

Please Read the Abstract

By

Abstract Writer

Submitted to the graduate degree program in Department of People who read Abstracts and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Committee members

MEMBER 1, Chairperson

MEMBER 2, Occasional Visitor

MEMBER 3

MEMBER 4, The One Who Never Answers Email

The One with an Extra Long Name

The Fifth Beatle

Date defended: October 02, 2016

The Thesis Committee for Abstract Writer certifies
that this is the approved version of the following thesis :

Please Read the Abstract

MEMBER 1, Chairperson

Date approved: October 06, 2016

Abstract

Hopefully, you are reading “ku-thesis.pdf”. If you are reading a file with some other name, then there’s been a goof up. This document is produced by the LaTeX compiler “pdflatex”. The file collection needed to reproduce this document is named “KU-thesis-20170331.zip” (the date changes from time to time, of course). The Web home for this project is <https://crmda.ku.edu/latex>¹. That site will always point at the newest edition and there should also be a copy in the Electronic Thesis Webpages pages hosted by the office of the Graduate Dean.

You will love using L^AT_EX to prepare your thesis. The power to keep content structured, with a systematic framework for cross references among figures, tables, equations, and sections, will significantly improve your quality of life. This will be much better than using an ordinary “text editor.”

Well, that’s all well and good. But what *is* this? There are three kinds of files.

1. The LaTeX class file, `kuthesis.cls`. That’s necessary, you need that to produce a thesis.
2. The example document, `thesis-ku`, which can serve as a template for student projects.
3. A layout file for the LyX editor, `kuthesis.layout`. You need that if you want to use LyX to edit your thesis documents.

This is the Spring 2017 revision template. There have been some minor changes in “kuthesis.cls” in response to requests from users over time. The changes have been

¹Previous versions have been offered at <http://pj.freefaculty.org/guides/Computing-HOWTO/KU-thesis>.

relatively minor. The class file now allows students to list as many as 7 committee members, each with their own titles and roles. The size of the names of the chapters is now slightly reduced (from the LaTeX `\Huge` to `\Large`).

How to use these files.

Step 1. Study the features in this document. Please read through this Abstract. It is intended to be readable, pleasant, welcoming and helpful. The PDF you are reading was created by compiling `thesis-ku.tex`. After you finish inspecting this document, then look at the LaTeX document from which it came.

Step 2. Inspect the LaTeX source code that is provided in the same package as the PDF document.

There are some special features that will become apparent once you look at the LaTeX source code. The `thesis-ku` document is the “master” document. The separate chapters are in separate folders. It is possible to work on one chapter at a time, and compile just that chapter, or it is possible to compile the whole thing by compiling the master document.

In `thesis-ku`, we have included as many bells and whistles as possible so that users can see how the different features can be put to use. We have a BibTeX bibliography, graphs, equations, cross references, table of contents, and all of the other interesting features.

The most recently inserted feature is support for hyperlinks in the PDF output. We checked with the KU Graduate Dean’s office and they said there is no policy prohibiting the use of hyperlinks, but there is also no guarantee from the dissertation hosting institution that they will either work or not cause problems down the line. We believe there is not too much danger here, this feature is easy to turn off if need be. Also, it is not entirely clear what color the links must be inside the document, so we take a conservative step here of making the links black, so they appear as simple text. The default

settings for the `hyperref` package, which we have altered, caused ugly pink links with gross looking boxes around them. Users can change the link color to blue. It is fairly easy to see how this can be done in the document preamble. Look for something like this `"urlcolor={black},citecolor={black},allcolors={black}"` and think of Henry Ford's famous comment, "You can have a car in any color you like, as long as its black."

Step 3. Try to compile the thesis-ku document! Before you try to edit this and enhance it (and put your name on it), please **STOP!** Recompile this document exactly as it is. This will force you to test your LaTeX setup. Unzip the collection, consider installing the class file as described below, then try to compile `thesis-ku`. That zipped collection has everything in the right places, don't re-arrange directories yet. Until you reproduce the PDF you are reading now, you are not ready to start making changes. People often come forward with questions and our first question for them is "did you compile (without error) `thesis-ku.tex`?" Until we hear those people say "yes", we are generally unable to help with their revised documents. That's the only way we will know if your LaTeX setup is ready to go.

If you have used \LaTeX , you will find this more or less self explanatory. There's a LaTeX file "`thesis-ku.tex`". It is a "master" document, it links together the content of several files. Compile that with `pdflatex`. The class file that makes this go, "`kuthesis.cls`", is saved in the current working directory. It is not necessary to install it into your broader LaTeX distribution, but you can if you like. One reason to install `kuthesis.cls` in your larger setup is to silence warnings from editors that don't remember to look in your current directory. If you install `kuthesis.cls` in your system, you don't need to keep a copy of it with your dissertation. That may be convenient.

