Please Read the Abstract

Abstract Writer

B.A. Philosophy, Harvard, 1999

M.A. English, Oxford 2000

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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.

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Member Name 1, Chairperson

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Member 5 has a long name

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Date defended: July 02, 2019

The Dissertation Committee for Abstract Writer certifies
that this is the approved version of the following dissertation :

Please Read the Abstract

Member Name 1, Chairperson

Date approved: August 06, 2019

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-20190201.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 LaTeX 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 2019 revision template. The only major change this time is the introduction of a new environment, “chapterabstract”. This was a frequently requested feature. Before that, the other major changes in “`kuthesis.cls`” concerned the display of a student’s previous degrees and the members of the thesis committee. The class file 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

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

reduced (from the LaTeX \Huge to \Large). The “prior credits” enhancement was prepared by Amber Roberts-Graham of the KU Office of the Graduate Dean. This allows the inclusion of previously obtained degrees on the title page.

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.

Step 2. Inspect the LaTeX source code.

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.

In 2017, we included 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 be allowed in submitted documents. 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. Colors can be revised in the hyperref options. Look for “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 edit this (and put your name on it), please **STOP**! Recompile this document exactly as it is. This will test your LaTeX setup. 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.

Windows & Mac users: it is *necessary to extract* the project folder. Do not use the file manager's "zip preview" feature. Extract the files, or else nothing at all will work.

When you extract the folder, do not rearrange or rename files yet. Don't change chapter directories. All of these things work together. Test our setup before altering it.

The file `kuthesis.cls` is the class file. The document should compile if that file is in the same directory as the document `thesis-ku`. However, there may be warnings from your LaTeX editor that "`kuthesis.cls`" is not available because it is not "installed" into your LaTeX distribution. For testing, ignore the warning. For the long term, consider installing `kuthesis.cls`.

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.

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. LyX will warn you when you open `thesis-ku.lyx` `because the cls file seems unavailable. Don't worry about that.`

Step 4. Revise thesis-ku: Write a Dissertation.

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. LyX versions change over time. We are using LyX-2.2.3 at the moment.

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}
% Following is OPTIONAL list of previous degrees earned.
% If there are more than 5 or so, then title pagelayout
% may become too crowded,
% depending on the number of committee members.
\priorcreds{B.A. Philosophy, Harvard, 1999}{M.A. English, Oxford
    2000}{M.A. History, Johnson County Community College, 2005}
% It is acceptable to delete \priorcreds if it is not desired
% on title page
\dept{Department of People who read Abstracts}
\degreetitle{Doctor of Philosophy}
\papertype{Dissertation}%or Thesis
% (Choose whatever word you want to put on p.2)
% Committee member names are required for the title page.
% We make space for as many as 7 members, with various
% roles/titles.
% It is required to have 7 entries, even if some are empty
% for committee and role
\committee{Member Name 1}{Member Name 2}{Member Name 3}{Member Name
    4}{Member 5 has a long name}{Member 6}{}
\role{Chairperson}{Co–Chair}{}{The One Who Never Answers
    Email}{}{External Reviewer}{}
```

Here you see the most important template updates for October, 2015. We have enhanced `\committee` and `\role` environments. We allow as many as 7 committee members and each one can have a different role. Why provide all of this luxury? There were unexpected requests from students. 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 {}. 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.

The other thing to change is the date section. Lower in the preamble, you should see a place to insert some dates. Fix the dates:

```
%BOTH dates must be included.
\@printd@testrue
\datedefended{July 02, 2019}
\dateapproved{August 06, 2019}
```

Originally, we told students “just write those dates in by hand, like we did back in the olden days.” That was incorrect, they need to be typeset into the document.

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. If you want to use kuthesis.cls for several documents, the best approach is 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

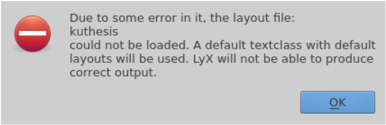
This document with LyX! It will work. LyX is a pleasant-to-use editor, it can protect you from some of the details that ordinary LaTeX will present. LyX is free to use on all major computing platforms, including Linux, Macintosh, and Windows. LyX can be downloaded at `http://www.lyx.org`. To make this work, LaTeX programs are also needed.

1. Mac users: install the "MacTeX" package (`https://www.tug.org/mactex`).

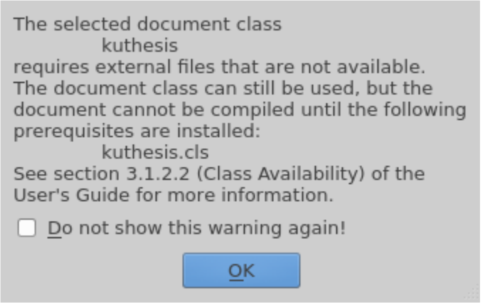
2. Linux users: install your distribution's version of TeXLive or install the TeXLive files from the TeXLive website (`https://www.tug.org/texlive`) .

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". Warnings–*not errors*–appear.



Due to some error in it, the layout file:
kuthesis
could not be loaded. A default textclass with default layouts will be used. LyX will not be able to produce correct output.



The selected document class
kuthesis
requires external files that are not available.
The document class can still be used, but the document cannot be compiled until the following prerequisites are installed:
kuthesis.cls
See section 3.1.2.2 (Class Availability) of the User's Guide for more information.

□ Do not show this warning again!

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 **`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. See previous subsection “How to Configure your LaTeX Distribution with kuthesis.cls” Do that!

2. Set a LyX layout file in your use LyX configuration.

In essence, copy our file “`stylefiles/kuthesis.layout`” into the user configuration.

Finding the correct user configuration folder is the hard part.

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 the LyX settings were saved in

