API - 209 | Problem Set 7

Prof. Dan Levy

Due on Tuesday, October 20, 2022 at 10:00 am.

INSTRUCTIONS

To successfully complete this problem set, please follow these steps:

1. **Download this RMarkdown document file into your computer.**
2. **Insert all your answers into this document.** Guidance **here** on how to insert objects such as handwritten work or screenshot images in your answers.
3. **SAVE your work frequently**.
4. To make things easier to visualize in RStudio, you can set the view mode as "Visual" instead of as "Source" in the top left of your screen (just below the Save button).
5. Once your document is complete, please save it as a PDF by clicking the **KNIT** button.
6. Please submit an electronic copy of the PDF (and any separate requested files) to the Canvas course page.

   6.a) If you want to check a PDF version of this problem set before starting to work on it, you can always knit it. In fact, you can knit the document at any point.

   6.b) If you cannot Knit and it's time to submit the problem set, submit the RMarkdown file and make an appointment with a member of the teaching team
7. Remember to consult the R resources from math camp, particularly the HKS R cheat sheet (available **here**, which contains many of the commands needed to answer the questions in this problem set.

IDENTIFICATION

1. Your information

```
Last Name:     Chaturvedi
First Name:   Shreya
```

2. Group Members (please list below the classmates you worked with on this problem set):

```
Group members:
```

3. Compliance with Harvard Kennedy School Academic Code: Do you certify that my work in this problem set complies with the Harvard Kennedy School Academic Code[1] (mark with an X below)?

[1]We abide by the Harvard Kennedy School Academic code (available here) for all aspects of the course. In terms of problem sets, unless explicitly written otherwise, the norms are the following: You are free (and encouraged) to discuss problem sets with your classmates. However, you must hand in your own unique written work and code in all cases. Any copy/paste of another's work is plagiarism. In other words, you can work with your classmate(s), sitting side-by-side and going through the problem set question-by-question, but you must each type your own answers and your own code. For more details, please see syllabus.

[X] YES [ ] NO

QUESTION 0 - RECORDING TIME

In an effort to understand better and more accurately the length of time that it takes you to complete problem sets, I would like to ask you to please fill in the form linked at the end of this problem set as accurately as possible. **As you go through this problem set, please keep track of the time you spend on each question and then record your time (in minutes).**

QUESTION 1 – SMOKING AND CANCER BIVARIATE REGRESSION

The purpose of this exercise is to help you learn the mechanics of ordinary least squares (OLS) regression and understand what the different terms in a regression mean. You will calculate the regression "by hand" using the formulas developed in class, and then you will use R to confirm the calculation. This is the only time in the course you will be asked to calculate the regression coefficients manually; I think it is important to do it once so you have a sense of what is really happening.

Few medical professionals doubt that smoking leads to many health problems, including lung cancer. While it is more difficult to determine that smoking causes lung cancer than simply to say that the two are related, in this assignment you will perform analysis that can begin to document the relationship between smoking and lung cancer. However, this is far from a definitive analysis. The sample is very small, and no effort is made to control for other differences between the countries in the sample.

The death rate from lung cancer in 1950 and the per capita cigarette consumption in 1930 are shown below for five countries. The cancer rates are shown for a later time period because it presumably takes time for lung cancer to develop and be diagnosed. Our hypothesis is that the dependent variable, lung cancer (Y), is a function of the independent variable, smoking (X).

Country	Cigarettes Consumer per capita (1930)	Lung Cancer Deaths per million people (1950)
Holland	460	245
Finland	1115	350
Great Britain	1145	465
Canada	510	150
Norway	250	90

Source: Edward R. Tufte, *Data Analysis for Politics and Management*, Table 3.3.

1. Using the appropriate formulas (given in the appendix below), show how to calculate each of the following. Please (1) write the appropriate formula; (2) plug in the appropriate values; and (3) show the computed answer. You do not need to show the intermediate calculations between steps 2 and 3. Note: You may use Excel (or R) to do the calculations as long as you do not use the built-in regression functions.

    a. $\hat{\beta}_1$, the estimated slope coefficient from the regression $Y = \beta_0 + \beta_1 X + u$
    b. $\hat{\beta}_0$, the estimated intercept coefficient from the same regression
    c. $\hat{Y}_i$, the predicted values for the five countries
    d. $\hat{u}_i$, the OLS residual for each country
    e. $\sum_i \hat{u}_i{}^2$, the sum of squared residuals

Answer:

Please insert your answer here.