If you have never used \LaTeX , we will tell you how to compile this document. But, before you try, can we give you a warning: *please don't make writing your dissertation your first \LaTeX project*. Start with some simpler example documents. Write some

letters to your loved ones, experiment a little bit. In the KU Center for Research Methods and Data Analysis, there are occasional workshops for people who want to get started with \LaTeX . There are many “how to get started with \LaTeX ” websites. Ours is <http://crmda.ku.edu/latex>.

If you have never used LaTeX before, a good way to start is with the editor named LyX. Instead of editing the “raw” LaTeX file `thesis-ku.tex`, use LyX to edit `thesis-ku.lyx`. There is a separate section below about using LyX.

Step 4. Customize This and Write a Dissertation.

This PDF document is produced from a source document. If you are using a \LaTeX editor like TexShop, Tex Works, or \TeX Studio, the source document you need to edit and compile is “`thesis-ku.tex`.” If you plan to use LyX, the place to start is by opening “`thesis-ku.lyx`” in LyX’s editor. This document was prepared with version 2.1 and, if you are using an older version, you should update.

The first user customization is to insert your name and the names of some committee members. The document has a top section called a “preamble.” (If using LyX, click the Document menu, then Settings, and look down). In the preamble, you will find the following block:

```
% Set the title and author info
\title{Please Read the Abstract}
\author{Abstract Writer}

\dept{Department of People who read Abstracts}
\degreetitle{Doctor of Philosophy}
\papertype{Dissertation} %or Thesis
%% It is vital to have 7 entries , so leave the empty
   place holders {} even
```

%% if some of the committee and role lines are to remain empty

```
\committee{MEMBER 1}{MEMBER 2}{MEMBER 3}{MEMBER 4}{The  
One with an Extra Long Name}{The Fifth Beatle}{}  
\role{Chairperson}{Occasional Visitor}{}{The One Who  
Never Answers Email}{}{}{}
```

Here you see the most important template updates for October, 2015. We have newly enhanced `\committee` and `\role` environments. Now, we allow users to specify up to 7 committee members and each one can have a different role. Why provide all of this luxury? There were unexpected requests from students. The original KU Thesis template had only “Chair” for the first member. Users asked for a secondary title “Co-Chair” for member 2. Then they wanted to change the title of the first member to “Lead Chair”. Then they wanted to add a the third Co-Chair, and so forth.

Now we accommodate those requests by leaving blank spots for up to seven committee members and seven roles. It is vital for you to leave the blank place holders `{ }` if you don’t want to list additional members or roles. This example document shows some funny titles, we do that only to prove it is possible. Generally, there is only a Chair, possibly a Co-Chair. This example has more roles in this example for fun. Or to make fun of a professor. You can change them to `{ }`, of course, if you don’t want a named role.

The other thing to change is the date section. Lower in the preamble, you should see a place to insert some dates. Originally, we told students “just write those dates in by hand, like we did back in the olden days.” But they kept saying they wanted them type set, so here they are. If a date is currently unknown, just leave a blank inside the brackets

```
\dateddefended{October 02, 2016}
```

`\dateapproved{October 06, 2016}`

After you make those changes in the preamble, compile the document.

How to Configure your LaTeX Distribution with kuthesis.cls

I wish we had packaged `kuthesis.cls` into an official LaTeX distribution package so that it could be easily installed by your distribution. We did not do that, however, and so it is up to you to place a copy of `kuthesis.cls` in the right spot. This is not truly necessary. Programs like `pdflatex` will find `kuthesis.cls` if you have it in the same directory as the document. I believe, with 97.5% confidence, it will find `kuthesis.cls` if you keep it in the same directory as your document. If you want to use `kuthesis.cls` for several documents, it is necessary to install “`kuthesis.cls`” into your LaTeX file structure. That is generally an easy process, but it is different on every type of computer. The CRMDA staff has recently prepared a guide for this, entitled “How Users can Install LaTeX packages without Help from System Administrators” (https://crmda.ku.edu/guide-32-latex_config). The gist of this is as follows:

1. Copy “`kuthesis.cls`” into a directory in your LaTeX distribution. Usually (almost always), you will find a directory component that ends in “`tex/latex`” and you can put `kuthesis.cls` in there. The only puzzle is finding the right place, and that’s why you should review our guide.
2. Run “`texhash`” or to make the LaTeX distribution take notice of your new file. On Mac and Linux systems, open a terminal and run “`sudo texhash`” to get this done as the administrator.

