se	51	58.12895	0	58.12895	58.12895

Regression: saving regression coefficients/getting predicted values

You can see a list of stored results by typing after the regression `ereturn list`:

```
. xi: quietly regress  csat expense percent percent2 income high college i.region, robust
i.region          _Iregion_1-4        (naturally coded; _Iregion_1 omitted)

. ereturn list

scalars:
                  e(N) =  50
               e(df_m) =  9
               e(df_r) =  40
                  e(F) =  76.92400040408057
                 e(r2) =  .9404045015031877
               e(rmse) =  17.81259357987284
                e(mss) =  200269.8403983309
                e(rss) =  12691.53960166909
               e(r2_a) =  .9269955143414049
                 e(ll) =  -209.3636234584767
               e(ll_0) =  -279.8680043669825

macros:
            e(cmdline) : "regress csat expense percent percent2 income high college _Iregion_*, robust"
              e(title) : "Linear regression"
                e(vce) : "robust"
             e(depvar) : "csat"
                e(cmd) : "regress"
         e(properties) : "b V"
            e(predict) : "regres_p"
              e(model) : "ols"
          e(estat_cmd) : "regress_estat"
            e(vcetype) : "Robust"

matrices:
                  e(b) :  1 x 10
                  e(V) :  10 x 10

functions:
             e(sample)
```

Type `help return` for more details

Regression: general guidelines

The following are general guidelines for building a regression model*

1. Make sure all relevant predictors are included. These are based on your research question, theory and knowledge on the topic.
2. Combine those predictors that tend to measure the same thing (i.e. as an index).
3. Consider the possibility of adding interactions (mainly for those variables with large effects)
4. Strategy to keep or drop variables:
    1. Predictor not significant and has the expected sign -> Keep it
    2. Predictor not significant and does not have the expected sign -> Drop it
    3. Predictor is significant and has the expected sign -> Keep it
    4. Predictor is significant but does not have the expected sign -> Review, you may need more variables, it may be interacting with another variable in the model or there may be an error in the data.

*Gelman, Andrew, Jennifer Hill, *Data Analysis Using Regression and Multilevel/Hierarchical Models*, 2007, p. 69

Regression: publishing regression output (outreg2)

The command outreg2 gives you the type of presentation you see in published papers. If outreg2 is not available you need to install it by typing `ssc install outreg2`

Let's say the regression is `regress csat percent percent2 high, robust`

The basic syntax for outreg2 is: `outreg2 using [pick a name], [type either word or excel]`

After the regression type the following if you want to export the **results to excel***

```
outreg2 using results, excel
```

```
. outreg2 using results, excel
"results.xml"
seeout
```

Click here to see the file

Or this if you want to **export to word**

```
outreg2 using results, word
```

```
. outreg2 using results, word
"results.rtf"
seeout
```

Click here to see the file

In excel

	A	B
1	**v1**	**v2**
2		(3)
3	COEFFICIENT	csat
4		
5	percent	-6.520***
6		(0.49)
7	percent2	0.0537***
8		(0.0056)
9	high	2.987***
10		(0.55)
11	Constant	844.8***
12		(38.8)
13	Observations	51
14	R-squared	0.93
15	Robust standard errors in parentheses	
16	*** p<0.01, ** p<0.05, * p<0.10	

In word

COEFFICIENT	csat
percent	-6.520***
	(0.49)
percent2	0.0537***
	(0.0056)
high	2.987***
	(0.55)
Constant	844.8***
	(38.8)
Observations	51
R-squared	0.93

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.10

*See the following document for some additional info/tips http://www.fiu.edu/~tardanic/brianne.pdf

Regression: publishing regression output (outreg2)

You can add more models to compare. Lets say you want to add another model without percent2:

```
regress csat percent high, robust
```

Now type to export the results to word (**notice** we add the append option)

```
outreg2 using results, word append
```

In excel

3	COEFFICIENT	csat	csat
4			
5	percent	-6.520***	-2.315***
6		(0.49)	(0.17)
7	percent2	0.0537***	
8		(0.0056)	
9	high	2.987***	2.561***
10		(0.55)	(0.72)
11	Constant	844.8***	831.6***
12		(38.8)	(53.5)
13	Observations	51	51
14	R-squared	0.93	0.81
15	Robust standard errors in parentheses		
16	*** p<0.01, ** p<0.05, * p<0.1		

In word

COEFFICIENT	csat	csat
percent	-6.520***	-2.315***
	(0.49)	(0.17)
percent2	0.0537***	
	(0.0056)	
high	2.987***	2.561***
	(0.55)	(0.72)
Constant	844.8***	831.6***
	(38.8)	(53.5)
Observations	51	51
R-squared	0.93	0.81

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

NOTE: If you run logit/probit regression with odds ratios you need to add the option `eform` to export the odd ratios

Type `help outreg2` for more details. If you do not see `outreg2`, you may have to install it by typing `ssc install outreg2`. If this does not work type `findit outreg2`, select from the list and click "install".

