INTRODUCTION TO STATISTICS AND DATA ANALYSIS II
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Introduction

This course is intended for social scientists who are comfortable with algebra and introductory statistics, and now want to learn introductory applied ordinary least squares (OLS) bivariate and multiple regression analysis for their own research and/or to understand the work of others.

As social scientists, it is important that we know how to use regression. But it is also important for us to know why and how multiple regression works (and fails) under varying conditions. Given this, we will discuss much of the mathematical and statistical theory behind multiple regression and also some potential drawbacks and circumstantial limitations. So while the presentations will not be purely theoretical, neither will this course be “cookbook” in nature.

The primary goal of the course is to develop an applied and intuitive (as opposed to purely theoretical or mathematical) understanding of the topics. Whenever possible presentations will be in “Words,” “Picture,” and “Math” languages in order to appeal to a variety of learning styles.

Course Topics

We will begin with a quick review of basic univariate statistics and hypothesis testing. I am assuming that most of this material will indeed be a “review,” as opposed to “new,” for you.

Then we will cover topics in introductory regression (bivariate and then multiple), including

- Model specification and interpretation
- Diagnostic tests and plots
- Analysis of residuals and outliers
- Transformations to induce linearity
- Multicollinearity
- Multiplicative interaction terms
- Dummy (dichotomous) independent variables

Finally, as time permits and depending on the interest of the participants, we could also cover:

- Categorical (e.g., Likert) independent variables (Intervalness, Collapsing Categories)
- Logit models and analysis, and probit models
- Heteroscedasticity
- Autocorrelation
- Influence and leverage
Lecture Transcripts

This course will utilize approximately 550 pages of *Lecture Transcripts*. These Lecture Transcripts are organized in three Booklets, and will serve as the sole required “textbook” for this course and an information resource for you after the course ends. In addition, these Lecture Transcripts also significantly reduce the amount of notes you have to write during class, which means you can concentrate much more on learning and understanding the material itself.

A detailed outline of the Lecture Transcripts is included in this syllabus. Each of the three Booklets of Lecture Transcripts will also have a Table of Contents with page numbers.

Packets 1, 2, and 3 constitute “Booklet #1” of the Lecture Transcripts; this Booklet is furnished to all participants taking the course free of charge on the first day of class and will be used for the first week or so of class. Near the end of the course Packet 12 will be furnished to you free of charge. Booklet #2 and Booklet #3 (i.e., packets 4 through 11) are available for you to purchase from the Photoduplicating Office in the basement of the ISR building. The total cost should be approximately $20.00-25.00, and details will be shared the first day of class.

I urge you to purchase this year’s edition of the Lecture Transcripts, as opposed to using an earlier edition; I am constantly making substantive additions, deletions, and changes each year.

Although these Lecture Transcripts are detailed, comprehensive, and self-contained, it is still advisable for you to study the relevant Packets before and after each class, ask questions during class, and talk to either me or one of the Teaching Assistants outside of class if you are to maximize your learning and other benefits from this course. The Lecture Transcripts contain several algebraic derivations and proofs; we will not be taking class time to work through most of them, but instead they are provided for your information and inspection outside of class.

Textbooks and Other Readings

There is no required textbook. Later in this syllabus I provide you with information about several optional supplemental readings from various textbooks and journals, including which readings are appropriate for each of the twelve packets (organized into three booklets...) of Lecture Transcripts. See the beginning of the “Some Suggested Readings” section for a discussion of the four types of textbooks included in these optional readings.

I do not think that any one of these four textbooks is significantly better than the others; instead, the one(s) that you might think is best will depend upon a number of personal factors, including your particular learning style. Therefore, instead of just picking one textbook, I have designed the course so that you can experiment and pick-and-choose which style of learning and (therefore) textbook(s) you prefer. Of course, you may decide to read and study (and maybe purchase) none, one, two, three, or even all four of these textbooks; again, that is entirely up to you. See the alphabetized list of “Some Suggested Readings” near the end of this syllabus for the textbook readings corresponding to each Lecture Transcript packet. Finally, other textbooks are also appropriate for this course; see me if you have any questions about this.
At the end of this syllabus you will find a bibliography for the textbooks and all of the other readings. Note that I have included quite a few of the Sage University Paper Series on Quantitative Applications in the Social Sciences “Little Green Book” monographs; I like these a lot.... You may notice that some (though certainly not all) of the other readings tend to be from political science books and journals; however, this is not a cause for either rejoicing or concern since they deal with methodological topics that are easily and broadly generalizable across other social science disciplines (I would not have selected them otherwise!). I have also been careful to select substantive examples from other areas and journals (e.g., criminal justice, economics, law, sociology, and social science in general). All materials listed in the bibliography are available at the Summer Program’s Library. In addition, all textbooks and monographs should be available for purchase. However, before you actually buy anything for this course I strongly suggest you first “check it out” (in more ways than one...) from the Summer Program Library.