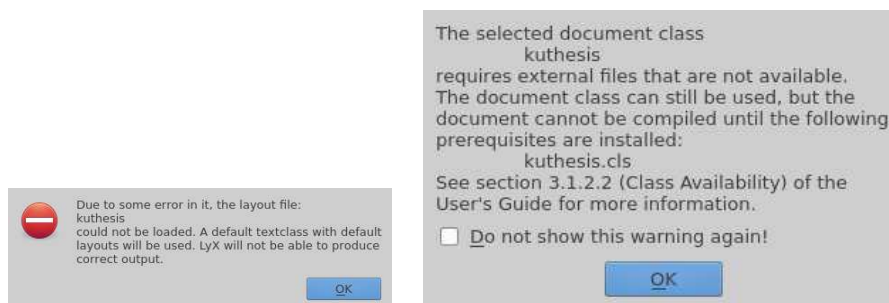
How to Get Started on this with LyX

This document with LyX! It will work. LyX is a pleasant-to-use editor, it can protect you from some of the details that ordinary LaTeX will present. LyX is free to use on all major computing platforms, including Linux, Macintosh, and Windows. LyX can be

downloaded at <http://www.lyx.org>. To make this work, LaTeX programs are also needed.

1. Mac users: install the “MacTeX” package (<https://www.tug.org/mactex>).
2. Linux users: install your distribution’s version of TeXLive or install the TeXLive files from the TeXLive website (<https://www.tug.org/texlive>) .
3. Windows Users: The LyX website offers 2 choices, a LyX-only package and an “installer bundle” that includes LyX along with a small subset of the MikTeX LaTeX distribution. This installs just a small subset of MikTeX and pieces can be separately downloaded when needed. In Fall, 2016, we had some difficulties during a LaTeX workshop because the MikTeX package server was unavailable. As a result, we have been migrating away from MikTeX (and the LyX installer bundle) to use TeXLive for Windows (<https://www.tug.org/texlive>). That’s a big 2GB package like MacTeX, after that we install the LyX program. If you choose the MikTeX setup instead, it will usually be fine, but users often complain that LyX seems to “freeze” when it downloads new MikTeX components.

If you install a LaTeX distribution and LyX, then you can open the file “thesis-ku.lyx”. At the very beginning, a couple of horrible warnings appear. These warnings look like this:



We will explain how to eliminate these warnings, but you can ignore them for the moment. Just click “OK” 5 or 6 times. After that, you will find that the dissertation document can be compiled (even though there were horrible scary warnings). To compile the document, either click on the “googly eyes” icon in the toolbar or

use the keyboard shortcut “Ctl-R”. If your system has a PDF viewer installed and LyX can find it, all will be well. We are warned by Windows 10 users that Microsoft has made the Web browser “Edge” the default PDF viewer and that does not work well with LyX. We recommend installing the PDF viewer Sumatra (<https://www.sumatrapdfreader.org/free-pdf-reader.html>) and then using the Windows configuration to set Sumatra as the default PDF viewer.

Why does LyX work? When the user asks LyX to preview the PDF output, a two step process happens behind the scenes. A file named “thesis-ku.tex” is created in a temporary directory, and then a program like `pdflatex` is asked to turn that into a PDF document. LyX will then send the PDF output to a PDF viewer, such as Yapp, Evince or Acrobat.

How to silence the LyX warnings.

1. Copy the LyX layout file “kuthesis.layout” into the layout folder of the user configuration.

The only problem is finding the correct user configuration folder.

On Linux, copy `kuthesis.layout` into the user HOME folder, under “.lyx/layouts”.

On Windows, there is a hidden AppData directory inside the user’s home folder. How to find it? Run LyX. A window should appear with a row of pull down menus at the top. Choose Tools/Preferences. Change something trivial, then close the menu. That will force LyX to create a user folder. Then search inside your user directory for a key word such as “lyxrc.defaults”. Probably, searching for “*lyx*” will be sufficient. In MS Windows 7, I found “C:\Users\pauljohn\AppData\Roaming\lyx212\la

Caution: The AppData folder is hidden/concealed and, in order to find it in Windows Explorer, it is necessary to change the folder options to NOT hide protected files and folders. Windows 10 is very similar.

On Macintosh OS X, we recently followed same “change a setting, then search”

procedure. The answer was “/Users/pauljohn/Library/Application Support/LyX-2.1/layouts”. Documentation for OS X El Capitan indicates that Apple has followed the Microsoft policy of hiding this folder, so the person who uses the Finder will have to change some preferences to show the directory.

