Mathematics 231

Lecture 33

Liam O'Brien

Announcements

- Today
  - Model Building

Model Building

- We have seen several examples of ways to select explanatory variables for a multiple regression model.
- We will examine all of the predictors in the birthweight dataset to determine which are important predictors.
- We had mother's age, toxemia, gestational age, infant length, and head circumference as predictors.

Continuous Predictors

- We should plot the response against each continuous explanatory variable to assess linearity.
- It's often useful to look at all pairwise correlations among the continuous predictors.
- We should then perform all possible simple linear regressions by regressing the outcome on each predictor, separately.
- The variable with the smallest p-value (or largest t-statistic) explains more of the variability of the response and should be included.
- This forward selection process is repeated until no variable adds to the model.
- We can also consider categorical variables in the selection.

Example

- We have 4 continuous predictors (momage, gestage, length, headcirc).
- We have one categorical (binary) predictor (toxemia).
- We have examined the plots of birthwt vs gestage, birthwt vs length, and birthwt vs headcirc.
- We now need to examine birthwt vs momage.

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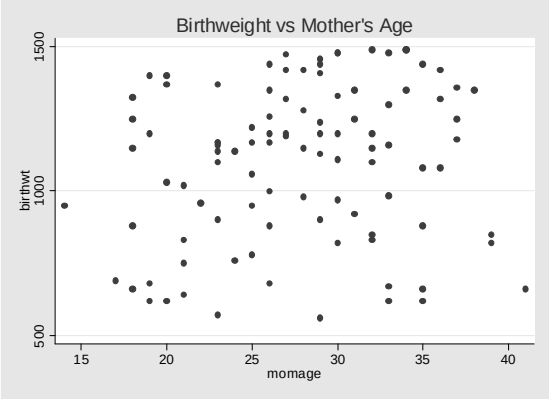

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Regress Birthwt on Gestage

```
. regress birthwt gestage

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  1,    98) =   75.61
       Model |  3143019.07     1  3143019.07           Prob > F      =  0.0000
    Residual |  4073723.68    98   41568.609           R-squared     =  0.4355
-------------+------------------------------           Adj R-squared =  0.4298
       Total |  7216742.75    99  72896.3914           Root MSE      =  203.88

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     gestage |   70.30993   8.085854     8.70   0.000     54.26382    86.35604
       _cons |  -932.4039   234.4884    -3.98   0.000    -1397.738   -467.0693
------------------------------------------------------------------------------
```

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Regress Birthwt on Headcirc

```
. regress birthwt  headcirc

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  1,    98) =  172.82
       Model |  4605298.87     1  4605298.87           Prob > F      =  0.0000
    Residual |  2611443.88    98  26647.3866           R-squared     =  0.6381
-------------+------------------------------           Adj R-squared =  0.6344
       Total |  7216742.75    99  72896.3914           Root MSE      =  163.24

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    headcirc |   85.17802   6.479268    13.15   0.000     72.32013    98.03592
       _cons |  -1154.109   172.1523    -6.70   0.000    -1495.739    -812.478
------------------------------------------------------------------------------
```

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Regress Birthwt on Length

```
. regress birthwt length

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  1,    98) =  194.65
       Model |  4800034.87     1  4800034.87           Prob > F      =  0.0000
    Residual |  2416707.88    98  24660.2845           R-squared     =  0.6651
-------------+------------------------------           Adj R-squared =  0.6617
       Total |  7216742.75    99  72896.3914           Root MSE      =  157.04

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |   61.65408   4.419149    13.95   0.000     52.88442    70.42373
       _cons |  -1171.253   163.4691    -7.16   0.000    -1495.652    -846.854
------------------------------------------------------------------------------
```


Regress Birthwt on Momage

```
. regress birthwt momage

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  1,    98) =    2.40
       Model |  172425.647     1  172425.647           Prob > F      =  0.1247
    Residual |  7044317.1     98  71880.7868           R-squared     =  0.0239
-------------+------------------------------           Adj R-squared =  0.0139
       Total |  7216742.75    99  72896.3914           Root MSE      =  268.11

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      momage |   6.975444   4.503782     1.55   0.125    -1.962164    15.91305
       _cons |   905.4209   127.7352     7.09   0.000     651.9346    1158.907
------------------------------------------------------------------------------
```


Example

- Infant length resulted in the largest t-statistic (13.95) just beating out head circumference.
- We include length in the model and add one additional continuous variable at a time to the model.
- We will also take notice to see if the predictive ability of length decreases with the addition of each variable (collinearity).

