Print

Demo: Performing a Post Hoc Pairwise Comparison Using PROC GLM

Filename: **st102d03.sas**

Recall that we already determined from a significant overall ANOVA result that at least one heating quality was different. In this demonstration, we use PROC GLM to determine which pairs are significantly different from each other in their mean sale price. In the program, we'll make all pairwise comparisons and apply Tukey's adjustment, as well as comparisons to a control using Dunnett's adjustment. In actual practice, you would determine in advance whether youre interested in all pairwise comparisons or only comparisons to a control, and request the appropriate technique.

PROC GLM DATA=*SAS-data-set* <*options*>;
    CLASS *variable(s)*;
    MODEL *dependent-variables=independent-effects* **<** */ options*>;
    MEANS *effects* **<** */ options*>;
RUN;

1. Open program st102d03.sas.

```
/*st102d03.sas*/
ods graphics;

ods select lsmeans diff diffplot controlplot;
proc glm data=STAT1.ameshousing3
         plots(only)=(diffplot(center) controlplot);
   class Heating_QC;
   model SalePrice=Heating_QC;
   lsmeans Heating_QC / pdiff=all adjust=tukey;
   lsmeans Heating_QC / pdiff=control('Average/Typical') adjust=dunnett;
   format Heating_QC $Heating_QC.;
   title "Post-Hoc Analysis of ANOVA - Heating Quality as Predictor";
run;
quit;

title;
```

As in the previous demonstration, the CLASS statement specifies the classification variable Heating_QC, and the MODEL statement specifies the response, SalePrice, equal to the classification variable, Heating_QC, as indicated in the ANOVA model.

Next, we request all the multiple comparison methods with options in the LSMEANS statements. Multiple LSMEANS statements are permitted, although typically you would only use one type of method for each LSMEANS effect. Two different methods are used for illustration here.

In the first LSMEANS statement, we specify our predictor variable, Heating_QC. The PDIFF= option requests p-values for the differences. PDIFF=ALL, which is the default, requests to compare all means, and produces a diffogram automatically. The ADJUST= option specifies the adjustment method for multiple comparisons. If you don't specify an option, SAS uses the Tukey method by default. Recall that Tukey's adjustment will maintain the experimentwise error rate at 0.05 for all six pairwise comparisons.

In the second LSMEANS statement, the PDIFF=CONTROL option requests that each level be compared to a control level. You choose the appropriate control level based on the research goals. The control level is written in quotation marks. We're using Average/Typical as the control for demonstration purposes, which will result in three comparisons, one for each remaining level versus the control. Because we specify the ADJUST=Dunnett option, the GLM procedure produces multiple comparisons using Dunnett's method. This method maintains an experimentwise error rate of 0.05 for all three comparisons and creates a control plot.

The PROC GLM statement includes the PLOTS= options. The DIFFPLOT option modifies the diffogram that's produced by the LSMEANS statement with the PDIFF=ALL option. The CENTER option adds a dot to the intersection of two least squares means for each comparison.

The CONTROLPLOT option requests a display in which least squares means are compared against a reference level. LS-mean control plots are produced only when you specify PDIFF=CONTROL or ADJUST=DUNNETT in the LSMEANS statement. In this case, they're produced by default.

2. Submit the program.

3. Review the output.

We'll start with the Tukey LSMEANS comparisons. The other tables and results are identical to the previous demonstration.

The LSMeans table shows the means for each group, and each mean is assigned a number to refer to it in the next table. The table shows that the average sale price of homes with Excellent heating quality is the highest, at approximately $154,000. Homes with Fair heating quality have the lowest average price, at approximately $97,000. The other two levels are nearly equivalent at about $130,000.

The second table is a Difference Matrix. It shows the p-values from pairwise comparisons of all possible combinations of means. Notice that row 2 column 4 has the same p-value as row 4 column 2, because the same two means are compared in each case. Both are displayed as a convenience to the user. The diagonal is blank of course, because it doesn't make any sense to compare a mean to itself. The only nonsignificant pairwise difference is between Average/Typical and Good. These p-values are adjusted using the Tukey method and are, therefore, larger than the unadjusted p-values for the same comparisons. However, the experimentwise Type 1 error rate is held fixed at alpha.

The comparisons of least square means are also shown graphically in the Heating_QC Diffogram. Six comparisons are shown, but because the Average/Typical and Good levels have very close means, two pairs of lines are close together. The blue solid lines denote significant differences between heating quality levels, because these confidence intervals for the difference do not cross the diagonal equivalence line. Red dashed lines indicate a non-significant difference between treatments. Starting at the top, left to right, we can see Excellent is significantly different from Fair, from Good, and from Average/Typical. Then at the middle left, Good heating quality houses are significantly different from Fair, but not from Average/Typical. Finally, Average/Typical is significantly different from Fair heating quality in their mean sales price. The text on the graph tells us that the Tukey adjustments have been applied to these comparisons.

The next Least Squares Means table for Heating_QC displays the Dunnett's LSMEANS comparisons. In this case, all other quality levels are compared to Average/Typical. Once again, Good is the only level that is not significantly different from that control level.

The Heating_QC Control Plot corresponds to the tables that were summarized. The horizontal line is drawn at the least squares mean for Average/Typical, which is $130,574. The other three means are represented by the ends of the vertical lines extending from the horizontal control line. The mean value for Good is so close to Average/Typical that it can't be seen here.

Notice that the blue areas of non-significance vary in size. This is because different comparisons involve different sample sizes. Smaller sample sizes require larger mean differences to reach statistical significance. This control plot shows significant differences between Excellent and Average/Typical, and between Fair and Average/Typical, just like in the table above.

As we've seen, tests for significant differences among treatments can be assessed graphically or through tables of p-values. Some people prefer graphs; others prefer the tables. It's your personal preference which to use.

Close