Done on excel below

country	cigs	lcd	Xi - Xavg	Yi - Yavg	(Xi-Xavg)^2	(Xi-Xavg)*(Yi-Y	Y_est	residual	residual^2
Holland	460.00	245.00	-236.00	-15.00	55696.00	3540.00	178.69	66.31	4396.45
Finland	1115.00	350.00	419.00	90.00	175561.00	37710.00	404.35	-54.35	2954.15
Great Britair	1145.00	465.00	449.00	205.00	201601.00	92045.00	414.69	50.31	2531.34
Canada	510.00	150.00	-186.00	-110.00	34596.00	20460.00	195.92	-45.92	2108.65
Norway	250.00	90.00	-446.00	-170.00	198916.00	75820.00	106.35	-16.35	267.19
	cigs	lcd							
mean	696.00	260.00							
beta_1	0.34								
beta_0	20.22								
sum_of_squ	12257.78								

---

2. Interpret $\hat{\beta}_0$ and $\hat{\beta}_1$ in words. Be precise and specific.

Answer:

$\hat{\beta}_0$: 20.22. This is the baseline rate of lung cancer deaths we expect with zero cigarette consumption per capita. That is, if a country does not smoke at all, it will have 20.22 lung cancer deaths per million people.

$\hat{\beta}_1$: 0.34. This is the average increase in lung cancer deaths associated with unit increase in cigarette smoking. That is, for 1 unit increase in cigarette consumption per capita, our model expects a 0.34 units increase in lung cancer deaths.

---

3. Now you will estimate the same regression you ran before but this time in R. Familiarize yourself with running regressions in R with the following two *screencasts* tailored to this course:

Part 1: Running `lm` goes over the basic syntax of the `lm` functions mentioned in lecture.

Part 2: Summarizing output from `lm` shows how to summarize and extract quantities of interest from a `lm` object.

Answer:

Please enter " Done" in this field once you have finished the *screencasts*.

Done

---

4. Import the data from the table above into R. The data is available in the csv file "table_1.csv". Run a linear regression of `lcd` on `cigs`. From the summary R output, find and label $\hat{\beta}_0$ and $\hat{\beta}_1$. These should match the quantities you calculated above

---

```
# Enter only code here.
input <- read_csv("table_1.csv")
```

```
# Insert here the code for yout result table.
model <- lm(lcd ~ cigs, input)
summary(model)
```

Call: lm(formula = lcd ~ cigs, data = input)

Residuals: 1 2 3 4 5 66.31 -54.35 50.31 -45.92 -16.35

Coefficients: Estimate Std. Error t value Pr(>|t|)
(Intercept) 20.2170 61.5422 0.329 0.7641
cigs 0.3445 0.0783 4.400 0.0218 * — Signif. codes:
0 ‘’ ***0.001*** ’’ *0.01* ” 0.05 ‘.’ 0.1 ’ ’ 1

Residual standard error: 63.92 on 3 degrees of freedom Multiple R-squared: 0.8658, Adjusted R-squared: 0.8211 F-statistic: 19.36 on 1 and 3 DF, p-value: 0.02177

Answer:

Please insert your answer here.

beta_zero = 20.217

beta_one = 0.3445

These are the same values as above.

---

5. Consider the hypothesis H_o: β_1=0 in the context of the above regression. Would you reject the null hypothesis at the 5% significance level? Explain

---

```
# Enter only code here.
```

Answer:

Please insert your answer here.

Since the p value is 0.02 which is smaller than 0.05, we reject the null hypothesis beta_one = 0.

---

6. Answer the following questions:
    a. What is the value of lung cancer deaths (per million) for Norway predicted by the OLS regression? What is the real value in the data? What term is used to denote their difference?

```
# Enter only code here.
```

Answer:

Please insert your answer here.

Value of lung cancer deaths per million for Norway predicted by OLS model: 106.35

Value of lung cancer deaths per million for Norway in the actual data: 90

The Residual (or difference): -16.35

---

    b. Suppose one country exhibits 50 more cigarettes consumed (per capita, in 1930) than another country. What would your OLS regression predict is the difference in their lung cancer deaths (per million)?

```
# Enter only code here.
```

Answer:

Please insert your answer here.

Since our model predicts a 0.34 units increase in lung cancer deaths for every 1 unit increase in cigarette consumption, the model would predict a 0.34*50 = 17 units increase in lung cancer deaths for 50 units increase in cigarette consumption.

---

c. What is the predicted difference in lung cancer deaths (per million) between Canada and Holland? How does it compare to your answer in (b)?

```
# Enter only code here.
```

Answer:

Please insert your answer here.

The predicted difference between Canada (195.9) and Holland (178.7) is (17.2), or approximately the same.