2. Copy the LaTeX class file “kuthesis.cls” into the LaTeX distribution and then do the appropriate reconfiguration.

Again, if you have done this before, it is no big deal. If you have not done it before, it seems daunting. We described it in an earlier, under the heading **How to Configure your LaTeX Distribution with kuthesis.cls**.

3. Let LyX find your changes.

In LyX, find the pull down menu item Tools -> Reconfigure.

After that, LyX should work and not warn you about files it thinks it does not have. Once again, it is not necessary to do these reconfigurations, but LyX will not warn about missing pieces anymore.

We notice that LyX is not, by default, configured to do spell-checking as you type. This is a vestigial setting, a reflection of the days long ago when people knew how to spell. To turn on the spell checker, use the pull down menu Tools -> Preferences -> Language Settings -> Spellchecker. One must choose a program to serve as the “Spellchecker engine” and then click “Spellcheck Continously”. The Spellchecker engine I use in Ubuntu Linux is called Enchant. I expect you will find one in your operating system, or can find one. If not, we may have to ask Mr. Google for help.

Other friendly advice.

Compile Early, Compile Often

The truly bad part of using L^AT_EX is that the errors and warnings are, generally, not understandable. They are not understandable to me and I’ve been using L^AT_EX for

about 20 years. I mean, well, they are simply too abstract. Too complicated. If you insert an illegal character, such as an “_” in a \LaTeX box, the document will fail with this unhelpful message

```
Missing $ inserted .
```

```
Missing $ inserted .
```

```
Missing } inserted .
```

```
Extra }, or forgotten \endgroup .
```

```
...
```

```
I've inserted a begin-math/end-math symbol since I think  
you left one out. Proceed, with fingers crossed.
```

At best, the message will point to the line you inserted to cause the problem, but often the \LaTeX system cannot guess where your mistake is, it can only say something is wrong. The best way to defend yourself: ***Compile Early, Compile Often.*** Don't make a lot of changes without trying to compile. It is easy to insert a feature that breaks the document. Compile often so you know when things have gone wrong.

Use a Version Management System!

If this is an important project, please consider installing Git or some other version management program. It is difficult to avoid clutter if you have to rename your file every day. I see user directories full of files named, “my_diss.lyx”, “my_diss.2.lyx”, “my_diss_final.lyx”, “my_diss_rejected.lyx” and so forth. It is very difficult to keep old and new versions straight unless you use a version manager. A version manager will handle that for you. You will just have one file “my_diss.lyx” and you will have the ability to compare old and new snapshots. The CRMDA has a more-or-less comprehensive, yet easy to follow guide for Git, “Git it Together”.

I urge you to keep your \LaTeX document in Git so you can make frequent commits and it will be easy to step back in time. This is one reason why you should work on

separate chapters, so if you break something, then you are more likely to find your mistakes.

KU requires that fonts be compiled with the final result

The pdf_latex compiler will insert fonts when it compiles the document. However, there is a “gotcha”. If you create PDF documents separately, and you forget to embed the fonts with them, then the KU Graduate Dean’s office is likely to reject your thesis. When a PDF is included within this document, pdf_latex does not check to see if fonts are embedded in those PDFs. It assumes they are as you want them; fonts for those included files are not automatically inserted by pdf_latex. When a graph, for example, is created in R and exported to PDF, it will not include the font encodings by default. It is possible to add those encodings. Little details like this come up from time to time and we make note of them in <https://crmda.ku.edu/latex-help>.

If you need help, ask, but please understand

I don’t have as much time as I would like to help users. I want you to use L^AT_EX. I think doing anything else is finger painting. I’ve watched 20 MA and PhD theses written with this template and I know a bright student will succeed and be happy with the result. If you have a laptop computer and you want to show me some errors, I can give you 5 or 10 minutes. But not much more...

CRMDA offers some workshops and I teach graduate courses in which we show how to use L^AT_EX. If you find something wrong with kuthesis.cls, I will be glad to try to fix it.

I don’t have time/ability to answer a million email questions about L^AT_EX or L^yX. If you are stuck on a tough problem, I may be able to help, but if I have to exert myself, you should know I expect you to give me a t-shirt and/or add me to the acknowledgements in your dissertation.

Paul Johnson <pauljohn@ku.edu>

Prof. Political Science & Director, Center for Research Methods and Data Analysis

2017-03-30

And that's the end of the abstract.

Acknowledgements

I would like to thank all of the little people who made this thesis possible. Sleepy, Dopey, Grumpy, you know who you are.

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Chapter 1

Ordinal Outcomes Regression

1.1 Introduction

This is my best effort to succinctly explain the theory behind the ordinal logistic regression model (with apologies to the probit model).

