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Statistics 252 Final Exam – Fall 2009 – Paul Cartledge

Statistics 252 – Final Exam – Version A

Instructor: Paul Cartledge

*Instructions:*

1. *Read all the instructions CAREFULLY.*

2. *This is a closed book exam.*

3. *You may only use the formula sheets, the output provided and a non-programmable*  *calculator.*

*You have 3 hours to complete the exam.* 4.

5. *The exam is out of a total of 70 marks and has 14 pages (in two parts).*

6. *Show your work for the long answer section to receive full credit.*

7. *Use the reverse side of pages for scrap work.*

*Make sure your name and signature are on the front and that your ID number is on the* 8.

*top of page two.*

9. *When referring to “log”, I am always referring to the natural log.*

10. *Unless instructed otherwise, give a range for the p-value. Also, use the “judgment*  *approach” to help state your conclusion in plain English.*

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Signature: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |
| --- | --- | --- | --- |
| **Component** | **Notes** | **Worth** | **Mark** |
|  |  |  |  |
| Short Answer | 3 questions | 6 |  |
| What test? | 2 questions (2 marks each) | 4 |  |
| Case Study 1 | 7 parts | 30 |  |
| Case Study 2 | 7 parts | 30 |  |
|  |  |  |  |
| Total |  | 70 |  |

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**ID:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**Short Answer Problems (6 marks)**

**Question 1 (2 marks)** In testing for a difference in the median responses for two treatments after back-transforming the data, you set up the following set of hypotheses on the original scale. Is there something wrong? If so, correct the mistake by simply re-writing the hypotheses. If not, say why there is nothing wrong.

*H*0: *Median*(Y1) / *Median*(Y2) > 0   
*HA*: *Median*(Y1) / *Median*(Y2) ≤ 0

**Question 2 (2 marks)** Suppose Optimus Prime determines a simple linear relationship between the cost of his monthly power (in thousands of dollars) and how many kilolitres (kL) of oil the Autobots consume at each of his parties. Checking assumptions, both variables required log-transformations. The estimated regression line is µˆ ( ln(*cost*) | ln(*oil*))= 2.908 + 0.458ln(*oil*).

Estimate the change in mean cost of monthly power associated with a change of 15 kL to 75 kL in oil consumption at Optimus’s Autobot parties. Give a statement relating this change to the given variables.

**Question 3 (2 marks)** Consider a dataset with 7 groups and 3 models: One-Mean, *J*-Mean, and Seven-Mean. If 10 observations are collected for each group, fill in the shaded areas and find *J*.

ANOVA Table for testing the One-Mean vs. the Seven-Mean model

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source of Variation | Sum of Squares | df | Mean Square | F-Statistic | *p*-value |
| Between (Extra) |  |  |  | 11.5 |  |
| Within (Full) |  |  | 6 |  |  |
| Total (Reduced) | 792 |  |  |  |  |

ANOVA Table for testing the One-Mean vs. the *J*-Mean model

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source of Variation | Sum of Squares | df | Mean Square | F-Statistic | *p*-value |
| Between (Extra) | 280 |  |  |  |  |
| Within (Full) |  |  | 8 |  |  |
| Total (Reduced) |  |  |  |  |  |

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**What test would you use? (4 marks)**

In each scenario, identify the appropriate procedure needed to answer the question. Be as descriptive as possible.

Choose from the following:   
i) One-Sample t-test for a single population mean,   
ii) Paired t-test for the difference between two population means,   
 Two Independent Sample t-test for the difference between two population means, iii)   
iv)   
 One-Factor ANOVA F-test for any difference among *I* population means, v) A t-test for a linear combination of means,   
vi) Some Extra-Sum-of-Squares F-test comparing two models for the *I* population means, An ANOVA F-test for any regression model effects, vii)   
viii)   
 A t-test for a single regression coefficient, ix) Some Extra-Sum-of-Squares F-test comparing two regression models (testing a subset of coefficients),   
x) An F-test for any factor effects (main OR interaction) in Two-Factor ANOVA,   
xi) The F-test for additivity in a Two-Factor ANOVA.

