An Introduction to Equations in LaTeX

Robert Andersen
University of Oxford
and
University of Western Ontario

ICPSR Summer Program, July 2002

Introduction to Math in LaTeX

- LaTeX has three basic modes:
  1. Text mode
  2. Inline math mode (allows math inside text)
  3. Display math mode (equations are separated from the text)
- Most math symbols can only be used in math mode (e.g., the hat and bar symbols above letters)
- Equations (and all math symbols) can be set within the text if they are surrounded by dollar signs ($). For example: $\hat{Y}=\alpha+\beta_1 X_1+\beta_2 X_1^2$, gives:

$$\hat{Y} = \alpha + \beta_1 X_1 + \beta_2 X_1^2$$

- Complicated equations, however, are best set in display math environments
- Before we look at environments, it is useful to look at some math symbols

Basic Math (1)

- **Subscripts and superscripts:**
  - Carets (^) indicate superscripts, `$X^2$`
  - Underscores (_) indicate subscripts, `$X_1$`.
  - When the sub/superscript contains more than one character, it is enclosed in braces, `$X^{n+1}$`.
- **Square Roots:** `$\sqrt{X}$`
- **Fractions and binomial coefficients:**
  - Fractions: `$\frac{x}{y}$`, where x is the numerator and y is the denominator.
  - Binomials: `$\binom{x}{y}$`

`$x^5$`	`$x_{n+1}$`	`$\sqrt{5}$`	`$\frac{1}{n+k+1}$`
x^5	x_{n+1}	$\sqrt{5}$	$\frac{1}{n+k+1}$

Basic Math (2)

- **Sums and integrals:**
  - Sums: \sum (different from the \Sigma symbol).
  - Integrals: \int
  - Size is adjusted automatically according to the equation
  - Lower and upper limits are specified as subscripts and superscripts:

`$\sum_{k=1}^n$`	`$\Sigma$`
$\sum_{k=1}^{n}$	Σ

- **Limits:**
  - "\lim" produces the "lim" symbol
  - Expression underneath (for example, "x tends to infinity") is obtained with the (_) used for subscripts

`$\lim_{x\rightarrow\infty}$`

$\lim_{x\to\infty}$

Basic Math (3)

- **Math Text:**
  - Text in math mode is normally *italicised*
  - This can be avoided for certain functions by typing the following: \sin, \cos, \log, \ln, \exp, etc.
  - Other text within equations is specified with an \mbox command (this command also keeps text together):

```
$\widehat{\mbox{prestige}}=\alpha+\beta\mbox{income}$
```

$$\widehat{\text{prestige}} = \alpha + \beta\text{income}$$

Greek letters (1)

- Greek letters are easily generated in MATH mode by typing a backslash and then spelling out the letter.
- Most of the codes are intuitive:

α	\alpha	θ	\theta
β	\beta	ϑ	\vartheta
γ	\gamma	ι	\iota
δ	\delta	κ	\kappa
ϵ	\epsilon	λ	\lambda
ε	\varepsilon	μ	\mu
ζ	\zeta	ν	\nu
η	\eta	ξ	\xi

Greek letters (2)

$\varnothing$	\o	υ	\upsilon
π	\pi	ϕ	\phi
ϖ	\varpi	φ	\varphi
ρ	\rho	χ	\chi
ϱ	\varrho	ψ	\psi
σ	\sigma	ω	\omega
ς	\varsigma	τ	\tau

- A selection of Greek letters are also available in uppercase:

Γ	\Gamma	Σ	\Sigma
Δ	\Delta	Υ	\Upsilon
Θ	\Theta	Φ	\Phi
Λ	\Lambda	Ψ	\Psi
Ξ	\Xi	Ω	\Omega
Π	\Pi		

Decorations

- Some of the most commonly used decorations in math mode are:

$\hat{y}$	\hat{y}
$\widehat{\text{income}}$	\widehat{\mbox{income}}
$\tilde{x}$	\tilde{x}
$\widetilde{\text{income}}$	\widetilde{\mbox{income}}
$\bar{x}$	\bar{x}
$\vec{x}$	\vec{x}
X'	X^\prime

Relations, Operators and Deliminators

	Command		Command		Command
$<$	<	$>$	>	$=$	=
$\leq$	\leq or \le	$\geq$	\geq or \ge	$\equiv$	\equiv
$\ll$	\ll	$\gg$	\gg	$\sim$	\sim
$\simeq$	\simeq	$\approx$	\approx		
$+$	+	$\pm$	\pm	$\div$	\div
$\times$	\times	$\sum$	\sum	$\prod$	\prod
$\int$	\int				
(	(	)	)		
[	[	]	]		
{	{	}	}		
/	/	\	\backslash		

Some other useful math commands

\dots; \cdots
- — Horizontal ellipsis with dots on bottom of line and in centre of the line