The main takeaway point is supposed to be this:

The same data leads to different estimates from different programs. That happens because the ordinal model can be written down in several different ways. None of them are wrong, but they are different, and as a result the user must be cautious.

Estimates obtained from four different programs are offered in Table 1.1. If we line these up side by side, we see that estimates from one of the routines for R matches Stata (after chopping off the small differences in the decimals), while SAS appears to provide the “wrong sign” for the first row and the second procedure for R seems to provide the “wrong signs” for the second and third rows. None of these are actually wrong, they are all correct *given the model they specified*. This the point at which the student may be tempted to give up. Please don’t. I’ve worked very hard to clear this up in the following sections.

Table 1.1: Ordinal Regression Results

| | R: polr | R: lrm | SAS | Stata |
|---------------|---------|--------|-------|-------|
| \hat{b}_1 | -0.28 | -0.28 | 0.28 | -0.28 |
| $\hat{\xi}_1$ | -4.24 | 4.24 | -4.24 | -4.24 |
| $\hat{\xi}_2$ | -2.32 | 2.32 | -2.32 | -2.32 |

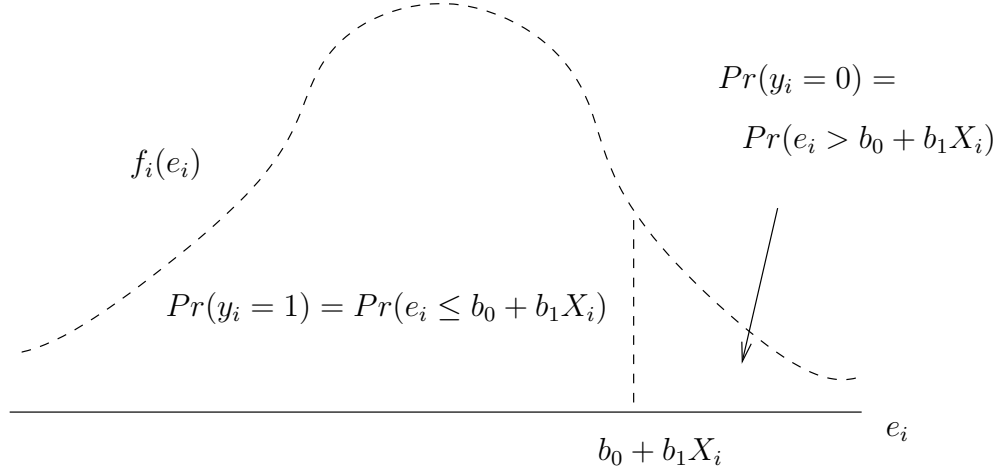


Figure 1.1: Dichotomous Outcome Variable

1.2 Extending the Logit Model to deal with Ordinal Dependent Variables

The easiest way to understand regression with ordinal dependent variables is to extend the “cumulative probability interpretation” of the two category model (Pinheiro & Bates, 2000).

In the two category model, y_i is 1 with probability

$$F(b_0 + b_1 X_i) = \int_{-\infty}^{b_0 + b_1 X_i} f(e_i) de_i \quad (1.1)$$

And, of course, the probability that y_i is 0 will be $1 - F(b_0 + b_1 X_i)$. The formula F is a “cumulative distribution function” (CDF), it represents the probability that a random variable e_i will be as small or smaller than $b_0 + b_1 X_i$. The function f is a “probability density function” (PDF), which represents the probability that e_i is equal to some particular value. This is illustrated in Figure 1.1. The “probability density function” f is defined from left to right and the possible outcomes are divided into two sets by the line drawn at $e_i = b_0 + b_1 X_i$. The area under the curve on the left side is the probability of getting a “yes” (or 1). The area on the right is the chance of a “no” (0).

Suppose y_i can have 3 values, 0, 1, and 2. (Keep in mind that this model can be written down in several ways. We tackle my favorite first, and then consider the others.) Leave the predictive part of the model ($b_0 + b_1 X_i$) the same, but we now introduce two new positive constants (Π_0 and Π_1) that divide the space. Considering Figure 1.2, it should be easy to see why some people call