**Question 4 (2 marks)** An organization (Protecting Animals Caringly & Kindly) wants to see if wild dogs have a longer lifespan than those held in captivity. In a time-consuming study, the leaders of P.A.C.K. record the lifespan of 15 randomly selected dogs (10 wild and 5 held in captivity) from each of six different African countries. What test would you use to see if the lifespan of wild and captivity-based dogs are different within each country? What is the distribution of the test statistic under the null hypothesis?

**Question 5 (2 marks)** Guillermo is attempting to market a new kind of special super-spicy salsa. He’s not sure where to market his product to maximize his profit, so he observes prices from two random samples (each with 42 observations) from Canada and Mexico, adjusting the latter values to match Canadian currency. What test will denote that the average price in Canada is greater than that in Mexico? What is the distribution of the test statistic under the null hypothesis?

|  |  |
| --- | --- |
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**Case Study 1 – Raiders of the Lost Statistical Analysis (25 marks)**

**When needed, use the output on pages 12 and 13 to answer the following questions.**

Earlier in the term, we (namely me) made fun of a certain director’s talent. This time, however, we’ll be nicer and completely ignore him. Let’s suppose a study was done to investigate the association of box office gross in the United States with the year the film came out, the film’s rating at IMDB.com, and the appearance of certain actors in the films under study. The study consists of 21 random and independent films directed by Steven Spielberg. “Actor appearance” is categorized into 3 levels: Harrison Ford, Tom Hanks, and Other. Box office gross (*BoxOffice*, measured in millions of US$), the year the film came out (*Year*), and the film’s rating at IMDB.com (*Rating*, measured on a scale of 0 to 10, with 10 being the highest) are modeled as continuous (numerical) variables.

To fit an MLR model, the categorical variable *Actor* uses the first two levels listed to correspond to indicator variables. Use the following “original model” to answer the questions:

*µ*(*BoxOffice* | *Year*, *Rating*, *Actor*) = *β*0 + *β*1*Year* + *β*2*Rating* + *β*3*Ford* + *β*4*Hanks* + *β*5*Year* ×*Rating* + *β*6*Year* ×*Ford* + *β*7*Year* ×*Hanks* + *β*8*Rating* ×*Ford* + *β*9*Rating* ×*Hanks* + *β*10*Year* ×*Rating* ×*Ford* + *β*11*Year* ×*Rating* ×*Hanks*

**a) (3 marks)** What is the effect of the film’s rating on mean box office gross, after accounting for year and actor appearance?

**b) (4 marks)** What is the effect of actor appearance on mean box office gross, after accounting for year and rating, for each listed pair of levels below? (Hint: If you need more room, please direct me to where you did your work…perhaps the back of page 3?)

|  |  |  |
| --- | --- | --- |
| Level 1 | Level 2 | Effect of actor appearance on mean box office gross |
| Ford | Hanks |  |
| Ford | Other |  |
| Hanks | Other |  |

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**c) (3 marks)** Using the original model, state the null and alternative hypothesis to test whether the year a film comes out depends on actor appearance, after accounting for the film’s rating. What is the distribution of the test statistic under the null hypothesis?

**Note: For parts d) – g), remove all interaction terms from the original model.**

**d) (3 marks)** Calculate a 95% confidence interval for the mean difference in box office gross between films starring Harrison Ford and Other films.

**e)(4 marks)** Calculate a 90% prediction interval for the box office gross of a film starring Tom Hanks that came out in 2002 and has a rating of 7.7.