Add Headcirc

```
. regress birthwt length  headcirc

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  2,    97) =  154.71
       Model |  5494338.63     2  2747169.31           Prob > F      =  0.0000
    Residual |  1722404.12    97  17756.7435           R-squared     =  0.7613
-------------+------------------------------           Adj R-squared =  0.7564
       Total |  7216742.75    99  72896.3914           Root MSE      =  133.25

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |   37.82793   5.346058     7.08   0.000     27.21749    48.43838
    headcirc |   47.15045   7.540371     6.25   0.000      32.1849      62.116
       _cons |  -1541.104   150.7971   -10.22   0.000    -1840.394   -1241.813
------------------------------------------------------------------------------
```

Add Gestage

```
. regress birthwt length gestage

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  2,    97) =  106.48
       Model |  4958359.24     2  2479179.62           Prob > F      =  0.0000
    Residual |  2258383.51    97  23282.3043           R-squared     =  0.6871
-------------+------------------------------           Adj R-squared =  0.6806
       Total |  7216742.75    99  72896.3914           Root MSE      =  152.59

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |   51.40366   5.821408     8.83   0.000     39.84978    62.95754
     gestage |   21.39402   8.204112     2.61   0.011     5.111133    37.67692
       _cons |  -1411.906   183.6993    -7.69   0.000    -1776.499   -1047.314
------------------------------------------------------------------------------
```

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Add Momage

```
. regress birthwt length momage

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  2,    97) =   96.58
       Model |  4804117.61     2   2402058.8           Prob > F      =  0.0000
    Residual |  2412625.14    97  24872.4242           R-squared     =  0.6657
-------------+------------------------------           Adj R-squared =  0.6588
       Total |  7216742.75    99  72896.3914           Root MSE      =  157.71

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |   62.05571   4.547482    13.65   0.000     53.03022     71.0812
      momage |  -1.099813   2.714578    -0.41   0.686    -6.487499    4.287872
       _cons |  -1155.543   168.6876    -6.85   0.000    -1490.342   -820.7452
------------------------------------------------------------------------------
```

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Example

- Adding head circumference has slightly decreased the usefulness of length (the t-statistic decreased for length).
- Adding gestational age didn't decrease the usefulness of length as much, but it isn't as a good a predictor as head circumference.
- Notice the model with headcirc has a larger R^2 value than the model with gestage (0.76 to 0.69) and also a larger adjusted R^2.
- We will keep length and headcirc, and examine the remaining variables.

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Add Gestage

```
. regress birthwt length headcirc  gestage

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  3,    96) =  102.92
       Model |  5505033.78     3  1835011.26           Prob > F      =  0.0000
    Residual |  1711708.97    96  17830.3017           R-squared     =  0.7628
-------------+------------------------------           Adj R-squared =  0.7554
       Total |  7216742.75    99  72896.3914           Root MSE      =  133.53

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |    38.9962   5.565441     7.01   0.000     27.94889    50.04352
    headcirc |   51.30345   9.265343     5.54   0.000     32.91189    69.69501
     gestage |  -6.818412   8.803777    -0.77   0.441    -24.29377    10.65695
       _cons |  -1496.982   161.4911    -9.27   0.000     -1817.54   -1176.425
------------------------------------------------------------------------------
```

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Add Momage

```
. regress birthwt length headcirc momage

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  3,    96) =  102.18
       Model |  5495606.98     3  1831868.99            Prob > F      =  0.0000
    Residual |  1721135.77    96  17928.4976           R-squared     =  0.7615
-------------+------------------------------           Adj R-squared =  0.7541
       Total |  7216742.75    99  72896.3914           Root MSE      =   133.9

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |   38.08653   5.459126     6.98   0.000     27.25025    48.92281
    headcirc |   47.08196   7.581126     6.21   0.000     32.03354    62.13037
      momage |  -.6133579   2.306035    -0.27   0.791    -5.190801    3.964085
       _cons |  -1531.805   155.5052    -9.85   0.000    -1840.481    -1223.13
------------------------------------------------------------------------------
```


Add Toxemia

```
. regress birthwt length headcirc toxemia

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  3,    96) =  108.20
       Model |  5569504.96     3  1856501.65            Prob > F      =  0.0000
    Residual |  1647237.79    96   17158.727           R-squared     =  0.7717
-------------+------------------------------           Adj R-squared =  0.7646
       Total |  7216742.75    99  72896.3914           Root MSE      =  130.99

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |    38.0639   5.256473     7.24   0.000     27.62989    48.49792
    headcirc |   48.36315   7.434922     6.50   0.000     33.60495    63.12135
     toxemia |  -67.92159   32.45179    -2.09   0.039    -132.3379    -3.50529
       _cons |  -1567.605   148.7759   -10.54   0.000    -1862.923   -1272.287
------------------------------------------------------------------------------
```


Example

- We see that adding toxemia has helped in our prediction of birthweight.
- We will include toxemia in the model, but now want to consider its interactions with head circumference and infant length.
- We have seen collinearity with gestational age and both head circumference and length and will not consider it further.
- Mother's age has given us no indication that it is a useful predictor at all.
- We consider toxemia as a modifying variable.