---

d. **OPTIONAL**: Graph the 5 data points and the best-fit regression line using ggplot2. Label the axes and data points. Create annotations for the residuals as well as well as the slope and intercept of the regression line.

```
# Enter only code here.
```

Answer:

Please insert your answer here.

APPENDIX: Selected Regression Formulas (for Bivariate Regression)

***Slope and intercept coefficients*:**

$$\hat{\beta}_1 = \frac{\sum(X_i - \bar{X})\sum(Y_i - \bar{Y})}{\sum(X_i - \bar{X})^2}$$

$$\hat{\beta}_0 = \bar{Y} - \hat{\beta}_1 \bar{X}$$

***Predicted values*:**

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_i$$

***OLS Residual*:**

$$\hat{u}_i = Y_i - \hat{Y}_i$$

NOTE: Please remember to **record the time** it took you to complete this question.

QUESTION 2 – ESTIMATING IMPACTS OF A FITNESS PROGRAM

You are in charge of evaluating the impact of a fitness program at your organization aimed at increasing the number of steps people walk everyday. You have designed and implemented an RCT, where you track peoples' steps with a pedometer for 3 initial weeks. After this tracking period, participants in the study were divided into a treatment and control group. The treatment group got a push notification on their phone telling them their average step count over the initial weeks, while no message was sent to the control group. You then recorded total steps after 1 additional week from when this notification was sent out.

1. Define the average causal effect of the fitness program. Using the framework in handout 13, define conceptually and mathematically what is the average causal effect of the fitness program on the number of steps for the people in the treatment group.

a. Conceptually (in words):

Answer:

Please insert your answer here.

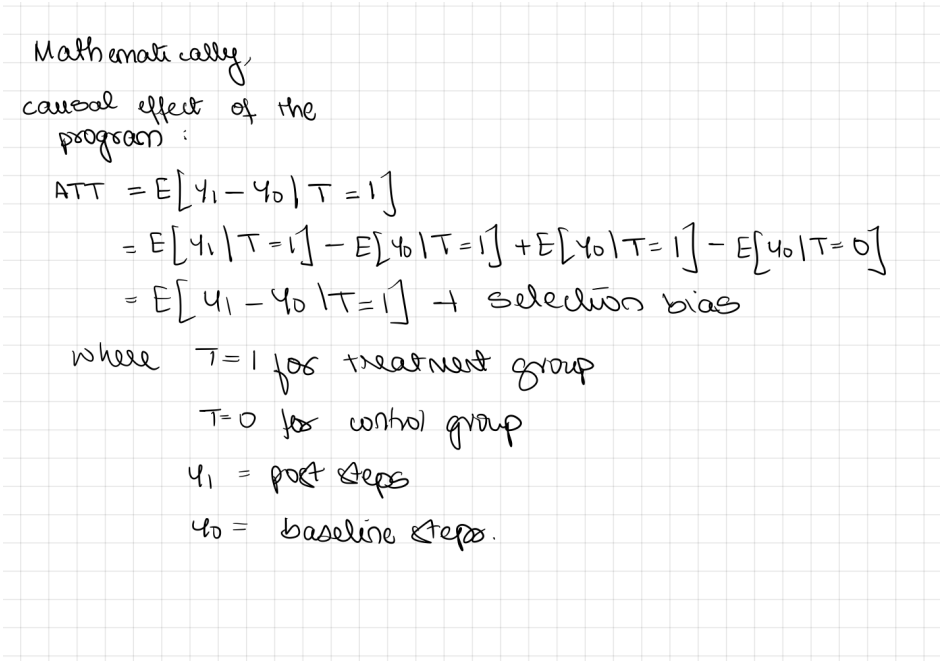
The average causal effect of the fitness program is the average change in the number of steps between people who received the notifications and people who didn't, with the assumption that these two groups of people are on average similar across aspects except receiving the notification.

---

b. Mathematically (you can either write the formulas using *LATEX* or upload a picture of your work):

Answer:

Please insert your answer here.