\ddots
- — Diagonal ellipsis

\vdots
- — Vertical ellipsis

\overbrace; \underbrace
- — Makes a brace over or under the text

\overline; \underline
- — Overlines or underlines text

An example using the ellipsis commands

```
\begin{equation*}
E(\varepsilon \varepsilon^\prime)
=\left[
\begin{array}{cccc}
\sigma^2&0& \cdots &0 \\
0&\sigma^2&&\vdots\\
\vdots&&\ddots&\vdots\\
0&\cdots&0&\sigma^2
\end{array}
\right]
\end{equation}
```

$$E(\varepsilon\varepsilon') = \begin{bmatrix} \sigma^2 & 0 & \cdots & 0 \\ 0 & \sigma^2 & & \vdots \\ \vdots & & \ddots & \vdots \\ 0 & \cdots & 0 & \sigma^2 \end{bmatrix}$$

Spacing in Math Mode

- All blank spaces are ignored inside math mode
- Usually LaTeX knows the proper distance to put between characters, but sometimes you may find it helpful to adjust the distance
- The "\quad" command adds horizontal space to separate to equations
- Other smaller spaces can be achieved with:
  1. \; - a thick space
  2. \: - a medium space
  3. \, - a thin space
  4. \! – a negative thin space

Math Environments

- In display math modes (e.g., `displaymath`, `equation`, `eqnarray`, `equation*`), equations are displayed on separate lines from the regular text
- Most of the display mode that I'll show here uses the `amsmath` package, which should be loaded before the "`\begin{document}`" statement as follows: `\usepackage{amsmath}`
- The `equation` environment will number each equation; `equation*` will give the same equation without numbering it

```
\begin{equation}
\hat{y}=\alpha+\beta_1X_1+\beta_2X_2+\varepsilon
\end{equation}
```

$$\hat{y} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \qquad (1)$$

Equations are displayed differently in math environments than inline

- Examine the following example, using exactly the same commands but one using the $ signs inline, and the other in the "equation" environment:

```
\lim_{n \rightarrow \infty}\sum_{k=1}^n \frac{1}{x^2}
```

- Inline with text:

$\lim_{n\rightarrow\infty} \sum_{k=1}^{n} \frac{1}{x^2}$

- Using the "equation" environment:

$$\lim_{n\rightarrow\infty} \sum_{k=1}^{n} \frac{1}{x^2}$$

Often we need to "align" equations

- The "aligned" environment in the `amsmath` package makes it easy to align equations. The "&" indicates where the equations should be aligned at; the "\\" starts a new line
- This is particularly important considering that LaTeX will not break up your equations automatically

```
\begin{equation*}
\begin{aligned}
F_0&=\frac{\mbox{RegSS}/k}{\mbox{RSS}/(n-k-1)}\\
   &=\frac{n-k-1}{k}\times\frac{R^2}{1-R^2}
\end{aligned}
\end{equation*}
```

$$
\begin{aligned}
F_0 &= \frac{\text{RegSS}/k}{\text{RSS}/(n-k-1)} \\
&= \frac{n-k-1}{k} \times \frac{R^2}{1-R^2}
\end{aligned}
$$

Arrays (1)

- The array environment arranges information into columns
- New rows are started by a "double-backslash" \\
- Column entries in each row are separated by the "and" sign &
- Column alignment is specified immediately after the start of the environment:
  - l is for left-adjusted columns
  - r is for right-justified columns
  - c is for centred columns

Arrays (2):
An example

```
\begin {equation*}
\begin {array} {clcr}
X + y & 3 \times 4 & X^10 & 0\\
\beta_i + 3 & z & \frac{1}{2} & 5
\end{array}
\end{equation*}
```

Produces:

$$\begin{array}{clcr} X + y & 3 \times 4 & X^{10} & 0 \\ \beta_i + 3 & z & \frac{1}{2} & 5 \end{array}$$

Using the "array" environment to make matrices

- Once inside a math environment (such as "equation" or "displaymath") we can use the "array" environment to make matrices
- By putting "\left" and "\right" beside the left and right square brackets, LaTeX will now to make the brackets for the matrix large enough for the array

```
\begin{equation*}
\mbox{I}=\left[
\begin{array}{rrr}
1&0&0\\
0&1&0\\
0&0&1
\end{array}
\right]
\end{equation*}
```

$$\mathrm{I} = \left[\begin{array}{rrr} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{array} \right]$$

The "newcommand" command:
Creating commands for often used symbols

- If we are doing a long equation that involves using different symbols over and over again, it is efficient to create your own command
- For example, when exploring the matrix formula for linear regression, the X matrix and the y matrix are used frequently
- Since they are matrices, they should be in bold symbols—without a "newcommand" this could become very tedious and you would be likely to make many errors
- The new command allows you to make a simple command for these matrices

The "newcommand" command:
Creating commands for often used symbols (2)

```
\begin{equation*}
\newcommand{\y}{\boldsymbol{y}}
\newcommand{\X}{\boldsymbol{X}}
\mbox{\bf{b}}=(\X^\prime\X)^-1\X^\prime\y
\end{equation*}
```

$$\mathbf{b} = (X'X)^{-1}X'y$$