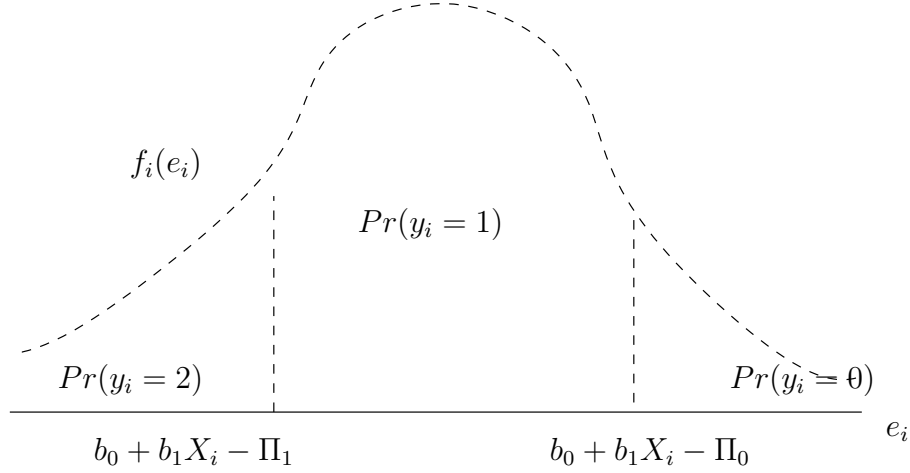


Figure 1.2: Ordinal Logit

these new parameters “thresholds”.

To summarize the effect of these new thresholds, we write down 1 equation for each possible outcome. My tendency is to write the thresholds as positive values like so:

$$y_i = \begin{cases} 2 & \text{if } b_0 + b_1 X_i - e_i \geq \Pi_1 \\ 1 & \text{if } \Pi_0 \leq b_0 + b_1 X_i - e_i < \Pi_1 \\ 0 & \text{if } b_0 + b_1 X_i - e_i < \Pi_0 \end{cases} \quad (1.2)$$

Note we don’t really need 3 equations. If we have two, say $Pr(y_i = 0)$ and $Pr(y_i = 1)$, then the chance of ending up in the other category is $1 - Pr(y_i = 0) - Pr(y_i = 1)$.

In order to translate this into a model involving the cumulative probability distribution, rearrange so that the random variable e_i is by itself.

$$y_i = \begin{cases} 2 & \text{if } e_i \leq b_0 + b_1 X_i - \Pi_1 \\ 1 & \text{if } b_0 + b_1 X_i - \Pi_1 < e_i \leq b_0 + b_1 X_i - \Pi_0 \\ 0 & \text{if } b_0 + b_1 X_i - \Pi_0 < e_i \end{cases} \quad (1.3)$$

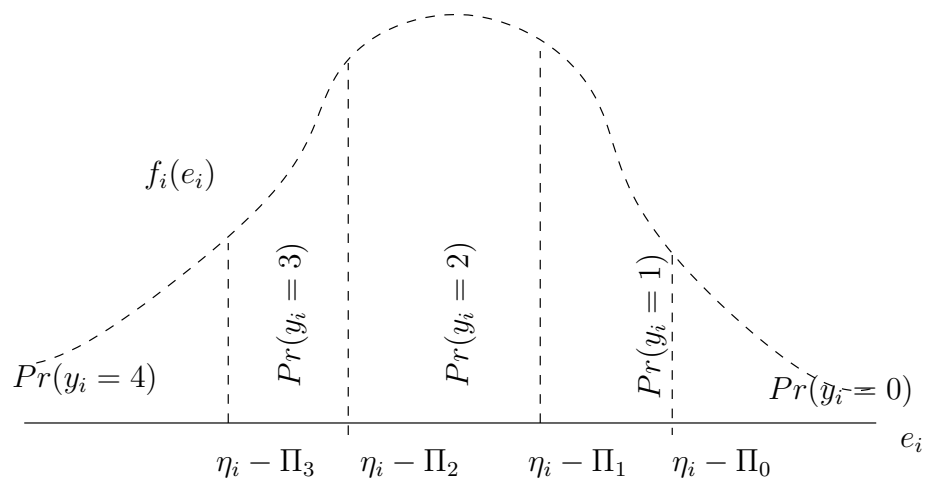
As in the dichotomous case, the probabilities of the various outcomes are calculated by use of cumulative probability. Rearrange 1.2 to convert these into probabilities of the individual outcomes.

$$\begin{aligned}
Pr(y_i = 2) &= Pr(e_i \leq b_0 + b_1 X_i - \Pi_1) &= F(b_0 + b_1 X_i - \Pi_1) \\
Pr(y_i = 1) &= Pr(b_0 + b_1 X_i - \Pi_1 \leq e_i < b_0 + b_1 X_i - \Pi_0) \\
&= 1 - F(b_0 + b_1 X_i - \Pi_0) - F(b_0 + b_1 X_i - \Pi_1) \\
Pr(y_i = 0) &= Pr(b_0 + b_1 X_i - \Pi_0 < e_i) &= 1 - F(b_0 + b_1 X_i - \Pi_0)
\end{aligned} \tag{1.4}$$