Note: If you get the following error message (when you use the option `append` or `replace` it means that you need to close the excel/word window.

```
file results.rtf is read-only; cannot be modified or erased
```

Regression: publishing regression output (outreg2) continue

For a customized look, here are some options:

*** Excel

```
outreg2 using results, bdec(2) tdec(2) rdec(2) adec(2) alpha (0.01, 0.05, 0.10)
addstat(Adj. R-squared, e(r2_a)) excel
```

*** Word

```
outreg2 using results, bdec(2) tdec(2) rdec(2) adec(2) alpha (0.01, 0.05, 0.10)
addstat(Adj. R-squared, e(r2_a)) word
```

For excel

```
. outreg2 using results, bdec(2) tdec(2) rdec(2) adec(2) alpha(0.001, 0.01, 0.05) addstat(Adj. R-squared, e
> (r2_a)) excel
"results.xml"
seeout
```

Click here to see the output, a excel/word window will open

For word

```
. outreg2 using results, bdec(2) tdec(2) rdec(2) adec(2) alpha(0.001, 0.01, 0.05) addstat(Adj. R-squared, e(r
> 2_a)) word
"results.rtf"
seeout
```

Click on `seeout` to browse the results

Name of the file for the output

Set # of decimals for coefficients

Set # of decimals for auxiliary statistics

Set # of decimals for the R^2

Set # of decimals for added statistics (`addstat` option)

Levels of significance

Include some additional statistic, in this case adj. R-sqr. You can select any statistics on the return lists (e-class, r-class or s-class). After running the regression type `ereturn list` for a list of available statistics.

Regression: interaction between dummies

Interaction terms are needed whenever there is reason to believe that the effect of one independent variable depends on the value of another independent variable. We will explore here the interaction between two dummy (binary) variables. In the example below there could be the case that the effect of student-teacher ratio on test scores may depend on the percent of English learners in the district*.

- Dependent variable (Y) – Average test score, variable `testscr` in dataset.
- Independent variables (X)
  - Binary `hi_str`, where '0' if student-teacher ratio (`str`) is lower than 20, '1' equal to 20 or higher.
    - In Stata, first `generate hi_str = 0 if str<20`. Then `replace hi_str=1 if str>=20`.
  - Binary `hi_el`, where '0' if English learners (`el_pct`) is lower than 10%, '1' equal to 10% or higher
    - In Stata, first `generate hi_el = 0 if el_pct<10`. Then `replace hi_el=1 if el_pct>=10`.
  - Interaction term `str_el = hi_str * hi_el`. In Stata: `generate str_el = hi_str*hi_el`

We run the regression

```
regress testscr hi_el hi_str str_el, robust
```

```
. regress  testscr  hi_el hi_str str_el, robust

Linear regression                               Number of obs =     420
                                                F(  3,   416) =   60.20
                                                Prob > F      =  0.0000
                                                R-squared     =  0.2956
                                                Root MSE      =  16.049

------------------------------------------------------------------------------
             |               Robust
    testscr  |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       hi_el |  -18.16295   2.345952    -7.74   0.000    -22.77435   -13.55155
      hi_str |  -1.907842   1.932215    -0.99   0.324    -5.705964    1.890279
      str_el |  -3.494335   3.121226    -1.12   0.264    -9.629677    2.641006
       _cons |   664.1433   1.388089   478.46   0.000     661.4147    666.8718
------------------------------------------------------------------------------
```

The equation is `testscr_hat = 664.1 – 18.1*hi_el – 1.9*hi_str – 3.5*str_el`

The effect of `hi_str` on the tests scores is -1.9 but given the interaction term (and assuming all coefficients are significant), the net effect is `-1.9 -3.5*hi_el`. If `hi_el` is 0 then the effect is -1.9 (which is `hi_str` coefficient), but if `hi_el` is 1 then the effect is -1.9 -3.5 = -5.4. In this case, the effect of student-teacher ratio is more negative in districts where the percent of English learners is higher.

