Latex math notations and Example R codes with PDF output

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Contents

Objective

For the assignments in econometrics and microeconomics classes, you will most likely need to create PDFs (unless your TA says otherwise). You can use the Rmarkdown (and Quarto) file to do this.

The objectives of this document are:

1. to introduce basic LaTeX commands to produce math notations.
2. to demonstrate how to write math equations with LaTeX commands.
3. to explain how to show R codes and their outputs in a PDF document.

Especially, Sections 1 and 2 might be helpful for students unfamiliar with LaTeX commands. These are the most commonly used LaTeX commands when you write assignments for econometrics and microeconomics classes in APEC!

For Section 1, I adapted the content from the document created by Prof. Joe Ritter, my previous Econometrics instructor.

Section 1: LaTeX Building blocks

Goal	How to get it	Notes
$\alpha, \beta, \omega, \Omega$	`\alpha, \beta, \omega, \Omega`	Spell names of Greek letters.
$\bar{X}, \hat{\beta}, \tilde{\beta}$	`\bar X, \hat\beta, \tilde\beta`	Can't do stats without $\bar{X}$. Can't do econometrics without $\hat{\beta}$!
$\mathbf{X}, \boldsymbol{\beta}$	`\mathbf{X}, \boldsymbol{\beta}`	Bold math symbols. To make Latin-letters bold, you can use `\boldsymbol`from "bm" package: `\usepackage{bm}`
σ^2	`\sigma^2`	Superscripts.
$\sim$	`\sim`	For example, $X \sim N(0,1)$
$\succ, \succsim$	`\succ, \succsim`	Preference relations in micro.
$\xrightarrow{p}, \xrightarrow{d}$	`\xrightarrow{p}, \xrightarrow{d}`	Convergence in probability, and convergence in distribution
$\geq, \leq, >, <$	`\ge, \leq, >, <`	Inequality,
X_i, σ_{ij}	`X_i, \sigma_{ij}`	Subscripts. When a sub(super)script has more than one symbol, like the ij, braces around it are needed to say where the sub(super)script ends.
$\sum_{i=1}^{n} X_i$	`\sum_{i=1}^n X_i`	Summation.
$\prod_{i=1}^{n} X_i$	`\prod_{i=1}^n X_i`	Products.
$\lim_{x \to \infty} f(x)$	`\lim_{x\to\infty} f(x)`	Limits.
$\int_{x=-\infty}^{\infty} x\,dx$	`\int_{x=-\infty}^\infty x\,dx`	Integrals.
$\frac{1}{1-\beta}$	`\frac{1}{1 - \beta}`	Fractions. Braces enclose numerator and denominator.
$\frac{\partial f(x,y)}{\partial x}$	`\frac{\partial f(x,y)}{\partial x}`	Partial derivative.
$\log(x), \exp(x)$	`\log(x), \exp(x)`	Named functions. Looks better if you don't omit the \.
$\sqrt{V+1}$	`\sqrt{V+1}`	Square root.

$\begin{pmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{pmatrix}$	`\begin{pmatrix}`
	`  1 & 2 & 3 \\`
	`  4 & 5 & 6 \\`
	`\end{pmatrix}`
		Matrices.

$\begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \end{bmatrix}$	`\begin{bmatrix}`
	`  \beta_0 \\`
	`  \beta_1 \\`
	`  \beta_2 \\`
	`\end{bmatrix}`
		Matrices.

Section 2: Example math equations

Example 1: Aligning equations with expression after equal sign

Syntax:

```
\begin{align*}
\hat{\beta}
  &= \mathbf{(X^{\prime}X)^{-1} (X^{\prime}Y)} \\
  &= \mathbf{(X^{\prime}X)^{-1} (X^{\prime}(X\beta + e))} \\
  &= \mathbf{(X^{\prime} X)^{-1} X^{\prime}{X} \beta + (X^{\prime} X)^{-1} X^{\prime} e} \\
  &= \beta + \mathbf{(X^{\prime} X)^{-1} X^{\prime} e}
\end{align*}
```

becomes:

$$\begin{aligned}
\hat{\beta} &= \mathbf{(X'X)^{-1}(X'Y)} \\
&= \mathbf{(X'X)^{-1}(X'(X\beta + e))} \\
&= \mathbf{(X'X)^{-1}X'X}\beta + \mathbf{(X'X)^{-1}X'e} \\
&= \beta + \mathbf{(X'X)^{-1}X'e}
\end{aligned}$$

Example 2: Writing equations within a curly brace

Syntax:

```
\begin{equation*}
  F(x) =
    \begin{cases}
      0 &  \quad x < 0 \\
      x &  \quad 0 \ge x \ge 1 \\
      1 &  \quad x > 1
    \end{cases}
\end{equation*}
```

becomes:

$$F(x) = \begin{cases} 0 & x < 0 \\ x & 0 \geq x \geq 1 \\ 1 & x > 1 \end{cases}$$

Example 3: Including comments within equations

Syntax:

```
\begin{equation*}
  Z_n =
    \begin{cases}
      -n & \text{with probability $1/n$} \\
      0 &  \text{with probability $1-2/n$} \\
      n &  \text{with probability $1/n$} \\
    \end{cases}
\end{equation*}
```

becomes:

$$Z_n = \begin{cases} -n & \text{with probability } 1/n \\ 0 & \text{with probability } 1-2/n \\ n & \text{with probability } 1/n \end{cases}$$

