

Replication of Examples in Chapter 4

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1 Introduction

This document is to show how to estimate a simple regression model and perform linear hypothesis testing. The application concerns the test scores of the California school districts. We will use R to estimate the simple regression model with the data set in Chapter 4.

Before running all R codes, we may first load the package **AER** for loading several particular packages of regression.

```
library(AER)
```

2 Reading the data and basic summary statistics

Let's first read the data into R and show some basic statistics.

2.1 Read the data file

The textbook comes with two files for the California test score data set, **caschool.xlsx** and **caschool.dta**, the former of which is an Excel file and the latter is a Stata file. We need to read either one of these two files into R so that we can use the data set.

R has several built-in functions that can read an ASCII data file, which can have such an extension as `.txt`, `.csv`, `dat`, to name a few. However, these built-in functions cannot handle an Excel file or a Stata file. So, in order to read `caschool.xlsx` or `caschool.dta` in to R, we need additional packages.

To read a State file with an extension of `.dta`, we use the function, `read.dta`, in the library of `foreign`.

```
library(foreign)
classdata <- read.dta("./data/caschool.dta")
```

`classdata` is a dataframe object in R. If you want to check whether your reading is correct, you can type `head(classdata)`, which, by default, displays the first six observations of all variables in the data frame object.

```
head(classdata[c("observat", "district", "testscr", "str")])
```

	observat		district	testscr	str
1	1		Sunol Glen Unified	690.80	17.88991
2	2		Manzanita Elementary	661.20	21.52466
3	3		Thermalito Union Elementary	643.60	18.69723
4	4		Golden Feather Union Elementary	647.70	17.35714
5	5		Palermo Union Elementary	640.85	18.67133
6	6		Burrel Union Elementary	605.55	21.40625

2.2 Summary

Upon reading the data, we often use `summary()` to see some basic statistics. Here we are not going to show summary statistics of all variables in the data set for the purpose of saving space, but only to select several variables of interest in Chapters 4, including test scores, `testscr`, student-teacher ratio, `str`.

```
df <- classdata[c("testscr", "str")]
summary(df)
```

	testscr		str
Min.	:605.5	Min.	:14.00
1st Qu.:	640.0	1st Qu.:	18.58
Median	:654.5	Median	:19.72
Mean	:654.2	Mean	:19.64
3rd Qu.:	666.7	3rd Qu.:	20.87

Max. :706.8 Max. :25.80

Formally, we can create a table showing important summary statistics, like the following table (Table 4.1 in the book).¹

```
# Replicate the summary statistics in Table 4.1
summary4.1 <- function(df){
  ave <- sapply(df, mean)
  std <- sapply(df, sd)
  percstile <- sapply(df, function(x)
quantile(x, probs=c(0.1, 0.25, 0.4, 0.5, 0.6, 0.75, 0.9)))
  return(rbind(ave, std, percstile))
}
library(xtable)
sumtab <- xtable(t(summary4.1(df)))
```

In the above code, I defined a function called `summary4.1`. In R, we use `function()` to define a custom function. In this case, the function `summary4.1` takes one argument `df`. The code within the function is enclosed with the curly braces, `{ }`, and what the function yields is controlled by `return()` in the last line.

Within the function `summary4.1`, I use a special function in R, `sapply()`. It takes each component in a list object, which is `df` in this case, and impose a function on this component, and return a simplified object. Check the help information for `apply()`, `lapply()`, `sapply()`, `mapply()`, and `tapply()`.