Add Length*Toxemia

```
. regress birthwt length headcirc toxemia  lentox

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  4,    95) =   85.05
       Model |  5641405.82     4  1410351.46            Prob > F      =  0.0000
    Residual |  1575336.93    95   16582.494           R-squared     =  0.7817
-------------+------------------------------           Adj R-squared =  0.7725
       Total |  7216742.75    99  72896.3914           Root MSE      =  128.77

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |   35.89579   5.271313     6.81   0.000     25.43091    46.36067
    headcirc |   46.05232   7.392782     6.23   0.000      31.3758    60.72885
     toxemia |  -854.8818   379.2735    -2.25   0.026    -1607.835   -101.9288
      lentox |   21.05083   10.10944     2.08   0.040      .981055    41.12061
       _cons |  -1427.483   160.9943    -8.87   0.000    -1747.097   -1107.869
------------------------------------------------------------------------------
```

Add Headcirc*Toxemia

```
. regress birthwt length headcirc toxemia headtox

      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  4,    95) =   81.81
       Model |  5593029.44     4  1398257.36            Prob > F      =  0.0000
    Residual |  1623713.31    95  17091.7191            R-squared     =  0.7750
-------------+------------------------------           Adj R-squared =  0.7655
       Total |  7216742.75    99  72896.3914            Root MSE      =  130.74

------------------------------------------------------------------------------
     birthwt |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      length |   37.99741   5.246506     7.24   0.000     27.58178    48.41304
    headcirc |   45.28098   7.871737     5.75   0.000     29.65361    60.90836
     toxemia |   -475.261    348.715    -1.36   0.176    -1167.548    217.0258
     headtox |   15.12886   12.89553     1.17   0.244    -10.47199    40.72971
       _cons |  -1484.175   164.6359    -9.01   0.000    -1811.019   -1157.331
------------------------------------------------------------------------------
```

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Example

- It looks like headcirc, length, toxemia, and length*toxemia give us the best model.
- We should now at least look at the residual vs predicted value plot (looking at residual vs predictor plots when there is an interaction is difficult).

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Regression Diagnostics in Stata

- Click on **Graphics > Regression diagnostic plots**.
- For a residual vs fitted value plot choose **residual-vs-fitted** plot.
- For an added variable plot choose the **added variable** plot and the "all variables" option. Otherwise you can examine predictors individually.
- For a leverage plot choose the **leverage versus fitted value** plot.
- For any of these plots, you may choose an identifying variance to put in the "Marker Label" box under the Plot tab.

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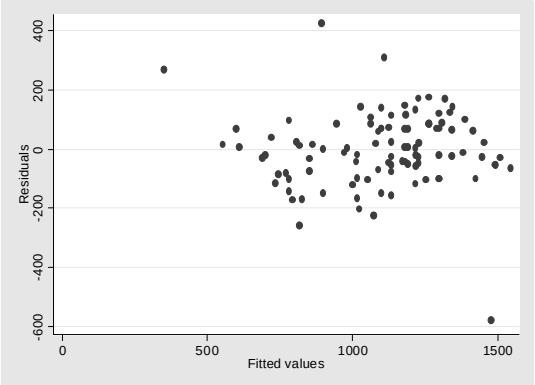
Residuals versus Fitted Values



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Added Component Plot

- These plots examine the relationship between the predicted response with each explanatory variable, averaging over the explanatory variables not under immediate consideration.
- These plots should not depart markedly from linearity.
- These aren't generally appropriate to run for a model with an interaction term.
- We will consider this plot for the predictor not involved in the interaction – head circumference.

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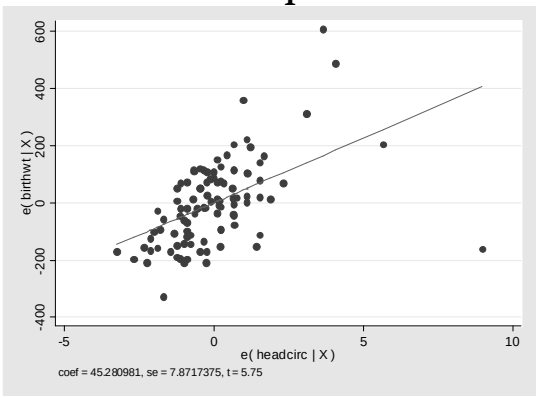
Added Component Plot



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More Diagnostics

- We still need to consider whether we have points that have had undue influence on our model.
- This can be checked by looking at leverage plots.
- We consider the leverage plot for the final model we've obtained here.

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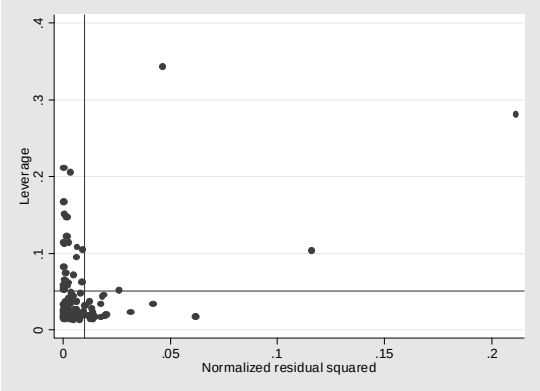
Leverage Plot



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Leverage Plot

- The horizontal line represents the average "leverage"
- Points far above it have a possibly undue influence on the regression.
- The vertical line represents the average normalized squared residual.
- Points far to the right of this line represent points with large residuals.

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