Classes, Assignments, Software, and Matrix Algebra

During the first two or three classes we will have a review of basic statistics; after that, we will begin our consideration of Ordinary Least Squares regression models.

Your grade will be determined by your performance on three or four data analysis Assignments. For each of these Assignments you will use SPSS (also known as “PASW”) as a tool to generate some output. Please note that your substantive task will be to then interpret, explain, and evaluate that output.

It is important to note that this is a course on Regression Analysis, NOT on computer or software usage. So do not worry if you are unfamiliar with SPSS; it is very quick and easy to learn and to use (which is why we use it in this course). We will examine SPSS output, and discuss how it was generated, in class.

Each participant will be assigned to a “Computer Usage Group.” Each Computer Usage Group session will be held in one of the computer labs in the Helen Newberry building and led by one of the Teaching Assistants. NOTE: It will be very important for you to attend these sessions!

Accessing the SPSS data files for the homework, as well as for most of the in-class examples, will be covered in the Computer Usage Group sessions. Do not be concerned if you will eventually use some software other than SPSS in your own work; never forget that our goal here is to learn “Regression Analysis,” not to learn “software usage.”

I will distribute a “Tutorial and Answer Key” for each Assignment immediately after it is due; each of these provides you with yet another excellent learning opportunity. IMPORTANT: You will definitely want to attend some of the ICPSR Summer Program Lecture Series “Introduction to Computing” if you are not already extremely comfortable with basic computer operations, SPSS (PASW), or Microsoft Windows.

We will not be using matrix algebra. The course (including the TAs and the instructor) will not use, or support, any computer software package except for SPSS (PASW).
Learning and the Course’s Teaching Assistants

Remember, the primary purpose of the class meetings, Lecture Transcripts, and Assignments is to help you learn this material and be successfully introduced to regression models and analysis.

You are not in this alone. Studying and learning with your fellow participants is probably a good (a very good!) idea for many of you, as is taking advantage of Office Hours opportunities involving myself and the Teaching Assistants for the course.

Remember, attending the Computer Usage Group sessions led by the Teaching Assistant to whom you have been assigned is very important!

The Teaching Assistants and I make every effort to be accessible to you. I encourage you to attend our office hours, or to make an appointment if those hours do not work well within your schedule. Early in the course I will give you more information (e.g., an office hours schedule) regarding these matters.

“Practical Matters” Involving Assignments and Grading

Quantity. There will be three or four data analysis Assignments that count toward your course grade. Details regarding points, etc., will be given later in the course.

Purpose. The primary purpose of the Assignments is to further enhance your learning of the material. The Assignments also serve as the sole graded evaluation vehicle for those of you taking the course for a grade.

Due Date. You will submit each Assignment at the beginning of the class on the day it is due.

Answer Keys. Everyone in the class will receive a “Tutorial and Answer Key” for each Assignment immediately after it is due. Use each of them as an opportunity to learn!

Calculator. You will need a basic calculator for some of the Assignments.

Details Matter. Your work will be graded on the quality, clarity, completeness, and accuracy of your presentation, so:

- Make it easy to read, follow, and understand your work (be organized and print neatly).
- Show all of your work and supporting evidence, not just your bottom-line answer.
- Neatly print your name and the Assignment Number at the top of the first page.
- Also neatly print your name at the top of each page.
- Staple all of the submitted sheets of paper together, in the upper-left-hand corner.

No Late Submissions. Unless we have made specific arrangements beforehand, no Assignment submitted late will be accepted.
Not “For Credit”? Not a Problem! If you are not taking the course “for credit” then you can still submit none, some, or all of the Assignments for grading; it is completely up to you. In order to optimize your learning opportunity, any work you decide to submit will be evaluated as if you were taking the course for credit.

