

Analysis of Covariance and Blocking with SAS

```

/***** pigweight.sas *****/
options linesize=79 noovp formdlim='_' nodate;
title 'Analysis of covariance on the Pig Weight Data';

data oink;
  infile 'pigweight.data';
  input drug momweight dadweight pigweight;
  if drug=1 then d1=1; else d1=0;
  if drug=2 then d2=1; else d2=0;
  d1m = d1*momweight; d2m = d2*momweight;
  d1d = d1*dadweight; d2d = d2*dadweight;

proc reg;
  title2 'Test parallel planes assumption';
  model pigweight = momweight dadweight d1 d2 d1m d2m d1d d2d;
  interaction: test d1m=d2m=d1d=d2d = 0;

proc means;
  title2 'Sample means';
  class drug;
  var pigweight;

proc reg;
  title2 'Main analysis';
  model pigweight = momweight dadweight d1 d2;
  /* Want Bonferoni pairwise comparisons */
  One_vs_2: test d1=d2;

proc glm;
  title2 'Double check with proc glm';
  class drug;
  model pigweight = momweight dadweight drug;
  lsmeans drug / adjust=bon;

```

Analysis of covariance on the Pig Weight Data
Test parallel planes assumption

1

The REG Procedure
Model: MODEL1
Dependent Variable: pigweight

Number of Observations Read 75
Number of Observations Used 75

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	205.88526	25.73566	7.17	<.0001
Error	66	236.85500	3.58871		
Corrected Total	74	442.74027			

Root MSE	1.89439	R-Square	0.4650
Dependent Mean	72.36267	Adj R-Sq	0.4002
Coeff Var	2.61791		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	7.47372	17.64626	0.42	0.6733
momweight	1	0.29975	0.09704	3.09	0.0029
dadweight	1	0.14418	0.05613	2.57	0.0125
d1	1	1.47073	23.08125	0.06	0.9494
d2	1	-9.91290	24.90012	-0.40	0.6918
d1m	1	-0.06860	0.11933	-0.57	0.5673
d2m	1	-0.01921	0.13498	-0.14	0.8873
d1d	1	0.04560	0.08620	0.53	0.5986
d2d	1	0.06391	0.08573	0.75	0.4586

Analysis of covariance on the Pig Weight Data
 Test parallel planes assumption

2

The REG Procedure
 Model: MODEL1

Test interaction Results for Dependent Variable pigweight

Source	DF	Mean Square	F Value	Pr > F
Numerator	4	0.98832	0.28	0.8929
Denominator	66	3.58871		

Analysis of covariance on the Pig Weight Data
Sample means

3

The MEANS Procedure

Analysis Variable : pigweight

drug	Obs	N	Mean	Std Dev	Minimum	Maximum
1	25	25	73.1512000	2.3760600	66.6700000	76.7600000
2	25	25	71.8788000	2.4463533	67.7300000	76.4900000
3	25	25	72.0580000	2.4143201	67.5200000	75.8800000

Analysis of covariance on the Pig Weight Data
Main analysis

4

The REG Procedure

Model: MODEL1

Dependent Variable: pigweight

Number of Observations Read 75
Number of Observations Used 75

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	201.93200	50.48300	14.67	<.0001
Error	70	240.80826	3.44012		
Corrected Total	74	442.74027			

Root MSE 1.85476 R-Square 0.4561
Dependent Mean 72.36267 Adj R-Sq 0.4250
Coeff Var 2.56314

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	6.77683	9.09308	0.75	0.4586
momweight	1	0.26363	0.04727	5.58	<.0001
dadweight	1	0.17442	0.03465	5.03	<.0001
d1	1	0.70480	0.52871	1.33	0.1868
d2	1	-0.90077	0.53916	-1.67	0.0992

Analysis of covariance on the Pig Weight Data 5
Main analysis

The REG Procedure
Model: MODEL1

Test One_vs_2 Results for Dependent Variable pigweight

Source	DF	Mean Square	F Value	Pr > F
Numerator	1	31.82472	9.25	0.0033
Denominator	70	3.44012		