See the next slide for more detailed computations.

*The data used in this section is the "California Test Score" data set (`caschool.dta`) from chapter 6 of the book *Introduction to Econometrics* from Stock and Watson, 2003. Data can be downloaded from http://wps.aw.com/aw_stock_ie_2/50/13016/3332253.cw/index.html.For a detailed discussion please refer to the respective section in the book.

Regression: interaction between dummies (cont.)

You can compute the expected values of test scores given different values of `hi_str` and `hi_el`. To see the effect of `hi_str` given `hi_el` type the following right after running the regression in the previous slide.

```
. predict yhat1 if hi_str==0 & hi_el==0
(option xb assumed; fitted values)
(271 missing values generated)

. predict yhat2 if hi_str==1 & hi_el==0
(option xb assumed; fitted values)
(341 missing values generated)

. predict yhat3 if hi_str==0 & hi_el==1
(option xb assumed; fitted values)
(331 missing values generated)

. predict yhat4 if hi_str==1 & hi_el==1
(option xb assumed; fitted values)
(317 missing values generated)
```

These are different scenarios holding constant `hi_el` and varying `hi_str`. Below we add some labels

```
. label variable yhat1 "Low str/Low el"
. label variable yhat2 "High str/Low el"
. label variable yhat3 "Low str/High el"
. label variable yhat4 "High str/High el"
```

We then obtain the average of the estimations for the test scores (for all four scenarios, notice same values for all cases).

```
. summarize yhat1 yhat2 yhat3 yhat4
```

Variable	Obs	Mean	Std. Dev.	Min	Max
yhat1	149	664.1433	0	664.1433	664.1433
yhat2	79	662.2355	0	662.2355	662.2355
yhat3	89	645.9803	0	645.9803	645.9803
yhat4	103	640.5782	0	640.5782	640.5782

```
. display 664.1 - 662.2
1.9

. display 645.9 - 640.5
5.4

. display 5.4 - 1.9
3.5
```

Here we estimate the net effect of low/high student-teacher ratio holding constant the percent of English learners. When `hi_el` is 0 the effect of going from low to high student-teacher ratio goes from a score of 664.2 to 662.2, a difference of 1.9. From a policy perspective you could argue that moving from high str to low str improve test scores by 1.9 in low English learners districts.

When `hi_el` is 1, the effect of going from low to high student-teacher ratio goes from a score of 645.9 down to 640.5, a decline of 5.4 points (1.9+3.5). From a policy perspective you could say that reducing the str in districts with high percentage of English learners could improve test scores by 5.4 points.

*The data used in this section is the "California Test Score" data set (`caschool.dta`) from chapter 6 of the book *Introduction to Econometrics* from Stock and Watson, 2003. Data can be downloaded from http://wps.aw.com/aw_stock_ie_2/50/13016/3332253.cw/index.html.For a detailed discussion please refer to the respective section in the book.

Regression: interaction between a dummy and a continuous variable

Lets explore the same interaction as before but we keep student-teacher ratio continuous and the English learners variable as binary. The question remains the same*.

- Dependent variable (Y) – Average test score, variable `testscr` in dataset.
- Independent variables (X)
  - Continuous `str`, student-teacher ratio.
  - Binary `hi_el`, where '0' if English learners (`el_pct`) is lower than 10%, '1' equal to 10% or higher
  - Interaction term `str_el2 = str * hi_el.` In Stata: `generate str_el2 = str*hi_el`

We will run the regression

```
regress testscr str hi_el str_el2, robust
```

```
. regress testscr str hi_el str_el2, robust

Linear regression                               Number of obs =     420
                                                F(  3,   416) =   63.67
                                                Prob > F      =  0.0000
                                                R-squared     =  0.3103
                                                Root MSE      =   15.88

------------------------------------------------------------------------------
             |               Robust
    testscr |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         str |  -.9684601   .5891016    -1.64   0.101    -2.126447    .1895268
       hi_el |   5.639141   19.51456     0.29   0.773    -32.72029    43.99857
     str_el2 |  -1.276613   .9669194    -1.32   0.187     -3.17727    .6240436
       _cons |   682.2458   11.86781    57.49   0.000     658.9175    705.5742
------------------------------------------------------------------------------
```

The equation is `testscr_hat = 682.2 – 0.97*str + 5.6*hi_el – 1.28*str_el2`

The effect of `str` on `testscr` will be mediated by `hi_el`.