Grading Templates. In order to facilitate more efficient and accurate grading by the course’s Teaching Assistants, and also to enhance your understanding of the grading (e.g., partial credit) decisions and your total numerical grade, each Assignment will be returned along with a completed grading template form.

Grade Appeals. If you ever have any questions about any of your grades (e.g., partial credit decisions) then you can see me (not a Teaching Assistant!) to discuss the situation, including possibly appealing a grading decision. However, here are a couple of relevant course policies:

- You must wait at least 24 hours after receiving your grade. This “24 Hour Rule” gives you time to study and contemplate your work-product, your notes, the Lecture Transcripts, the Grading Template, and the “Tutorial and Answer Key”... and to think about your work and the corresponding grading decision.
- The maximum amount of time you have to appeal a grading decision is three class days after that Assignment is returned; after then no grading appeals will be considered.

Exceptions to this course policy:

- The “24 Hour Rule” is waived for the last Assignment.
- All grading appeals must be made before the start of the last class meeting.

Working Together and Doing Your Own Work. I encourage you to work and learn with other participants on all learning activities in this course, including the Assignments. However, all of the work on each Assignment you submit needs to be your work; i.e., you need to produce your own actual submitted work-product material.

See me if you have any questions about this.

Conclusion

Remember, the learning objectives in this course encompass learning introductory applied ordinary least squares (OLS) bivariate and multiple regression analysis for your own research and/or to understand the work of others.

Learning the material in this course will require a substantial amount of effort on your part... but that is why you are here, and the payoff will be worth that effort.

Let me know if the Teaching Assistants or I can be of any assistance to you in this endeavor.

It is an honor to be your instructor for this course.
Course (and Lecture Transcript) Outline

Packet 1
I. Basic Statistics Review
   A. Summations and Sigma Notation
   B. Basic Statistics
      1. Mean
      2. Variance and Standard Deviation
      3. Probability
      4. Random Variables
         a. Continuous versus Discrete
         b. Nominal, Ordinal, and Interval
      5. Standardized Variables
      6. Expected Value
      7. Covariance, Correlation, and Causality
      8. Independence
      9. Normal Distribution: Notation, Skewness & Kurtosis, Areas
     10. Central Limit Theorem
    11. “Student’s t” Distribution
    12. Hypothesis Testing
    13. Prob-Values (“p-Values”)
    14. Confidence Intervals
    15. Properties of Estimators

Packet 2
II. Supplement to Basic Statistics Review
   A. A Closer Look at Population and Sample Variances
   B. Hypothesis Testing: Summary, Flowchart, Protocol, and p-Values
   C. Some Abuses and Misuses of Probability and Statistics
   D. Symbol Glossary

Packet 3
III. Bivariate Regression
   A. Notation
   B. Fitting a Line
   C. Ordinary Least Squares Assumptions
   D. Deriving the Sample Intercept and the Slope Coefficient Using Algebra
   E. Centered Variables
   F. The Estimated Slope Coefficient, “b”
      1. Variance and Confidence Interval
      2. Confidence Interval and Hypothesis Testing
   G. The Gauss-Markov Theorem
   H. Appendix: Deriving the Formulas for “a” and “b” Using Calculus
Packet 4 I. Residuals
   1. Definition and Estimation
   2. True, Population “Error” as a Disturbance, or Stochastic Element
J. Explained, Unexplained, and Total Deviations and Sums of Squares
K. Goodness of Fit
   1. Coefficient of Determination (R-Squared)
      a. Correlations (Again...)
      b. Why the R-Squared Can Be Inappropriate and Misleading
      c. Perils of Maximizing R-Squared: A Monte Carlo Simulation
   2. Standard Error of Regression (SER)
L. Standardized Variables and Beta Weights
M. Reporting OLS Regression Results
N. Regression Forced Through the Origin
   1. Definition, Illustrations, and Examples
   2. The Importance of Theoretical and Substantive Justifications
O. Comparison of Centering, Standardizing, and Forcing Through the Origin
P. Another Note on the Meaning and Interpretation of “a,” “b,” and Y-Hat
Q. An Analogy: Means, Slopes, Standardization, Samples and Populations

Packet 5 R. Functional Transformations of Independent Variables
   1. The Need for Transformations
   2. The Regression is Still Linear
   3. The Natural Log and the Square Root Transformations
   4. The X-Squared Transformation
   5. Presenting Findings with Transformed Independent Variables