Analysis of covariance on the Pig Weight Data 6
Double check with proc glm

The GLM Procedure

Class Level Information

Class	Levels	Values
drug	3	1 2 3

Number of Observations Read 75
Number of Observations Used 75

Analysis of covariance on the Pig Weight Data 7
Double check with proc glm

The GLM Procedure

Dependent Variable: pigweight

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	201.9320040	50.4830010	14.67	<.0001
Error	70	240.8082626	3.4401180		
Corrected Total	74	442.7402667			

R-Square 0.456096 Coeff Var 2.563139 Root MSE 1.854756 pigweight Mean 72.36267

Source	DF	Type I SS	Mean Square	F Value	Pr > F
momweight	1	90.88635041	90.88635041	26.42	<.0001
dadweight	1	79.15166806	79.15166806	23.01	<.0001
drug	2	31.89398557	15.94699278	4.64	0.0129

Source	DF	Type III SS	Mean Square	F Value	Pr > F
momweight	1	107.0239997	107.0239997	31.11	<.0001
dadweight	1	87.1749985	87.1749985	25.34	<.0001
drug	2	31.8939856	15.9469928	4.64	0.0129

Analysis of covariance on the Pig Weight Data 8
Double check with proc glm

The GLM Procedure
Least Squares Means
Adjustment for Multiple Comparisons: Bonferroni

drug	pigweight LSMEAN	LSMEAN Number
1	73.1327884	1
2	71.5272231	2
3	72.4279885	3

Least Squares Means for effect drug
Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: pigweight

i/j	1	2	3
1		0.0099	0.5605
2	0.0099		0.2977
3	0.5605	0.2977	

```

/***** potash.sas *****/
options linesize=79 noovp formdlim='_';
title 'Modified version of Potash Data from Cochran and Cox (1957) p.108';

data cotton;
  infile 'potash.data' firstobs=2; /* Skip the header */
  input Block Potash Strength;

proc glm;
  title2 'Basic Analysis';
  class Block Potash;
  model Strength = Block Potash;
  means block potash;
  lsmeans potash / adjust=tukey;

/* Explore a little more: Linear trend? */

data c2;
  set cotton;
  if Block=1 then b1=1; else b1=0;
  if Block=2 then b2=1; else b2=0;
  p2 = potash**2;
  p3 = potash**3;
  p4 = potash**4;

proc reg;
  title2 'Simpler model';
  model Strength = b1 b2 Potash;

proc reg;
  title2 'Test departure from a linear trend';
  model Strength = b1 b2 Potash p2 p3 p4;
  Checkpot: test Potash=p2=p3=p4=0;
  Linear: test p2=p3=p4=0;

proc glm;
  title2 'Potash as Quantitative with proc glm';
  class Block;
  model Strength = Block Potash / solution;

```

Modified version of Potash Data from Cochran and Cox (1957) p.108 1
 Basic Analysis

The GLM Procedure

Class Level Information

Class	Levels	Values
Block	3	1 2 3
Potash	5	36 54 72 108 144
Number of Observations Read		15
Number of Observations Used		15

The GLM Procedure

Dependent Variable: Strength

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1.62156000	0.27026000	6.19	0.0109
Error	8	0.34948000	0.04368500		
Corrected Total	14	1.97104000			

R-Square	Coeff Var	Root MSE	Strength Mean
0.822693	2.706677	0.209010	7.722000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	0.88912000	0.44456000	10.18	0.0063
Potash	4	0.73244000	0.18311000	4.19	0.0404

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	2	0.88912000	0.44456000	10.18	0.0063
Potash	4	0.73244000	0.18311000	4.19	0.0404

The GLM Procedure

Level of Block	N	-----Strength-----	
		Mean	Std Dev
1	5	7.43000000	0.35972211
2	5	8.02600000	0.24047869
3	5	7.71000000	0.28853076

Level of Potash	N	-----Strength-----	
		Mean	Std Dev
36	3	7.85000000	0.39610605
54	3	8.05333333	0.25929391
72	3	7.74333333	0.18502252
108	3	7.51333333	0.47077950
144	3	7.45000000	0.37322915

The GLM Procedure
 Least Squares Means
 Adjustment for Multiple Comparisons: Tukey