Finally, the function `xtable()` writes the matrix that contains the summary statistics into a table in either a LaTeX or an HTML file.

```
print(sumtab, type = "latex")
```

	ave	std	10%	25%	40%	50%	60%	75%	90%
testscr	654.16	19.05	630.40	640.05	649.07	654.45	659.40	666.66	678.86
str	19.64	1.89	17.35	18.58	19.27	19.72	20.08	20.87	21.87

¹To create such a table, I use the function `xtable` in the package of `xtable`, which generates a LaTeX table. Also, I modified the format of the LaTeX table using the LaTeX package `booktabs`. LaTeX is a typesetting system, like Microsoft Word, that is capable of creating professional looking-like documents. Though LaTeX is not required for this course, learning it would be a great benefit for your future career development, especially in academia

2.3 Create a scatterplot using plot()

It is always a good practice to make a scatterplot between an independent variable and a dependent variable before setting up a regression model. Let's draw a scatterplot of student-teacher ratios and test scores. `plot` is the most basic function in R to draw figures. Here I use it to draw the scatterplot as follows.

```
plot(df$str, df$testscr, col = "blue", pch = 16, cex = 0.7, bty = "l",  
     main = "Scatterplot of Test Score vs. Student-Teacher Ratio",  
     xlab = "Student-teacher ratio", ylab = "Test scores")
```

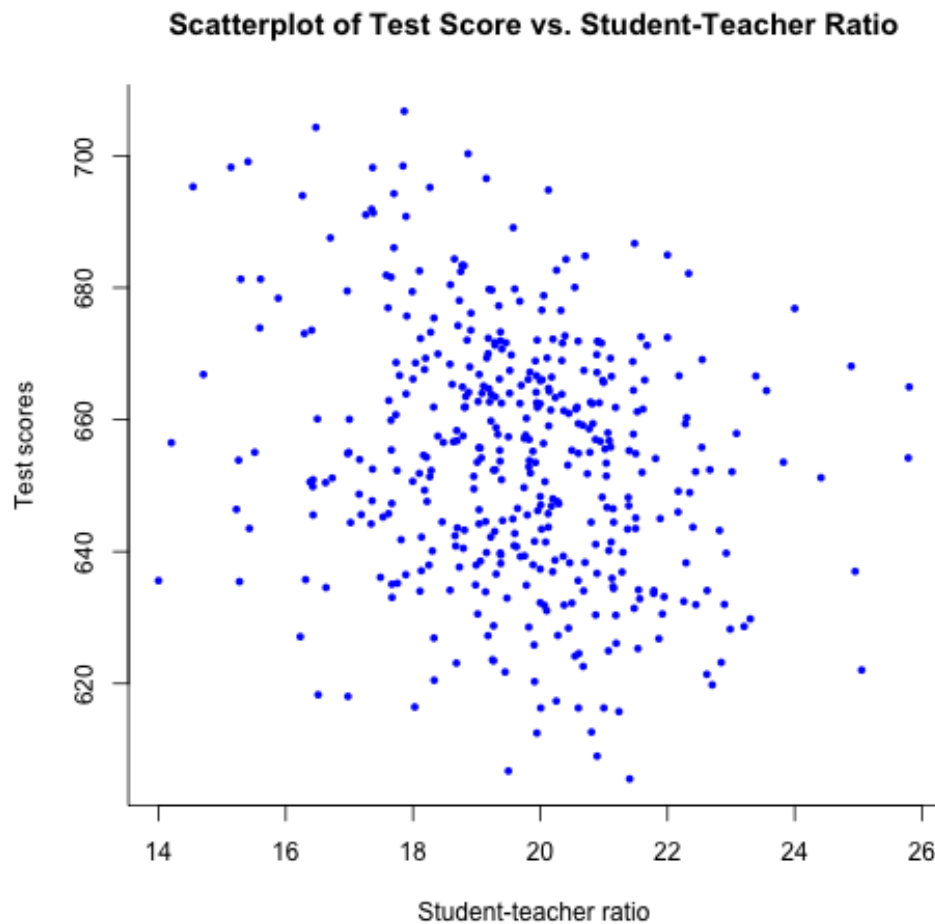


Figure 1: The scatterplot between student-teacher ratios and test scores

We can compute the correlation coefficient between the two variables, using the function `cor`. Typing the command `cor(dfstr, dftestscr)` yield the value of `-0.23`.