- If `hi_el` is 0 (low) then the effect of `str` is 682.2 – 0.97*str.
- If `hi_el` is 1 (high) then the effect of `str` is 682.2 – 0.97*str + 5.6 – 1.28*str = 687.8 – 2.25*str

Notice that how `hi_el` changes both the intercept and the slope of `str`. Reducing `str` by one in low EL districts will increase test scores by 0.97 points, but it will have a higher impact (2.25 points) in high EL districts. The difference between these two effects is 1.28 which is the coefficient of the interaction (Stock and Watson, 2003, p.223).

*The data used in this section is the "California Test Score" data set (`caschool.dta`) from chapter 6 of the book *Introduction to Econometrics* from Stock and Watson, 2003. Data can be downloaded from http://wps.aw.com/aw_stock_ie_2/50/13016/3332253.cw/index.html.For a detailed discussion please refer to the respective section in the book.

Regression: interaction between two continuous variables

Lets keep now both variables continuous. The question remains the same*.

- Dependent variable (Y) – Average test score, variable `testscr` in dataset.
- Independent variables (X)
  - Continuous `str`, student-teacher ratio.
  - Continuous `el_pct`, percent of English learners.
  - Interaction term `str_el3 = str * el_pct`. In Stata: `generate str_el3 = str*el_pct`

We will run the regression

```
regress testscr str el_pct str_el3, robust
```

```
. regress testscr str el_pct str_el3, robust

Linear regression                               Number of obs =     420
                                                F(  3,   416) =  155.05
                                                Prob > F      =  0.0000
                                                R-squared     =  0.4264
                                                Root MSE      =  14.482

------------------------------------------------------------------------------
             |               Robust
    testscr |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         str |  -1.117018   .5875135    -1.90   0.058    -2.271884    .0378468
      el_pct |  -.6729116   .3741231    -1.80   0.073    -1.408319    .0624958
      str_el3 |   .0011618   .0185357     0.06   0.950    -.0352736    .0375971
       _cons |   686.3385   11.75935    58.37   0.000     663.2234    709.4537
------------------------------------------------------------------------------
```

The equation is `testscr_hat = 686.3 – 1.12*str - 0.67*el_pct + 0.0012*str_el3`

The effect of the interaction term is very small. Following Stock and Watson (2003, p.229), algebraically the slope of `str` is `–1.12 + 0.0012*el_pct` (remember that `str_el3` is equal to `str*el_pct`). So:

- If el_pct = 10, the slope of str is -1.108
- If el_pct = 20, the slope of str is -1.096. A difference in effect of 0.012 points.

In the continuous case there is an effect but is very small (and not significant). See Stock and Watson, 2003, for further details.

*The data used in this section is the "California Test Score" data set (`caschool.dta`) from chapter 6 of the book *Introduction to Econometrics* from Stock and Watson, 2003. Data can be downloaded from http://wps.aw.com/aw_stock_ie_2/50/13016/3332253.cw/index.html.For a detailed discussion please refer to the respective section in the book.

Creating dummies

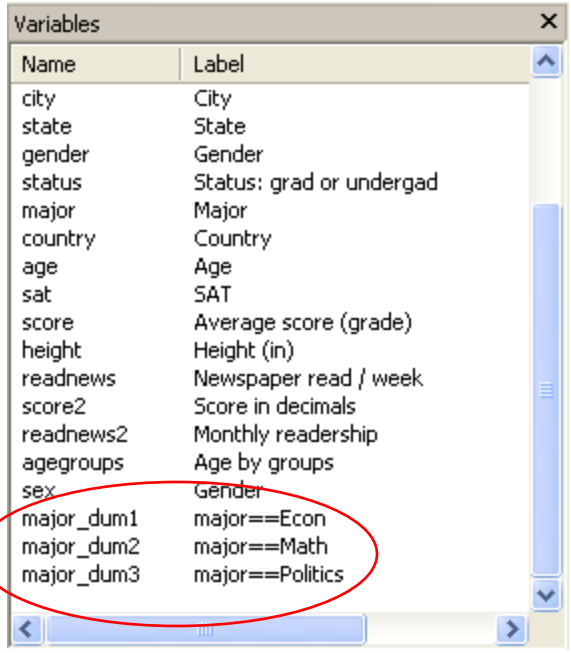
You can create dummy variables by either using `recode` or using a combination of `tab/gen` commands:

`tab major, generate(major_dum)`

```
. tab major, generate(major_dum)

      Major |      Freq.     Percent        Cum.
------------+-----------------------------------
      Econ |         10       33.33       33.33
      Math |         10       33.33       66.67
  Politics |         10       33.33      100.00
------------+-----------------------------------
      Total |         30      100.00
```