---

2. Estimate average effect of the fitness program. The data set "Steps.csv" contains the data from the study. It includes the following variables:

- `treatment`: a binary indicator of whether a participant was in the treatment or control group
- `BaselineSteps`: the total number of steps recorded after the initial 3 weeks
- `PostSteps`: the total number of steps recorded after 4 weeks. Note, this value includes the `BaselineSteps`, plus the additional steps taken in the final week (after treatment was administered)
- `StepChange`: the change in steps between the `PostSteps` and `BaselineSteps` measurements. This is equal to the number of new steps taken in the final week of the program

Your boss wants to know whether the fitness program had a positive impact (on average) on the outcome of interest (`StepChange`). Conduct the statistical analysis that you think should be done to respond to your boss and in one paragraph summarize your conclusions. Feel free to add a table or graph to your paragraph.

```
# Enter only code here.
steps <- read_csv("Steps.csv")
model <- lm(StepChange ~ treatment, data = steps)
summary(model)
```

```
##
## Call:
## lm(formula = StepChange ~ treatment, data = steps)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -26418.7 -12352.8     93.7  12359.5  26346.7
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  23635.3      185.2  127.64   <2e-16 ***
## treatment     2793.4      269.7   10.36   <2e-16 ***
## ---
## Signif. codes:
## 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 14350 on 11361 degrees of freedom
## Multiple R-squared:  0.009352,   Adjusted R-squared:  0.009265
## F-statistic: 107.3 on 1 and 11361 DF,  p-value: < 2.2e-16
```

```
# Insert here the code for yout result table.
bt <- balance_table(steps,"treatment")
names(bt) <- c("Variable","Control Group Mean","Treatment Group Mean","P Value")
bt
```

A tibble: 3 x 4

Variable `Control Group Mean` Treatment Gr~1 P Valu~2 1 BaselineSteps 75512. 69887. 1.06e-11 2 PostSteps 99147. 96316. 1.14e- 3 3 StepChange 23635. 26429. 4.47e-25 # … with abbreviated variable names # 1: `Treatment Group Mean`, 2: `P Value`

Answer:

Please insert your answer here.

Conclusions:
1. We see that the average number of steps in the treatment group is higher by approximately 2800 and this difference is statistically significant (very very small p value).

2. However, we also note the caveat that the treatment and control groups were not balanced to begin with (p value of difference is almost zero too).

Simply put, our treatment of sending a push notification did improve the number of steps in the treatment group, but the treatment group was taking many more steps than the control group to begin with, so we cannot be sure that this is a result of the push notification.

	Variable	Control Group Mean	Treatment Group Mean	P Value
1	BaselineSteps	75511.95	69887.10	1.063156e-11
2	PostSteps	99147.29	96315.84	1.137073e-03
3	StepChange	23635.34	26428.75	4.468000e-25

NOTE: Please remember to **record the time** it took you to complete this question.

QUESTION 3 – ONLINE MODULE ON MULTIPLE REGRESSION

Background: The goal of this problem set question is to help you get familiar with **Multiple Linear Regression**. You will be asked to watch a short module and answer some questions in a quiz. The quiz results will give me information about overall performance of the class that I will use to prepare for class; your individual performance in the quiz will be registered in the system but will not count towards your grade in any way.

To get full credit for this question, you need to engage with the module and complete the quiz. Please make sure you **submit** your answers at the end of the quiz/survey so that they are registered.

The module is available here:

https://canvas.harvard.edu/courses/109224/modules/227109

Answer:

Please insert your answer here.

Done

NOTE: Please remember to **record the time** it took you to complete this question.

TIME USE

Please enter in the form linked below the time you spent on each question.

This information will only be used for teaching improvements; **please be candid** and report the time (in **MINUTES**) spent in each question.

The form is available here:

https://forms.gle/iJAiJQfgeXajoMgF7

Please enter "Done" in this field once you have completed the form.

Done

This is a copy of your code.

```
.answer-box {
  background-color: LemonChiffon;
}
knitr::opts_chunk$set(echo = TRUE)
knitr::opts_chunk$set(options(width = 60))
knitr::opts_chunk$set(class.output = "bg-warning")

packages <- c('haven','dplyr', 'ggplot2', 'reshape2', 'tidyverse', 'pracma',
              'lubridate', 'scales', 'ggthemes', 'gt','RCT')
to_install <- packages[!(packages %in% installed.packages()[,"Package"])]
if(length(to_install)>0) install.packages(to_install,
                                          repos='http://cran.us.r-project.org')
lapply(packages, require, character.only=TRUE)


Last Name:     Chaturvedi
First Name:   Shreya
Group members:
                             [X] YES                [   ] NO
# Enter only code here.
input <- read_csv("table_1.csv")
# Insert here the code for yout result table.
model <- lm(lcd ~ cigs, input)
summary(model)
# Enter only code here.

# Enter only code here.

# Enter only code here.

# Enter only code here.

# Enter only code here.

# Enter only code here.
steps <- read_csv("Steps.csv")
model <- lm(StepChange ~ treatment, data = steps)
summary(model)



# Insert here the code for yout result table.
bt <- balance_table(steps,"treatment")
names(bt) <- c("Variable","Control Group Mean","Treatment Group Mean","P Value")
bt
```