**f) (5 marks)** Carry out a test to determine if there is significant evidence that the mean box office gross has a negative association with the year the film comes out, after accounting for the film’s rating. State the null and alternative hypothesis in terms of the regression coefficients, the test statistic and all of its components (see its formula), the distribution of the test statistic under the null hypothesis, and the *exact* p-value of the test. Conclude in plain English.

|  |  |
| --- | --- |
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**g) (8 marks)** Carry out a test to determine if there is significant evidence that mean box office gross depends on the film’s rating or the year it came out, after accounting for actor appearance.

State the null and alternative hypothesis in terms of the regression coefficients, the sum-of-squares residuals for the models under the null and alternative hypotheses, and the distribution of the test statistic under the null hypothesis. Calculate the test statistic and the *p*-value of the test. Conclude in plain English.

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**Case Study 2 – Feel the Rhythm, Feel the Rhyme, Time to Analyze the Bobsled Time! (30 marks)**

**When needed, use additional output on page 14 to answer the following questions.**

With Vancouver 2010 just over two months away, a scientist (Hercules) decides to observe the bobsled times at the 2006 Torino Olympics while simultaneously identifying the measurements by two factors: whether they belong to one of three country pairings (Canada/U.S., Italy/Russia, or Switzerland/Germany) as well as the specific sport (Two Woman, Two Man, or Four Man). Recording the results from 4 random and independent subjects per combination, the table below summarizes their “finishing times” (the time it takes to get to the finish line) in seconds.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Group** | **Country Pair** | **Sport** | **n** | **Sample Mean** | **Sample S.D.** |
| 1 | Canada/U.S. | Two Woman | 4 | 231.84 | 1.40 |
| 2 | Italy/Russia | Two Woman | 4 | 232.01 | 0.80 |
| 3 | Swiss/German | Two Woman | 4 | 231.55 | 1.22 |
| 4 | Canada/U.S. | Two Man | 4 | 225.05 | 1.15 |
| 5 | Italy/Russia | Two Man | 4 | 225.40 | 1.07 |
| 6 | Swiss/German | Two Man | 4 | 224.18 | 0.50 |
| 7 | Canada/U.S. | Four Man | 4 | 221.81 | 1.16 |
| 8 | Italy/Russia | Four Man | 4 | 221.98 | 1.03 |
| 9 | Swiss/German | Four Man | 4 | 221.02 | 0.58 |

The following table is the ANOVA output.

**ANOVA**

Time

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Sum of  Squares | df | Mean Square | F | Sig. |
| Between Groups Within Groups  Total | 656.125 28.645  684.770 |  |  |  |  |

**a) (4 marks)** Is there any significant evidence of a difference in average finishing times among the nine different groups? State the sum-of-squares residuals for the model under the alternative hypothesis, the test statistic, the distribution of the test statistic under the null hypothesis, and the range of the *p*-value (you do not have to answer the question).

SSR for the model under *H*A:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Test statistic:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Distribution:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

*p*-value range:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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There is a treatment contrast that might be of interest in the experiment for estimating the main

effects of the two factors on mean heart rate. Let µ1, µ2, µ3, µ4, µ5, µ6, µ7, µ8, and µ9 correspond

to the population mean responses for groups 1, 2, 3, 4, 5, 6, 7, 8, and 9, respectively.

**b) (5 marks)** Does the pairing of Canada/U.S. take more time on average at all bobsled sports

compared to the pairing of Switzerland/Germany?

**i. (2 marks)** First, define the treatment contrast (i.e. fill in the blanks with the appropriate contrast

coefficients) that will define the contrast described in the above question.