Check the 'variables' window, at the end you will see three new variables. Using `tab1` (for multiple frequencies) you can check that they are all 0 and 1 values




```
. tab1  major_dum1 major_dum2 major_dum3

-> tabulation of major_dum1

major==Econ |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |         20       66.67       66.67
          1 |         10       33.33      100.00
------------+-----------------------------------
      Total |         30      100.00

-> tabulation of major_dum2

major==Math |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |         20       66.67       66.67
          1 |         10       33.33      100.00
------------+-----------------------------------
      Total |         30      100.00

-> tabulation of major_dum3

major==Poli |
       tics |      Freq.     Percent        Cum.
------------+-----------------------------------
          0 |         20       66.67       66.67
          1 |         10       33.33      100.00
------------+-----------------------------------
      Total |         30      100.00
```

Creating dummies (cont.)

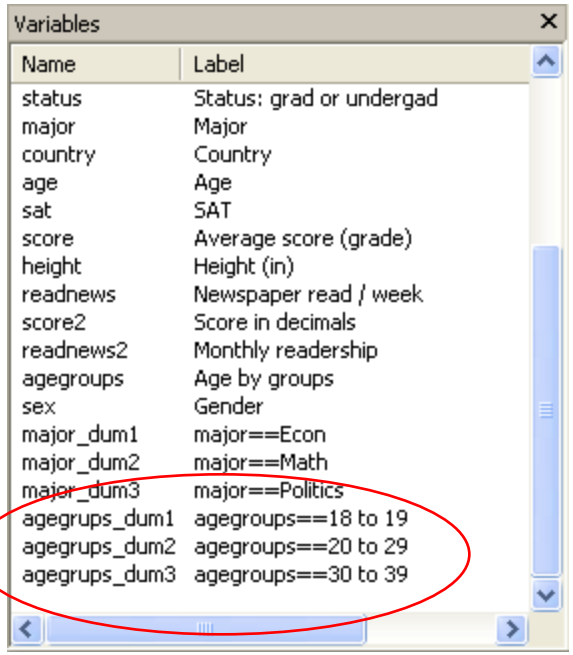
Here is another example:

`tab agregroups, generate(agegroups_dum)`

```
. tab agegroups, generate(agegrups_dum)

    Age by |
    groups |      Freq.     Percent        Cum.
-----------+-----------------------------------
  18 to 19 |         10       33.33       33.33
  20 to 29 |          9       30.00       63.33
  30 to 39 |         11       36.67      100.00
-----------+-----------------------------------
     Total |         30      100.00
```

Check the 'variables' window, at the end you will see three new variables. Using `tab1` (for multiple frequencies) you can check that they are all 0 and 1 values




```
. tab1  agegrups_dum1 agegrups_dum2 agegrups_dum3

-> tabulation of agegrups_dum1

agegroups== |
  18 to 19 |      Freq.     Percent        Cum.
-----------+-----------------------------------
         0 |         20       66.67       66.67
         1 |         10       33.33      100.00
-----------+-----------------------------------
     Total |         30      100.00

-> tabulation of agegrups_dum2

agegroups== |
  20 to 29 |      Freq.     Percent        Cum.
-----------+-----------------------------------
         0 |         21       70.00       70.00
         1 |          9       30.00      100.00
-----------+-----------------------------------
     Total |         30      100.00

-> tabulation of agegrups_dum3

agegroups== |
  30 to 39 |      Freq.     Percent        Cum.
-----------+-----------------------------------
         0 |         19       63.33       63.33
         1 |         11       36.67      100.00
-----------+-----------------------------------
     Total |         30      100.00
```

Frequently used Stata commands

Category	Stata commands
Getting on-line help	**help** **search**
Operating-system interface	**pwd** **cd** **sysdir** **mkdir** **dir / ls** **erase** **copy** **type**
Using and saving data from disk	**use** **clear** **save** **append** **merge** **compress**
Inputting data into Stata	**input** **edit** **infile** **infix** **insheet**
The Internet and Updating Stata	**update** **net** **ado** **news**
Basic data reporting	**describe** **codebook** **inspect** **list** **browse** **count** **assert** **summarize** **Table (tab)** **tabulate**
Data manipulation	**generate** **replace** **egen** **recode** **rename** **drop** **keep** **sort** **encode** **decode** **order** **by** **reshape**
Formatting	**format** **label**
Keeping track of your work	**log** **notes**
Convenience	**display**