Note that any one category can be thought of as a “residual” category after the others have been assigned their shares. The middle category, $y_i = 1$, is left over if we “chop off” the outcomes on the left ($y_i = 2$) and the right ($y_i = 0$). We are left with the chance of ending up in the middle. In that sense, the probability of landing in the middle is equal to 1.0 minus the chance of a very small amount of random noise ($e_i \leq b_0 + b_1 X_i - \Pi_1$) and minus the chance of having a very large random noise ($b_0 + b_1 X_i - \Pi_0 < e_i$). Similarly, the chances of being in the top category equal 1 minus the chance of ending up in the lower categories.

Any probability distribution can be used for the random error e_i , the two most common being Logistic and Normal. If the Normal is chosen, it is customary to call this a “probit” model and the symbol for the cumulative distribution is usually $\Phi()$.

What if your dependent variable have more categories? Add more thresholds! See the example in Figure 1.3.



$$\eta_i = b_0 + b_1 X_i$$

Figure 1.3: Ordinal Model with More Categories

Chapter 2

Elementary Regression

2.1 Example

Here's what I would do to begin a regression exercise. I'm using the dataset "Prestige" that is in the car package for R.

```
library(car)

pdf(file="car.inc.ed.pdf", height=5,width=5, onefile=F,
    paper="special")
plot(income~education, xlab="Education", ylab="Income", main="",
    data=Prestige)
dev.off()
```

That plot is presented in the top panel in Figure 2.1.

A regression model Gelman et al. (2003) can be fitted to that scatterplot with R's `lm` function.

```
mymod <- lm(income~education, data=Prestige)
```

`mymod` is an "object", a complicated structure that contains a great deal of information. Observe:

```
attributes(mymod)
$names
[1] "coefficients" "residuals"    "effects"      "rank"
[5] "fitted.values" "assign"        "qr"           "df.residual"
[9] "xlevels"      "call"         "terms"        "model"
```



```
$class
```

```
[1] "lm"
```

We can access values from mymod by 2 methods.

1. Direct access

```
> mymod$coefficients
> mymod$coefficients
(Intercept)    education
-2853.5856      898.8128
```

2. Or by “accessor” methods.

```
> coef(mymod)
(Intercept)    education
-2853.5856      898.8128
```

Some values are needed so regularly that a “summary” method is written to gather and summarize them.

```
> summary(mymod)
```

Call:

```
lm(formula = income ~ education, data = Prestige)
```

Residuals:

| | Min | 1Q | Median | 3Q | Max |
|--|----------|----------|--------|---------|----------|
| | -5493.20 | -2433.80 | -41.92 | 1491.50 | 17713.14 |

Coefficients:

| | Estimate | Std. Error | t value | Pr(> t) |
|-------------|----------|------------|---------|--------------|
| (Intercept) | -2853.6 | 1407.0 | -2.028 | 0.0452 * |
| education | 898.8 | 127.0 | 7.075 | 2.08e-10 *** |

Table 2.1: My Regression Table

| | |
|----------------|----------------|
| (Intercept) | −2853.586* |
| | (1407.039) |
| education | 898.813*** |
| | (127.035) |
| R-squared | 0.334 |
| adj. R-squared | 0.327 |
| sigma | 3483.378 |
| F | 50.060 |
| p | 0.000 |
| Log-likelihood | −975.609 |
| Deviance | 1213392025.001 |
| AIC | 1957.218 |
| BIC | 1965.093 |
| N | 102 |

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

Residual standard error: 3483 on 100 degrees of freedom

Multiple R-squared: 0.3336, Adjusted R-squared: 0.3269

F-statistic: 50.06 on 1 and 100 DF, p-value: 2.079e−10

There are some functions to make more beautiful tables that are closer to the needs of journals. Years ago, I wrote a function called “outreg” and it would make a nice looking table. You can use that if you want, but if I were you, I would use the regression tables from either of these packages for R: “memisc” or “apsrtable”. Since I already have memisc installed, I will demonstrate that:

```
> library(memisc)
> toLatex(mtable(mymod))
```

The \LaTeX code can be pasted into a document in the same way that we handled cross tabulation tables. Please see Table 2.1

Observe:

The function “predict” can be used to obtain predicted values for example values of the input. One specifies a “newdata” option which must be a data frame, but we can create the new dataframe “on the fly” without too much trouble.

```
> predict(mymod, newdata=data.frame(education=c(8,9,10,11,12)))
      1      2      3      4      5
4336.917 5235.730 6134.543 7033.356 7932.169
```