```
C:\Users\pauljohn\AppData\Roaming\lyx212\layouts
```

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.

On Macintosh OS X, we recently followed the same "change a setting, then search" procedure. The answer was "/Users/pauljohn/Library/Application Support/LyX-2.1/layouts". Documentation for OS X 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.

3. Let LyX find your changes.

In LyX, find the pull down menu item Tools -> Reconfigure. Then close LyX and restart.

4. Spell checking

We notice that LyX is not, by default, configured to do spell-checking as you type. 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 Continuously". 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 LaTeX is that the errors and warnings are, generally, not understandable. They are not understandable to me and I've been using LaTeX 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" (`http://crmda.ku.edu/git-help`).

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 pdflatex compiler will insert fonts when it compiles the document. However, there is a "gotcha". If you create illustrations (say, with R or Matlab) or sub-documents separately in PDF, 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, `pdflatex` 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 pdflatex. 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 LaTeX. 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 LaTeX. 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 LaTeX or LyX. 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 acknowledgments in your dissertation. (I'm not joking on that.) I spent about 20 hours helping a KUMC student fix his LaTeX and he assured me I'll get a big discount on treatment for any liver illnesses I may endure in the future. (I'm joking about that.) I did get a medical center license plate holder, though.

Paul Johnson <pauljohn@ku.edu>

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

2019-02-01

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.

Contents

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Chapter 1

Ordinal Outcomes Regression

Abstract

On January 19, 2019, the environment "chapterabstract" was introduced. This was a frequent request from science-department users, whose advisors wanted the chapters to be more-or-less directly imported from published article markup.

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
$\hat{\zeta}_1$	-4.24	4.24	-4.24	-4.24
$\hat{\zeta}_2$	-2.32	2.32	-2.32	-2.32

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 (**?**).

In the two category model, y_i is 1 with probability

$$F(b_0 + b_1 X_i) = \int_{-\infty}^{b_0+b_1X_i} f(e_i)de_i \tag{1.1}$$

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 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:

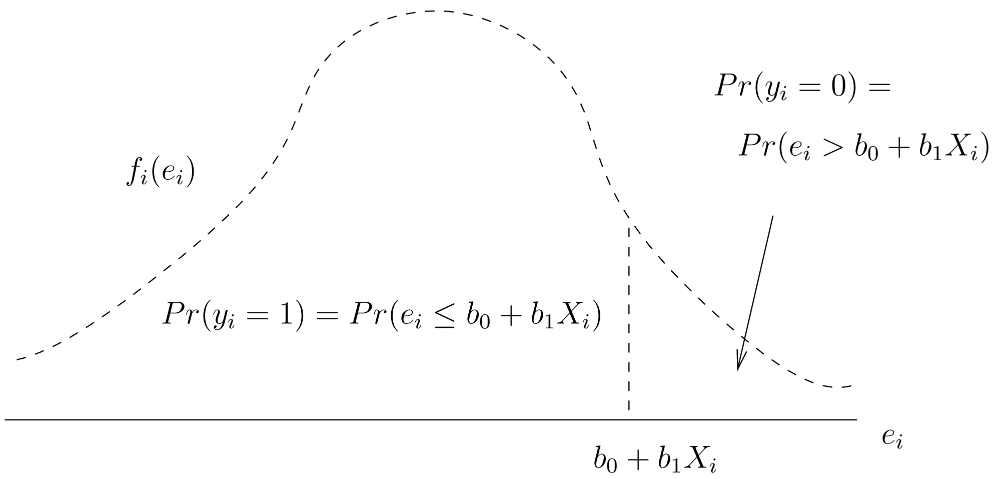


Figure 1.1: Dichotomous Outcome Variable

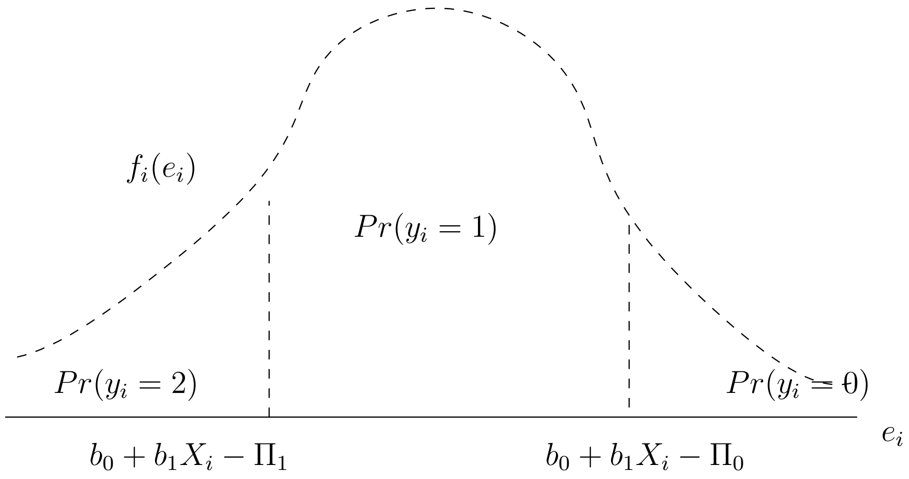


Figure 1.2: Ordinal Logit

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

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.

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

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.

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

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

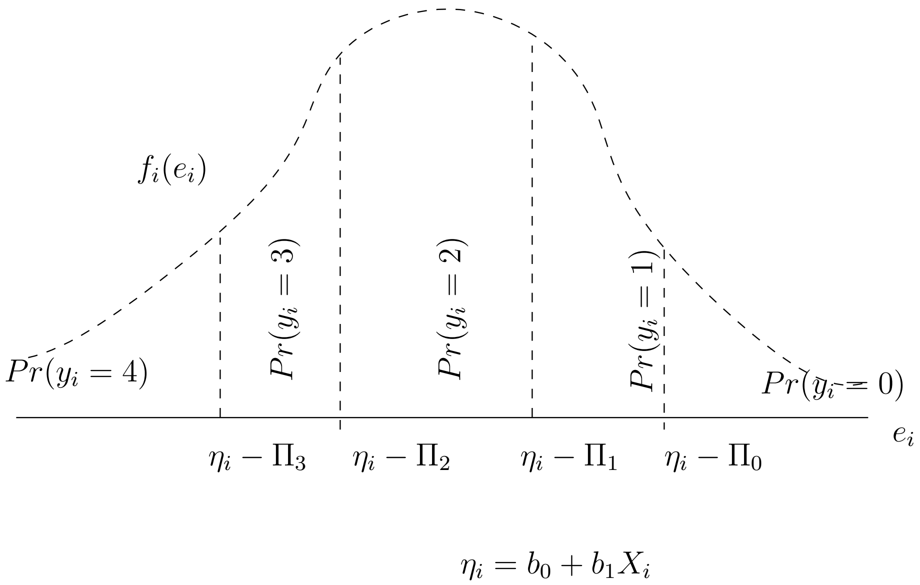


Figure 1.3: Ordinal Model with More Categories

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.

Chapter 2

Elementary Regression

Abstract

Use the chapterabstract environment, not the abstract environment, if you want to plant an abstract here at the top of this chapter.

2.0.1 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 **?**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 ***
---
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.

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