***γ*** = \_\_\_\_*µ*1 + \_\_\_\_*µ*2 + \_\_\_\_*µ*3 + \_\_\_\_*µ*4 + \_\_\_\_*µ*5

+ \_\_\_\_*µ*6 + \_\_\_\_*µ*7 + \_\_\_\_*µ*8 + \_\_\_\_*µ*9

**ii. (2 marks)** Determine the test statistic and the *exactp*-value.

**iii. (1 mark)** Make a decision using the *p*-value and answer the question at the top of this page.

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Another approach to test the effects of the two factors, as well as their interaction, is to model the data as a Two-Way ANOVA with the two factors:   
 Factor A – Sport (Two Woman, Two Man, Four Man)   
 Factor B – Country Pair (Canada/U.S., Italy/Russia, Switzerland/Germany)

**c)(8 marks)** Use the following incomplete Two-Way ANOVA table.

**Tests of Between-Subjects Effects**

Dependent Variable: Time

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |

table above.

|  |  |
| --- | --- |
| a R Squared = .958 (Adjusted R Squared = .946)  **i. (5 marks)** Is there any significant evidence that Sport depends on the presence of Country Pair? State the null and alternative hypothesis, the test statistic, the distribution of the test statistic under the null hypothesis, and the *exact* p-value of the test. Conclude in plain English.  **ii. (3 marks)** Does it appear that either Sport or Country Pair have any effect on mean time? Simply refer to the appropriate test statistic, the distribution of the test statistic and p-value in the | |
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|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Corrected Model | 656.125a | 8 | 82.016 |  | .000 |
| Intercept | 1840264.077 | 1 | 1840264.077 | 1734583.002 | .000 |
| A | 650.436 |  | 325.218 |  | .000 |
| B | 5.006 | |  | | --- | | 2.503 | | .114 |
| A \* B |
| .684 | .171 | .956 |
| Error |
| 28.645 |
| Total | 1840948.848 | 36 |  |  |  |
| Corrected Total |
| 684.770 | 35 |

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Note: With a p-value of approximately 0.956, we will remove the interaction term and fit the additive model.

**d) (5 marks)** The Two-Way ANOVA table is given below (Additive Fit) **Tests of Between-Subjects Effects**

Dependent Variable: Time

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
| Corrected Model Intercept  A  B  Error  Total  Corrected Total | 655.442a 1840264.077 650.436 5.006 29.329 1840948.848 684.770 | 4  1  2  2  31  36  35 | 163.860  1840264.077 325.218  2.503  .946 | 173.198  1945126.620 343.750  2.645 | .000  .000  .000  .087 |

a R Squared = .957 (Adjusted R Squared = .952)

**i. (3 marks)** What are the sum-of-squares residuals for the full and reduced models for one-way ANOVA for only Sport?

**ii. (2 marks)** Is there any significant evidence that Country Pair has an effect on mean time, after accounting for Sport? Simply refer to the appropriate test statistic and *p*-value in the table above.

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Yet another approach to test the effects of the two factors is to model the data as a multiple linear regression model using indicator variables:   
 Let Country Pair be represented by two indicator variables (*Pair1* and *Pair2*) that will indicate the Canada/U.S. and Switzerland/Germany pairs, respectively; the Italy/Russia pair is the “default”. Let Sport be represented by two indicator variables (*W2* and *M2*) that will indicate the Two Woman and Two Man sports, respectively; the Four Man sport is the “default”.

The corresponding regression model is:   
*µ*(*Time* | *Country Pair*, *Sport*) = *β*0 + *β*1*Pair1* + *β*2*Pair2* + *β*3*W2* + *β*4*M2*  + *β*5*W2* ×*Pair1* + *β*6*W2* ×*Pair2* + *β*7*M2* ×*Pair1* + *β*8*M2* ×*Pair2*

**e) (4 marks)** In terms of the coefficients, what is the effect of Sport on mean time for each pair of sport levels, after accounting for Country Pair?

Fill in the chart:

|  |  |  |  |
| --- | --- | --- | --- |
| Level 1 | Level 2 | Effect of sport on mean time | Estimate |
| Two  Woman | Two Man |  |  |
| Two  Woman | Four Man |  |  |
| Two Man | Four Man |  |  |

**f) (2 marks):** Estimate each defined effect in the rightmost column for the **Canada/U.S.** pair. Show your work below. No marks will be given if no work is shown.