Potash	Strength LSMEAN	LSMEAN Number
36	7.85000000	1
54	8.05333333	2
72	7.74333333	3
108	7.51333333	4
144	7.45000000	5

Least Squares Means for effect Potash
 Pr > |t| for H0: LSMean(i)=LSMean(j)

Dependent Variable: Strength

i/j	1	2	3	4	5
1		0.7565	0.9667	0.3563	0.2246
2	0.7565		0.4263	0.0743	0.0448
3	0.9667	0.4263		0.6729	0.4740
4	0.3563	0.0743	0.6729		0.9951
5	0.2246	0.0448	0.4740	0.9951	

The REG Procedure
 Model: MODEL1
 Dependent Variable: Strength

Number of Observations Read 15
 Number of Observations Used 15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1.45540	0.48513	10.35	0.0016
Error	11	0.51564	0.04688		
Corrected Total	14	1.97104			

Root MSE 0.21651 R-Square 0.7384
 Dependent Mean 7.72200 Adj R-Sq 0.6670
 Coeff Var 2.80379

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	8.12493	0.15371	52.86	<.0001
b1	1	-0.28000	0.13693	-2.04	0.0656
b2	1	0.31600	0.13693	2.31	0.0415
Potash	1	-0.00501	0.00144	-3.48	0.0052

Modified version of Potash Data from Cochran and Cox (1957) p.108 6
 Test departure from a linear trend

The REG Procedure
 Model: MODEL1
 Dependent Variable: Strength

Number of Observations Read 15
 Number of Observations Used 15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	6	1.62156	0.27026	6.19	0.0109
Error	8	0.34948	0.04368		
Corrected Total	14	1.97104			

Root MSE 0.20901 R-Square 0.8227
 Dependent Mean 7.72200 Adj R-Sq 0.6897
 Coeff Var 2.70668

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	1.81933	4.07456	0.45	0.6671
b1	1	-0.28000	0.13219	-2.12	0.0670
b2	1	0.31600	0.13219	2.39	0.0438
Potash	1	0.34750	0.23753	1.46	0.1816
p2	1	-0.00670	0.00474	-1.41	0.1957
p3	1	0.00005205	0.00003876	1.34	0.2162
p4	1	-1.41699E-7	1.10474E-7	-1.28	0.2355

Modified version of Potash Data from Cochran and Cox (1957) p.108 7
Test departure from a linear trend

The REG Procedure
Model: MODEL1

Test Checkpot Results for Dependent Variable Strength

Source	DF	Mean Square	F Value	Pr > F
Numerator	4	0.18311	4.19	0.0404
Denominator	8	0.04368		

Modified version of Potash Data from Cochran and Cox (1957) p.108 8
Test departure from a linear trend

The REG Procedure
Model: MODEL1

Test Linear Results for Dependent Variable Strength

Source	DF	Mean Square	F Value	Pr > F
Numerator	3	0.05539	1.27	0.3490
Denominator	8	0.04368		

The GLM Procedure

Class Level Information

Class	Levels	Values
Block	3	1 2 3

Number of Observations Read	15
Number of Observations Used	15

The GLM Procedure

Dependent Variable: Strength

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	1.45540282	0.48513427	10.35	0.0016
Error	11	0.51563718	0.04687611		
Corrected Total	14	1.97104000			

R-Square	Coeff Var	Root MSE	Strength Mean
0.738393	2.803793	0.216509	7.722000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
Block	2	0.88912000	0.44456000	9.48	0.0040
Potash	1	0.56628282	0.56628282	12.08	0.0052

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Block	2	0.88912000	0.44456000	9.48	0.0040
Potash	1	0.56628282	0.56628282	12.08	0.0052

Parameter	Estimate	Standard Error	t Value	Pr > t
Intercept	8.124925287 B	0.15370958	52.86	<.0001
Block 1	-0.280000000 B	0.13693226	-2.04	0.0656
Block 2	0.316000000 B	0.13693226	2.31	0.0415
Block 3	0.000000000 B	.	.	.
Potash	-0.005011175	0.00144178	-3.48	0.0052

NOTE: The X'X matrix has been found to be singular, and a generalized inverse was used to solve the normal equations. Terms whose estimates are followed by the letter 'B' are not uniquely estimable.