3 The OLS estimation

3.1 Set up the linear regression model

We establish the following linear regression model for the relationship between test scores and class sizes

$$TestScore_i = \beta_0 + \beta_1 STR_i + u_i \quad (1)$$

3.2 Estimate in R

The OLS estimation can be implemented in R with the function `lm`. The most important argument in this function is the model to be estimated, which is called a **formula** object in R. A formula is defined using the format `y ~ x1 + x2`, in which the symbol of `~` links the left-hand side variable, `y`, and the right-hand side variables, `x1`, `x2`. We can add more independent variables in the right-hand side with each being appended to the formula by the symbol of `+`. The constant term is by default included in the model. After estimation, we use `summary` to see the results.

```
mod1 <- lm(testscr ~ str, data = df)
summary(mod1)
```

Call:

```
lm(formula = testscr ~ str, data = df)
```

Residuals:

	Min	1Q	Median	3Q	Max
	-47.727	-14.251	0.483	12.822	48.540

Coefficients:

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	698.9330	9.4675	73.825	< 2e-16 ***
str	-2.2798	0.4798	-4.751	2.78e-06 ***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 18.58 on 418 degrees of freedom

Multiple R-squared: 0.05124, Adjusted R-squared: 0.04897

F-statistic: 22.58 on 1 and 418 DF, p-value: 2.783e-06

For now, we just pay attention to the estimates of the two coefficients, which is 698.93 for the intercept, β_0 , and -2.28 for the slope.

$$\widehat{TestScore} = 698.93 - 2.28 \times STR$$

3.3 Plot the sample regression line

The sample regression line can be added to the scatterplot by using the function `abline`. And an annotation can be added by using the function `text`

```
plot(df$str, df$testscr, col = "blue", pch = 16, cex = 0.7, bty = "n",  
     xlab = "Student-teacher ratio", ylab = "Test scores")  
abline(coef(mod1)[1], coef(mod1)[2], col="red")  
text(23.5, 655, "TestScore = 698.9 - 2.28 STR", cex.lab = 0.9, font.lab = 3)
```

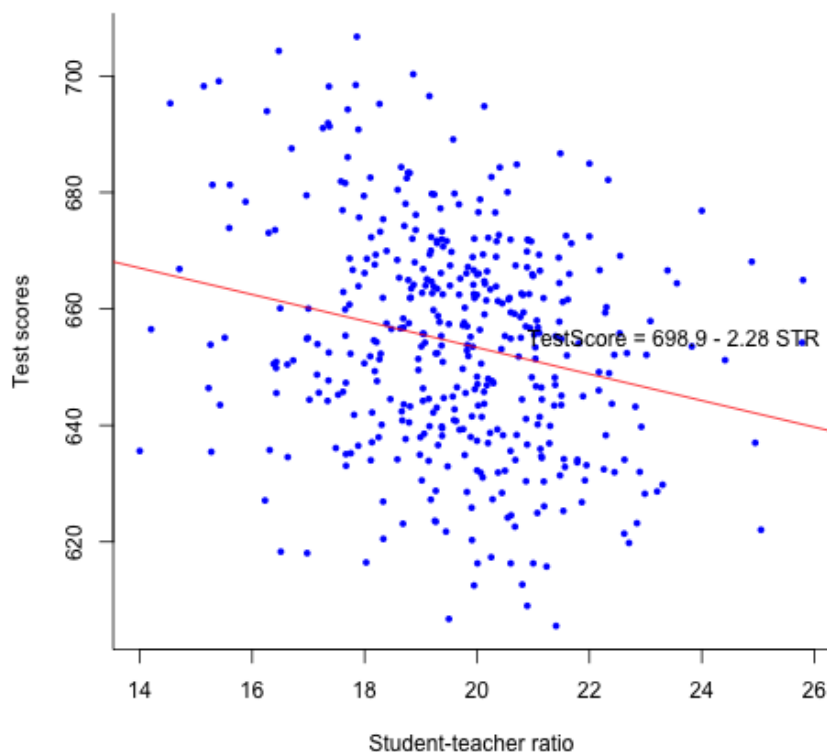


Figure 2: The estimated regression line for the California data