Advanced Regression: Nonlinear, Nonparametric, and Robustness Analyses Syllabus - Summer 2024

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1 Overview and Course Objectives

The Regression III course takes a considerably different form than the first two regression courses at the Summer Program. This course will hopefully prepare you for the things you will encounter when you publish quantitative work with linear models. Initial linear model classes focus on the assumptions and theoretical considerations of linear models and generally walk you through estimation and interpretation. Good courses also deal with diagnostics, though these often get less time than they should. Further, it is not always obvious what violations of these assumptions will lead to in practical terms. This course will provide you with a systematic approach to assessing, fixing and presenting your linear model results. Though we focus almost exclusively on the linear model (we will allude to nonlinear models occasionally), the logic we follow will be helpful in dealing with nonlinear models as well.

2 Requirements

This course is a practical, data-analytic extension of what you learned in your department's linear models class or the Regression II class at the ICPSR Summer Program. As such, I assume you are familiar with the types of things taught in these courses - Gauss-Markov assumptions, properties of OLS estimators, and statistical inference for linear model coefficients. While I assume this knowledge exists, we will spend review these ideas briefly in class where necessary. If you are not sure where you belong in the series of linear models courses at the Summer Program, please see me or the Summer

Program director and we will make sure you end up the most appropriate class.

In the past, I experimented with allowing participants to use either Stata or R and found, from student evaluations, and from both R and Stata users that the support for both pieces of software was both distracting and unnecessary. Stata users found that it was reasonably easy to pick up R for the purposes of the course. Further, Some of the specific software used in the course does not exist (or exist in the same useful way) in Stata. I found that the implementation in Stata often required some programming (loops, macros, etc...) and that was a threshold many participants did not want to cross. Thus, R will be the only officially supported software. If you want to use this course as an opportunity to strengthen your R skills, but have little familiarity with that software, you should take the R workshop taught in the first few weeks of the first session.

If you're one of those "glutton-for-punishment" types, you may also find it useful to learn LaTeX. LaTeXis a system for typesetting documents. People find it most useful for typesetting documents that are heavy on mathematical notation, but this is just the tip of the iceberg. LaTeXhas its own bibliographic software (BibTeX) and will automatically build (and re-build) tables of contents, lists of figures and lists of tables. It also automatically numbers (and re-numbers when necessary) tables, figures and equations, changing appropriately formed references to those objects when table, figure or equation numbers change. Best of all, common LaTeXtypesetting engines are free (see `http://www.latex-project.org/ftp.html` for links to the software appropriate for your OS). There is a LaTeXworkshop on the first Monday night of the Summer Program. I still write some papers in LaTeXand am glad that I got to know how it works, but am transitioning much of my writing and all of my slides to RMarkdown.

3 Course Text(s)

No one text effectively presents all of the material that will be covered in this course. That said, much of the material is covered (and covered well) in:

Fox, John. (2015) Applied Regression Analysis and Generalized Linear Models. *3rd ed.* Thousand Oaks, CA: Sage Publications, Inc.

Fox, John and Sanford Weisberg. (2018) An R Companion to Applied Regression. *3rd ed.* Thousand Oaks, CA: Sage Publications, Inc.

James, Gareth, Daniela Witten, Trevor Hastie and Robert Tibshirani. (2013) An Introduction to Statistical Learning with Application in R. New York: Springer. Available for free here.

The R Companion is a great book for those currently learning R. I would highly recom-

mend getting the recently updated and expanded second edition. This is widely recognized as one of the best ways for Social Scientists to get into R.

We will also use a number of other books and articles to deal with more specialized issues. These are listed below (along with the appropriate chapters/pages) for the classes in which we use them.

4 Software

One of R's main virtues from the grad-student point of view is that the base package and all of the add-ons (called packages in R) are free. You can download the base package of R from the Comprehensive R Archive Network (CRAN) website `http://www.cran.r-project.org`. As of this writing, the most recent version is 4.2.3. R is updated a couple of times per year so you'll have to look back here periodically for updates. We will be using a number of user-contributed packages that we will discuss as they become relevant.

4.1 Related Software

A good text editor is invaluable when using R and LaTeX. TeXWorks is a good, free editor for LaTeXthat works in most environments, including Windows and Mac(`http://www.tug.org/texworks/`). RStudio is a free IDE (Integrated Development Environment) for R that includes a nicely-featured text editor (`http://www.rstudio.org/`). If you're looking for a general purpose text editor, I often use Microsoft's VS Code (`https://code.visualstudio.com`), though there are other great options, too like Atom or SublimeText.

5 Course Schedule

Each entry represents a single topic. Readings are designated either as suggested (∗) or supplemental (−). For most of you, this is not the only class you are taking and as the weeks fly by, your time will undoubtedly be too limited to read everything indicated in the syllabus. However, this should serve as a nice reference to which you can return if the intricacies of a particular topic have faded from your memory.

1. Effective Model Presentation I (Tuesday, June 18)

   (a) Introductions and Preliminary Material.