Sintax:

```
\begin{equation*}
\overline{X}_n =
  \frac{1}{n}\sum{i=1}^{n}X_i \xrightarrow{p} E[X]
  \quad \text{ as } n \rightarrow \infty
\end{equation*}
```

becomes:

$$\overline{X}_n = \frac{1}{n}\sum_{i=1}^{n} X_i \xrightarrow{p} E[X] \quad \text{as } n \rightarrow \infty$$

Example 4: Maximization problem

Syntax:

```
\begin{align*}
\max_{x_1, x_2} \quad & u(x_1, x_2) = \frac{1}{2}log x_1 + \frac{1}{2} log x_2 \\
\textrm{s.t.} \quad & w = p_1 x_1 + p_2 x_2 \\
\end{align*}
```

becomes:

$$\begin{aligned} \max_{x_1,x_2} \quad & u(x_1,x_2) = \frac{1}{2}logx_1 + \frac{1}{2}logx_2 \\ \text{s.t.} \quad & w = p_1x_1 + p_2x_2 \end{aligned}$$

Section 3: Write R codes

In Rmarkdown (and Quarto) document, you write R codes inside a code chunk:

````
```{r}
write your code inside the chunk.
```
````

To insert a code chunk, you can use a shortcut key: `Cmd + Option + I` for Mac users (`Ctrl + Alt + I` for Windows users). Below are examples showing how the R codes and their output look on the output document

Example 1

```r
# === Load Packages === #
library(data.table)
library(ggplot2)

# === Data === #
# iris is a built-in dataset in R
data(iris)
# Convert the data into data.table
setDT(iris)
# Filter for the species "virginica"
virginica <- iris[Species == "virginica",]
```

```r
# === Visualization === #
ggplot(virginica, aes(x=Sepal.Length, y=Petal.Length))+
  geom_point()+
  # --- Add a regression line --- #
  geom_smooth(method = lm, se = FALSE)+
  # --- Change the background --- #
  theme_bw()+
  # --- Center the title --- #
  theme(plot.title = element_text(hjust = 0.5))
```

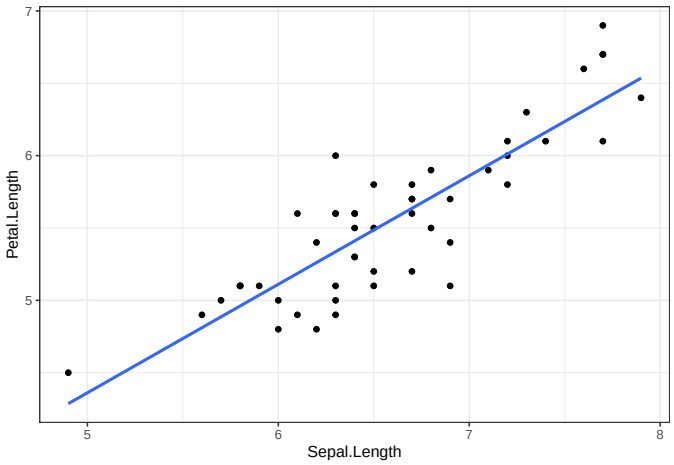

Figure 1: Relationship between Sepal.Length and Petal.Length

NOTE: you can adjust the size of figures by the chunk option `out.width` (or `fig.width`, `fig.height` and so on). For example:

````
```{r, out.width = '80%'}

```
````

or

```
```{r}
#|  out.width = '80%'

```
```

Example 2:

The following code run regression analysis with the `lm()` function and show the results with the `modelsummary` function from the modelsummary package.

```
# === Load packages === #
library(modelsummary)

# === Load Data === #
data(hprice2, package = "wooldridge")

# === Estimate three models === #
reg1 <- lm(log(price) ~ log(nox), data = hprice2)
reg2 <- lm(log(price) ~ log(nox) + rooms, data = hprice2)
reg3 <- lm(log(price) ~ log(nox) + rooms + I(rooms^2), data = hprice2)

# === Show the Results === #
ls_models <-
  list(
    "OLS 1" = reg1,
    "OLS 2" = reg2,
    "OLS 3" = reg3
  )

modelsummary(
  models = ls_models,
  output = "flextable",
  fmt = "%.2f",
  coef_map = c(
    "log(nox)" = "log(Nox)",
    "rooms" = "Rooms",
    "I(rooms^2)" = "Rooms sq"
    ),
  stars  =  c("*" = .05, "**" = .01, "***" = .001),
  gof_map = c("nobs", "r.squared"),
  title = "Example Regression Results",
  notes = list("Note: Std. Errors in parentheses")
  )
```

Table 1: Example Regression Results

	OLS 1	OLS 2	OLS 3
log(Nox)	-1.04***	-0.72***	-0.79***
	(0.08)	(0.07)	(0.06)
Rooms		0.31***	-0.76***
		(0.02)	(0.17)
Rooms sq			0.08***
			(0.01)
Num.Obs.	506	506	506
R2	0.264	0.514	0.549

* p < 0.05, ** p < 0.01, *** p < 0.001

Note: Std. Errors in parentheses

Section 4: Insert a picture to a document

Below is an example R chunk code to insert a picture.

```
```{r, fig.cap='A caption', out.width = '80%'}
knitr::include_graphics("path to the file")
```
```