Packet 6 S. Interpolation, Predictive Intervals, and Extrapolation
T. Some Simple Diagnostic Plots
   1. Y vs. X (and an Introduction to Outliers)
   2. Y vs. Y-Hat
   3. Residual vs. X
   4. Residual vs. Case Number
   5. Residual vs. Lagged Residual
   6. Residual vs. Y-Hat
U. Simpson’s Paradox (Aggregation Bias)
V. Generation and Interpretation of Computer Output Using Real Data
   1. Setting-Up the Substantive Example
   2. Generating and Analyzing the Output
W. The Usefulness of Simple Scatter Plots: An Illustration
X. R-Squared, “b,” and SER: A Monte Carlo Simulation
IV. Introduction to Multiple Regression

A. Limits of Bivariate Regression

B. Trivariate Regression
   1. Visualization
   2. The Residual Term
      a. Definition
      b. The SER and Degrees of Freedom
   3. The (Two) Estimated Slope Coefficients
      a. Partial Effects Equations, Models, and Venn Diagrams
      b. Computing the Two Slope Coefficients
      c. Variance and Confidence Intervals
      d. Meaning and Interpretation
   4. Holding One Variable “Constant”: What’s That All About?
   5. The Impact on OLS Assumptions

C. Multiple Regression: The General OLS Model
   1. The Slope Coefficient
      a. Partial Effects Equations
      b. Computing the Slope Coefficients
      c. OLS Assumptions and the Gauss-Markov Theorem
      d. Meaning and Interpretation
      e. Variance and Confidence Intervals
   2. The Residual Term
      a. Definition
      b. The SER and Degrees of Freedom
   3. Degrees of Freedom: From One to Many Variables

4. Summary and Review of Partial Effects and the Interpretation of “b”
5. Summary and Review of T-Stats, Prob-Values, and Hypothesis Tests
6. Units of the SER and Comparing SER’s Across Equations
7. R-Squared and Adjusted R-Squared
   a. Review of the R-Squared Statistic
   b. Inappropriateness of Comparing R-Squareds across Models
   c. R-Squared and Functional Transformations
   d. Multiple Independent Variables and the Effect on R-Squared
   e. Computing and Interpreting the Adjusted R-Squared Value
8. Interactions
   a. Description and Analogy to Functional Transformations
   b. Models with an Interaction of Two Dummy Variables
   c. Models with an Interaction of a Dummy and a Continuous Variable
   d. Interpreting Models with Interactions (Values, Algebra, Graphs)
   e. Model Specification (e.g., “Can I Exclude a Stand-Alone Term?”)
9. Multicollinearity and Multicollinearity Diagnostics
   a. Perfect Multicollinearity: An Example
   b. Auxiliary R-Squared, Tolerance, and Variance Inflation Factor
   c. Discussing Multicollinearity Using Venn Diagrams
   d. Consequences, Including Possible “Backdoor Bias”
   e. When to Suspect Multicollinearity Problems
   f. How NOT to Diagnose Multicollinearity: Bivariate Correlations
   g. Possible Remedies
   h. A Statistics, Estimation, and Information (Not a Theory!) Problem
   i. Narrowing Down the Source of the Multicollinearity

10. Dummy and Categorical Independent Variables
    a. Definition and Interpretation
    b. The Importance of “Intervalness” for Independent Variables
    c. Replacing a Categorical Independent Variable with Dummies
        i. Implementation and Interpretation
        ii. Excluding one Dummy from the Model
    d. Graphing Models with Dummy Variables (and Interactions)
    e. Comparison: “Regression Forced Through Origin” to “Having X in an Interaction, but Not as a Stand-Alone, Term”
    f. Interpretation of Category Dummies and “Jumps”

11. Functional Transformations
    a. Things to Consider Regarding Transforming Y
    b. Log Transformations and Constant Elasticity Models
    c. Conditional Impacts and Slopes in Models with Interaction Terms
    d. Models with an X-Squared Term (Including Threshold Models)
    e. The Bend Rule

12. Model Specification
    a. Review of Types of Specification Error
    b. Omitting Relevant Variables: Derivation and Consequences
    c. Including Irrelevant Variables: Consequences
    d. Variable Selection
    e. Perils of Stepwise Regression
    f. An Alternative to Standardization for Interval-Level Discrete X’s