   (b) Factors and contrasts; quasi-variances and graphical displays

   (c) Standardization and relative importance

   Readings:
   ∗ Armstrong II (2013)
   ∗ Armstrong II (2013)
   ∗ Silber, Rosenbaum and Ross (1995)

2. Effective Model Presentation II (Wednesday, June 19)

   (a) Interactions and effect displays

   Readings:
   ∗ Berry, Golder and Milton (2012)
   − Kam and Franzese (2007)

3. Linearity Diagnostics Monotonicity Constraints (Thursday, June 20)

   (a) Linearity and ordinal variables

   (b) Alternating Least Squares Optimal Scaling (ALSOS)

   (c) Montonicity Constraints

   (d) Diagnosing linearity through residual plots

   Readings:
   ∗ Fox (2015) Chapters 4 & 12 (Sections 12.3-12.5)
   ∗ Jacoby (1999)
   − Box and Tidwell (1962)

4. Modeling Non-linear Relationships (Friday, June 21)

   (a) Fixing non-linearity with data transformations and polynomials

   (b) Regression Splines

   (c) Inference for regression smoothers

   Readings:
   ∗ Fox (2015) Chapters 4 & 12 (Sections 12.3-12.5)
   ∗ Fox and Weisberg (2011) Chapter 3
   ∗ Fox (2015) Chapters 17 & 18
   ∗ James et al. (2013) Chapter 7
   – Keele (2008) Chapters 2-6

5. Resampling: Bootstrapping, Jackknifing and Cross-validation (Monday, June 24)

   (a) Bootstrapping and Jackknifing

   (b) Cross-validation

   Readings:
   ∗ James et al. (2013) Chapter 5
   ∗ Fox (2015) Chapter 21
   ∗ James et al. (2013) Chapter 6
   – Davison and Hinkley (1997)
   – Stone (1974)
   – Efron and Tibshirani (1993)

6. Model Selection (Tuesday, June 25)

   (a) Theoretical issues in model searching and post-data model construction

   (b) Model selection criteria and multi-model inference.

   (c) Subset selection models

   (d) Regularization: LASSO, Ridge Regression, Elastic Net

   Readings:
   ∗ Fox (2015) Chapter 22
   ∗ Burnham and Anderson (2004)
   – Leamer and Leonard (1983)
   – Leamer (1983)
   – Box (1976), Box and Hunter (1962)

7. Generalized Additive Models for Location, Scale and Shape (Wednesday, June 26)

   (a) GAMLSS framework.

   (b) Modeling higher moments.

   (c) Regression diagnostics in GAMLSS

   ∗ Stasinopoulos and Rigby (2007)
   – Stasinopoulos et al. (2017)
   – Rigby et al. (2020)

8. Smoothing Splines (Thursday, June 27)

   (a) Smoothing Splines

   (b) Smoothers in Generalized Additive Models

   Readings:
   ∗ Fox (2015) Chapters 18
   ∗ James et al. (2013) Chapter 7
   – Harezlak, Ruppert and Wand (2018) Chapters 2 and 3
   – Ruppert, Wand and Carroll (2003) Chapters 3, 5, 6 & 8

9. Comparing GAMLSS Diagnostics/Fixes to Conventional Diagnostics/Fixes (Friday, June 28)

   (a) Heteroskedasticity

   (b) Outliers and Influence

   (c) Non-linear GLMs

   ∗ Fox (2015) Chapters 12 & 13
   ∗ Fox and Weisberg (2011) Chapters 3 & 6
   – King and Roberts (2015)
   – Long and Ervin (2000)
   – Harvey (1976)
   – Cribari-Neto (2004), Cribari-Neto, Souza and Vasconcellos (2007), Cribari-Neto and da Silva (2011)

10. Flexible Models: Tree-based Regression, Multivariate Adaptive Regression Splines (Monday, July 1)

    - Fundamentals of flexible models
    - Automatic variable selection
    - Inference and effects in statistical learning models
    - When (and when not) to use these kinds of models

    ∗ Montgomery and Olivella (2018)
    ∗ James et al. (2013) Chapter 7
    ∗ Berk (2016) Section 3.14

11. Missing Data and Multiple Imputation (Tuesday, July 2)

    (a) What's the problem with missing data?
    (b) When can we fix it?
    (c) How do we impute the data and use those imputations?

    Readings:
    ∗ Fox (2015) Chapter 20
    ∗ van Buuren and Groothuis-Oudshoorn (2011) ∗ Honaker and King (2010)
    ∗ Cranmer and Gill (2013)
    ∗ Akande, Li and Reiter (forthcoming)
    ∗ Xia and Yang (2016)
    ∗ Resseguier, Giorgi and Paoletti (2011)
    – Schafer (1997)
    – Rubin (1987)

12. Finite Mixture Models (Wednesday, July 3)

    Readings:
    ∗ Imai and Tingley (2012)
    ∗ Grün and Leisch (2008)
    ∗ Grün and Leisch (2007)

13. Mixtures and Missing Data in GAMLSS (Thursday, July 4)

    (a) What's the problem with missing data?

    (b) When can we fix it?

    (c) How do we impute the data and use those imputations?

    Readings:
    ∗ Fox (2015) Chapter 20
    ∗ van Buuren and Groothuis-Oudshoorn (2011) ∗ Honaker and King (2010)
    ∗ Cranmer and Gill (2013)
    ∗ Akande, Li and Reiter (forthcoming)
    ∗ Xia and Yang (2016)
    ∗ Resseguier, Giorgi and Paoletti (2011)
    – Schafer (1997)
    – Rubin (1987)

14. Wrap-up (Friday, July 5)

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