```
> 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)
```

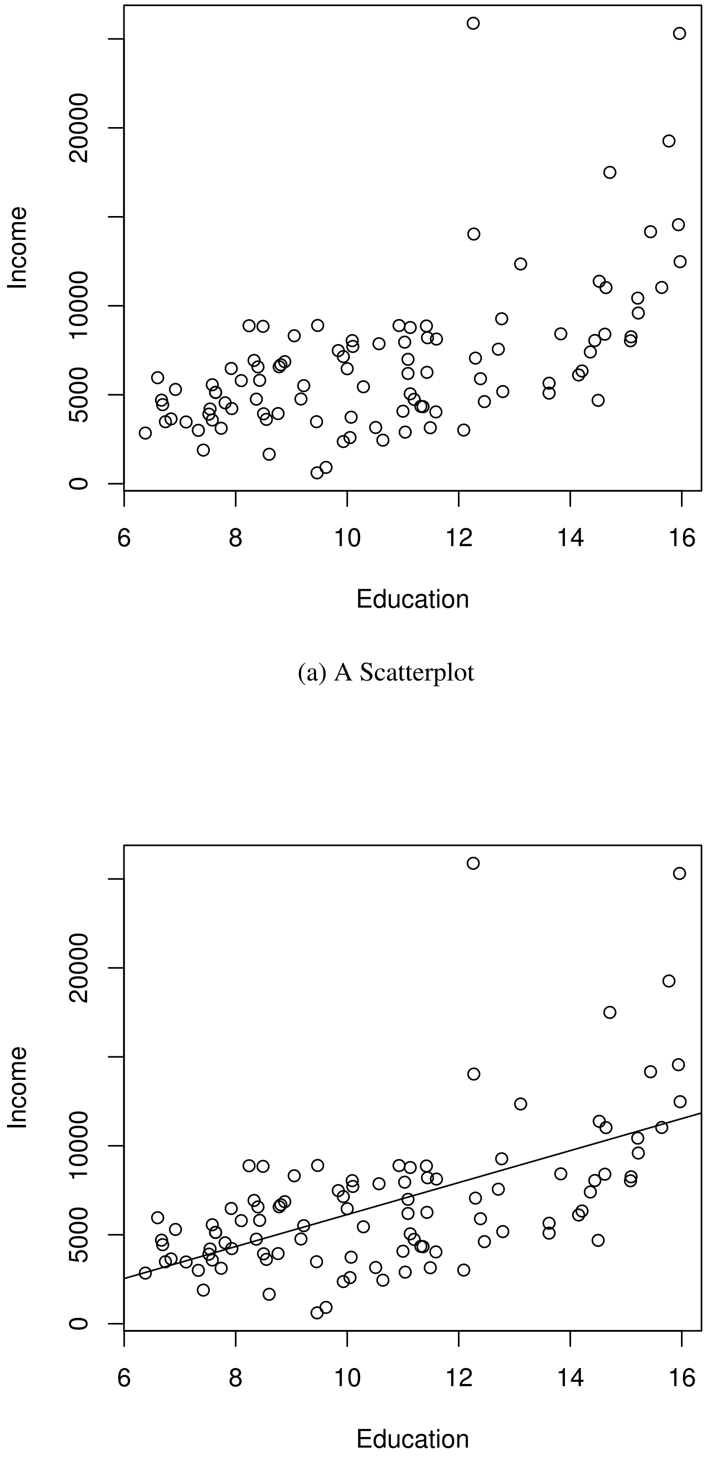
That adds a line to the figure, as seen in the bottom panel.

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