**g) (2 marks):** Consider a different MLR model that uses factors such as gender and how many people are in the bobsled.

*µ*(*Time* | *Gender*, *How Many*) = *β*0 + *β*1*Male* + *β*2*Two* + *β*3*Male* ×*Two*

Is there something wrong with this model? Why or why not?

|  |  |
| --- | --- |
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**VERSION A SPSS OUTPUT**

**Output for Case Study 1:**

**Regression on Rating**   
 **ANOVAb**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Model |  | Sum of  Squares | df | Mean Square | F | Sig. |
| 1 Regression  Residual  Total | | 59668.148 200916.809 260585.227 | 1  19  20 | 59668.148 10574.569 | 5.643 | .028a |

a Predictors: (Constant), Rating   
b Dependent Variable: BoxOffice

**Coefficientsa**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Unstandardized Coefficients | Standardized Coefficients |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Model |  | B | Std. Error | Beta | t | Sig. |
| 1 (Constant)  Rating | | -349.668 64.356 | 205.327 27.093 | .479 | -1.703  2.375 | .105  .028 |

a Dependent Variable: BoxOffice

**Regression on Rating and Year**   
 **ANOVAb**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Model |  | Sum of  Squares | df | Mean Square | F | Sig. |
| 1 Regression  Residual  Total | | 76235.629 184349.598 260585.227 | 2  18  20 | 38117.815 10241.644 | 3.722 | .044a |

a Predictors: (Constant), Rating, Year   
b Dependent Variable: BoxOffice

**Coefficientsa**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Unstandardized Coefficients | Standardized Coefficients |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Model |  | B | Std. Error | Beta | t | Sig. |
| 1 (Constant)  Year  Rating | | 5445.145 -2.918  65.828 | 4560.645 2.294  26.688 | -.252  .489 | 1.194 -1.272  2.467 | .248  .220  .024 |

a Dependent Variable: BoxOffice

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**Regression on Rating, Year, and Actor Appearance**

**ANOVAb**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Model |  | Sum of  Squares | df | Mean Square | F | Sig. |
| 1 Regression  Residual  Total | | 77378.949 183206.278 260585.227 | 4  16  20 | 19344.737 11450.392 | 1.698 | .201a |

a Predictors: (Constant), Rating, Year, Ford, Hanks   
b Dependent Variable: BoxOffice

**Coefficientsa**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Unstandardized Coefficients | Standardized Coefficients |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Model |  | B | Std. Error | Beta | t | Sig. |
| 1 (Constant) Year   Rating   Ford   Hanks | | 4716.707 -2.544  63.805  18.460  -12.339 | 5583.405 2.810  30.188  72.965  77.196 | -.220  .474  .058 -.039 | .845 -.905  2.114  .253 -.160 | .411  .379  .051  .803  .875 |

a Dependent Variable: BoxOffice

**Regression on Actor Appearance**

**ANOVAb**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Model |  | Sum of  Squares | df | Mean Square | F | Sig. |
| 1 Regression  Residual  Total | | 18671.195 241914.031 260585.227 | 2  18  20 | 9335.598 13439.668 | .695 | .512a |

a Predictors: (Constant), Hanks, Ford   
b Dependent Variable: BoxOffice

**Coefficientsa**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | Unstandardized Coefficients | Standardized Coefficients |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Model |  | B | Std. Error | Beta | t | Sig. |
| 1 (Constant)  Ford  Hanks | | 126.365 80.107  -18.621 | 29.933 73.320 73.320 | .252 -.058 | 4.222  1.093 -.254 | .001  .289  .802 |

a Dependent Variable: BoxOffice

|  |  |
| --- | --- |
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**Output for Case Study 2:**

**Linear Combinations of Means**

**Contrast Coefficients**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Contrast | Group | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|  |  |  |  |  |  |  |  |  |  |