13. Missing Data
    a. Data Missing at Random: Dependent and Independent Variables
    b. “Solutions” and Their Potential Problems
        i. Casewise (Listwise) Deletion
        ii. Pairwise Deletion
        iii. Mean and Conditional Mean Substitution
        iv. Other Methods (e.g., Profile Models)

14. Measurement Errors: In Y and in an X

15. Partial Effects Plots and Linearity in Multiple Regression Models
Packet 11

16. Summary: The Effects of Multicollinearity and Specification Errors on Slope Coefficient Estimation and Hypothesis Testing
   a. Type I and Type II Errors
   b. Flowcharts: Review of the Logic of Hypothesis Testing
   c. Essay: Hypothesis Testing and American Criminal Trials

17. Review: Category Dummy Variables
18. Review: Models with Continuous, Dummy, and Interaction Terms
19. Review: Diagnostic Partial Plots
20. Another Look at Outliers: What They Are and Why They Matter
22. Multiple Regression: A Computer Example Using ANES Data
   a. Setting-Up the Example (American National Election Study)
   b. Generation and Interpretation of Computer Output
      i. Control Variables, Multicollinearity, and Diagnostic Plots
      ii. Categorical Independent Variables, Intervalness, and “Jumps”
   c. Review, Analysis, and Wrap-Up of Computer Example
23. “Split-Samples” vs. “Big Models with Dummy Interaction Terms”

Packet 12

V. Analysis of Variance and the F-Test
   A. The F Distribution
   B. Total, Regression, and Error Sum of Squares... and the ANOVA Table
   C. The F-Statistic and the F-Test
      1. A Test Involving All of the Regression Coefficients
      2. The Special Case When the F-Test and Student’s t-Test Are Identical
   D. Analysis and Demonstrations Using Computer Output
      1. Interpreting the F-Test: A Randomly Generated Variables Illustration
      2. Another Look at R-Squared, Adjusted R-Squared, and SER

VI. Chart: Some Potential Problems When Using OLS Regression Models

VII. Final Remarks
   A. More than One Equation: Simultaneous Equations Models
   B. Additional Topics for Further Study
   C. The Importance of Parsimony and Presentation
   D. The Dangers of Over-Reliance on Statistical Procedures

Also: We can cover other topics related to introductory regression analysis as time permits and depending on the interest of the participants. See the bottom of Page 1 for some possible topics. We will discuss the more as we approach the end of the course.
Some Suggested Readings

The Lecture Transcripts that I wrote, and that we will use in each class, serve as the functional equivalence of a textbook for this course. I advise you to use the outline in this syllabus, along with the Table of Contents provided in each Booklet, as a guide for these Lecture Transcripts.

All of the additional readings in this section of the syllabus (details of which can be found in the Bibliography section that immediately follows) are totally optional for you.

Several of these readings are from the following four “traditional” textbooks, each of which I like a lot. While there are great similarities between them, I think that each takes a somewhat different (though at times only subtly different...) pedagogical approach.

- **Gujarati** takes more of a “Math Language” (but neither advanced nor solely) approach.
- **Hamilton** takes more of a “Picture Language” (lots of graphics, etc.) approach.
- **Kennedy** takes more of an “English Language” (narrative explanations) approach.
- **Wooldridge** takes more of a “Combined” (and accessible and comprehensive) approach.

You will also notice several “little green books” from the Sage Series on Quantitative Applications in the Social Sciences. Both the more recent ones and the older “classics” are very useful as learning vehicles.

Finally, I have included several articles from a number of journals across several academic disciplines—again, some that are older “classics” and some others that are newer and more recently published.

So... here are the suggested *optional* readings for each Packet of the Lecture Transcripts.