Sometimes we want to plot the predictive line in the model, and that can be done in a variety of ways. One way is to find some points and then use them with the lines function.

```
> range(Prestige$education)
[1]  6.38 15.97
> predict(mymod,
  newdata=data.frame(education=range(Prestige$education)))
      1      2
2880.840 11500.456
> X1 <- range(Prestige$education)
> Y1 <- predict(mymod,
  newdata=data.frame(education=range(Prestige$education)))
> lines(X1,Y1)
```

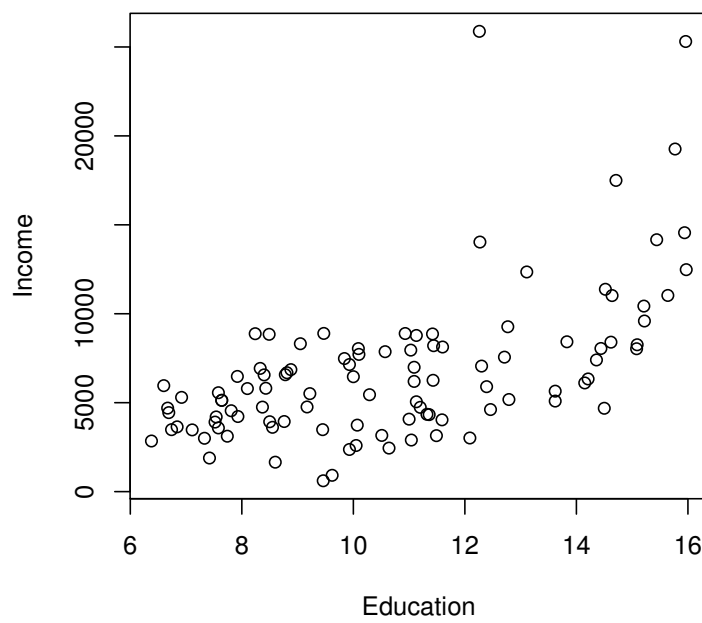
That adds a line to the figure, as seen in the bottom panel.

Because it is very common to add a regression line to a plot, the R function `abline` has been customized to do this for us automatically if you give it a regression object. The following commands were the ones I actually used to produce the figure.

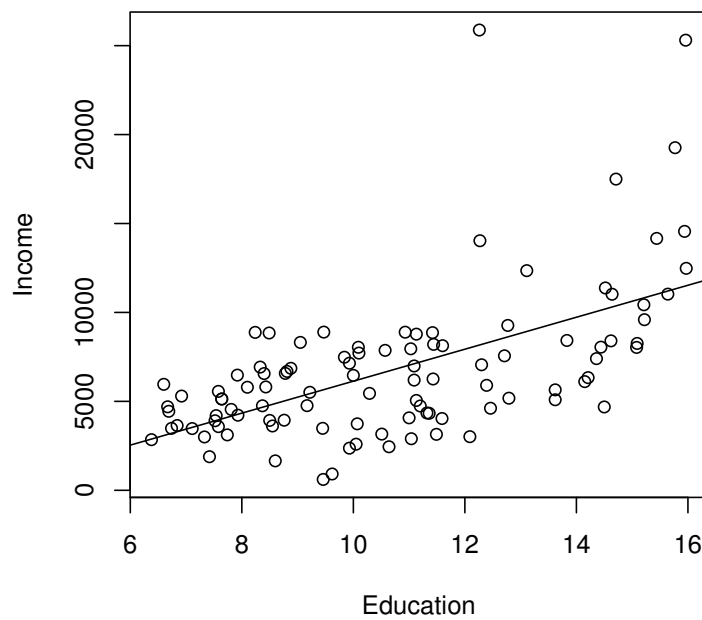
```
pdf(file="car.inc.ed-fit.pdf" height=5, width=5, onefile=F,
  paper="special")
plot(income~education, xlab="Education", ylab="Income",
  main="", data=Prestige)
abline(mymod)
dev.off()
```

I went to the trouble of illustrating the “old fashioned” way because I think it is possible to become

too dependent on simplifying functions, especially when they don't do exactly what you want.



(a) A Scatterplot



(b) Add the “regression line”

Figure 2.1: Income Depends on Education

References

Gelman, A., Carlin, J. B., Stern, H. S., & Rubin, D. B. (2003). *Bayesian Data Analysis, Second Edition*. Chapman & Hall, 2 edition.

Pinheiro, J. C. & Bates, D. M. (2000). *Mixed-effects models in S and S-PLUS*. Springer.

Appendix A

My Appendix, Next to my Spleen

There could be lots of stuff here