Type help [command name] in the windows command for details

Source: http://www.ats.ucla.edu/stat/stata/notes2/commands.htm

Is my model OK? (links)

Regression diagnostics: A checklist
http://www.ats.ucla.edu/stat/stata/webbooks/reg/chapter2/statareg2.htm

Logistic regression diagnostics: A checklist
http://www.ats.ucla.edu/stat/stata/webbooks/logistic/chapter3/statalog3.htm

Times series diagnostics: A checklist (pdf)
http://homepages.nyu.edu/~mrg217/timeseries.pdf

Times series: dfueller test for unit roots (for R and Stata)
http://www.econ.uiuc.edu/~econ472/tutorial9.html

Panel data tests: heteroskedasticity and autocorrelation

- http://www.stata.com/support/faqs/stat/panel.html
- http://www.stata.com/support/faqs/stat/xtreg.html
- http://www.stata.com/support/faqs/stat/xt.html
- http://dss.princeton.edu/online_help/analysis/panel.htm

I can't read the output of my model!!! (links)

Data Analysis: Annotated Output
http://www.ats.ucla.edu/stat/AnnotatedOutput/default.htm

Data Analysis Examples
http://www.ats.ucla.edu/stat/dae/

Regression with Stata
http://www.ats.ucla.edu/STAT/stata/webbooks/reg/default.htm

Regression
http://www.ats.ucla.edu/stat/stata/topics/regression.htm

How to interpret dummy variables in a regression
http://www.ats.ucla.edu/stat/Stata/webbooks/reg/chapter3/statareg3.htm

How to create dummies
http://www.stata.com/support/faqs/data/dummy.html
http://www.ats.ucla.edu/stat/stata/faq/dummy.htm

Logit output: what are the odds ratios?
http://www.ats.ucla.edu/stat/stata/library/odds_ratio_logistic.htm

Topics in Statistics (links)

What statistical analysis should I use?
http://www.ats.ucla.edu/stat/mult_pkg/whatstat/default.htm

***Statnotes: Topics in Multivariate Analysis*, by G. David Garson**
http://www2.chass.ncsu.edu/garson/pa765/statnote.htm

Elementary Concepts in Statistics
http://www.statsoft.com/textbook/stathome.html

Introductory Statistics: Concepts, Models, and Applications
http://www.psychstat.missouristate.edu/introbook/sbk00.htm

Statistical Data Analysis
http://math.nicholls.edu/badie/statdataanalysis.html

Stata Library. Graph Examples (some may not work with STATA 10)
http://www.ats.ucla.edu/STAT/stata/library/GraphExamples/default.htm

Comparing Group Means: The T-test and One-way ANOVA Using STATA, SAS, and SPSS
http://www.indiana.edu/~statmath/stat/all/ttest/

Useful links / Recommended books

- DSS Online Training Section http://dss.princeton.edu/training/
- UCLA Resources to learn and use STATA http://www.ats.ucla.edu/stat/stata/
- DSS help-sheets for STATA http://dss/online_help/stats_packages/stata/stata.htm
- *Introduction to Stata* (PDF), Christopher F. Baum, Boston College, USA. "A 67-page description of Stata, its key features and benefits, and other useful information." http://fmwww.bc.edu/GStat/docs/StataIntro.pdf
- STATA FAQ website http://stata.com/support/faqs/
- Princeton DSS Libguides http://libguides.princeton.edu/dss

Books

- *Introduction to econometrics* / James H. Stock, Mark W. Watson. 2nd ed., Boston: Pearson Addison Wesley, 2007.
- *Data analysis using regression and multilevel/hierarchical models* / Andrew Gelman, Jennifer Hill. Cambridge ; New York : Cambridge University Press, 2007.
- *Econometric analysis* / William H. Greene. 6th ed., Upper Saddle River, N.J. : Prentice Hall, 2008.
- *Designing Social Inquiry: Scientific Inference in Qualitative Research* / *Gary King, Robert O. Keohane, Sidney Verba, Princeton University Press*, 1994.
- *Unifying Political Methodology: The Likelihood Theory of Statistical Inference* / Gary King, Cambridge University Press, 1989
- *Statistical Analysis: an interdisciplinary introduction to univariate & multivariate methods* / Sam Kachigan, New York : Radius Press, c1986
- *Statistics with Stata (updated for version 9)* / Lawrence Hamilton, Thomson Books/Cole, 2006