<table>
<thead>
<tr>
<th>Lecture Packet</th>
<th>Suggested Optional Readings (In Alphabetical Order)</th>
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<tbody>
<tr>
<td>Packets 1 &amp; 2</td>
<td>Baumgartner, Breunig, et al. (especially pages 606-613)</td>
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<td>Gujarati and Porter: Intro; Sections 5.5-5.8, 6A.2; Appendix A</td>
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<td>Hamilton: Pages 289-296</td>
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<td>Kennedy: Sections 2.5-2.8</td>
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<td>Wooldridge: Appendices A.1-A.4, B, C.2-C.6</td>
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<td>Packets 3</td>
<td>Gujarati and Porter: Chapter 1; Sections 2.1, 2.2., 2.6, 2.7, 3.1-3.4, 3A.1-3A.7, 4.1-4.3, 5.1-5.3</td>
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<td>Hamilton: Pages 29-34, 42-49, 296-297</td>
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<td></td>
<td>Kennedy: Chapter 3; Sections 1.1, 1.4, 2.1-2.3, 2.11</td>
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<td>Lewis-Beck: Pages 9-20, 26-38</td>
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<td>Schroeder, Sjoquist, and Stephan: Pages 11-23, 81-82</td>
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<td>Wooldridge: Chapter 1; Sections 2.1-2.5</td>
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<td>Packet 4</td>
<td>Achen (1982): Pages 73-77</td>
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<td>Achen (1991)</td>
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<td>Gujarati and Porter: Sects. 2.4, 2.5, 3.5, 3.8, 5.4, 5.11, 6.1-6.3, 6A.1</td>
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<td>Hamilton: Pages 37-41, 49-51, 124-125</td>
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<td>Kennedy: Sections 1.2, 2.4, 2.10; Pages 109-110</td>
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<td>Lewis-Beck: Pages 20-25</td>
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<td>Lewis-Beck and Skalaban</td>
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<td>Schroeder, Sjoquist, and Stephan: Pages 23-29, 31-32</td>
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<td>Wooldridge: Section 2.6</td>
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<td>Packet 5</td>
<td>Gujarati and Porter: Sections 2.3, 6A.3; Pages 164-166</td>
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<td>Hamilton: Pages 53-58, 148</td>
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<td>Gujarati and Porter: Sections 3.6, 3.7, 5.10</td>
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<td>Lewis-Beck: Pages 38-47</td>
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<td>Packet 7</td>
<td>Achen (1982): Pages 7-51</td>
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<td>Asher: Pages 237-248</td>
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<td>Berry: Pages 1-24, 81-83</td>
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<td>Berry and Feldman: Pages 9-15</td>
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<td>Fox: Pages 3-9</td>
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<td>Gujarati and Porter: Sections 7.1-7.4, 7.6, 8.1-8.3, 8.8</td>
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<td>Hamilton: Pages 65-72, 109-113</td>
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<td>Kennedy: Section 1.3</td>
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<td>Lewis-Beck: Pages 47-52, 53-54</td>
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<td>Schroeder, Sjoquist, and Stephan: Pages 29-31</td>
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<td>Wooldridge: Chapters 3, 5; Sections 4.1-4.3</td>
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<td>Packet 8</td>
<td>Berry: Pages 24-27</td>
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<td>Berry and Feldman: Pages 15-16</td>
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<td>Brambor, Clark, and Golder</td>
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| Packet 9       | Asher: Pages 248-250  
                  | Berry: Pages 45-47  
                  | Berry and Feldman: Pages 37-50, 64-70  
                  | Fox: Pages 10-21  
                  | Gujarati and Porter: Chapter 10; Sections 8.5, 9.1-9.4  
                  | Hamilton: Pages 82, 85-92, 133-136  
                  | Hardy: Pages 1-21, 29-48  
                  | Kennedy: Chapter 12; Sections 15.1-15.4  
                  | Lewis-Beck: Pages 58-63, 66-71  
                  | Schroeder, Sjoquist, and Stephan: Pages 56-58, 71-72  
                  | Wooldridge: Sections 7.1-7.3, 7.6; Pages 238-243 |
| Packet 10      | Achen (1982): Pages 51-73; 77-79  
                  | Asher: Pages 250-255  
                  | Baumgartner, Breunig, et al. (especially pages 613-615)  
                  | Berry: Pages 27-41, 60-66  
                  | Berry and Feldman: Pages 18-37, 71-72  
                  | Fox: Pages 53-61  
                  | Gujarati and Porter: Sections 6.4, 6.5, 6.8, 6.9, 7.7, 7.9, 7.10,  
                  | Halvorsen and Palmquist  
                  | Hamilton: Pages 72-77, 82-84, 148-153, 163-167, 173-174  
                  | Kennedy: Sections 5.1-5.4, 6.1-6.3; Pages 49 (the first point), 111  
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| Packet 12      | Berry and Feldman: Pages 17-18  
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                  | Schroeder, Sjoquist, and Stephan: Pages 51-52  
                  | Wooldridge: Pages 152-153 |
| Other Topics   | Details Regarding Any Readings Will Be Provided Later.... |
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