# The Statistics of Causal Inference in the Social Sciences
# Political Science C236A
# Statistics C239A

Professor Jasjeet Singh Sekhon

Class: 2-4pm Tuesday
220 Wheeler

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Section: Thursday 6–8

### Description

Approaches to causal inference using the potential outcomes framework. Covers observational studies with and without ignorable treatment assignment, randomized experiments with and without noncompliance, instrumental variables, regression discontinuity, sensitivity analysis and randomization inference. Applications are drawn from a variety of fields including political science, economics, sociology, public health and medicine.

This course can be used to meet the Department's Methodology course-out option.

### Prerequisites

At least one graduate matrix based multivariate regression course in addition to introductory statistics and probability. If you need to review material, please consult David Freedman's excellent *Statistical Models: Theory and Practice* or John Fox's *Applied Regression Analysis, Linear Models, and Related Methods*, which includes examples using the *R* programming language.

## Evaluation

Final grades will be based on a series of homework assignments (30% of final grade), a midterm (30%), a term paper or final exam (30%), and class and section participation (10%). Student have the choice between a term paper and a final exam.

It is recommended that students write the term paper jointly with one or at most two other students. Experience has shown that this greatly facilitates learning as well as increases the likelihood

that the paper will eventually become a published article.

Weekly readings and homework assignments are the norm. It is highly recommended that students form study groups in order to complete the homework assignments. Although it is recommended that people work together in order to complete the assignments, students must hand in their own individual answers. Photocopies and other reproductions of someone else's answers are not acceptable. Students should hand in the answers to the problem sets, and all computer code written to find those answers.

During exams, students are not allowed to communicate or cooperate with anyone in any way about exam. Any questions should be asked directly to me and the GSI. To repeat: for exams, one is not allowed to use study groups, online help forms, the writing center, or any other form of help aside from those that are explicitly allowed on the exam instructions. If in doubt, ask.

Incompletes: all course material must be handed in by the first day of class of the spring semester unless an exemption is explicitly granted.

## Course Software and Books

The programming language for this course is the *R* variant of the *S* statistical programming language. It is available for download from: `http://www.r-project.org/`. *R* is open source software (released under the GNU public license) and is available at no charge. We will also be making extensive use of an R package called "Matching" (Sekhon 2011).

The books listed below are required and available at various online bookstores and at the University Book Store.

- Rubin, Donald. 2006. *Matched Sampling for Causal Effects*. Cambridge University Press. ISBN 0521674360.
- Rosenbaum, Paul R. 2002. *Observational Studies*. Springer-Verlag. 2nd edition. ISBN 0387989676.
- Morgan, Stephen L. and Christopher Winship. 2007. *Counterfactuals and Causal Inference: Methods and Principles for Social Research*. Cambridge University Press. ISBN-10: 0521671930.
- Krause, Andreas and Melvin Olson. 2005. *The Basics of S-PLUS*. Springer. ISBN-10: 0387261095.

In addition to the required books, you may wish to obtain a copy of:

- Freedman, David A. 2010. *Statistical Models and Causal Inference: A Dialogue with the Social Sciences*. David Collier, Jasjeet S. Sekhon, and Philip B. Stark, Editors. Cambridge University Press. ISBN-10 0521123909.

  This volume contains a collection of Freedman's articles of special interest to social scientists.
- Angrist, Joshua D. and Jörn-Steffen Pischke. 2008. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton University Press.
- Rosenbaum, Paul R. 2009. *Design of Observational Studies*. Springer-Verlag. ISBN-10 1441912126.

  This book is less technical than Rosenbaum's *Observational Studies*. The book is also available online via Cal's contract with Springer-Verlag: `http://www.springerlink.com/content/978-1-4419-1212-1/#section=627451&page=1`

- Venables, W.N and Brian D. Ripley. 2003. *Modern Applied Statistics with S.* New York: Springer-Verlag. 4th edition. ISBN: 0387954570

  A reference manual on the implementation of many statistical techniques in *R* and *S*.

**Course outline**

1. Causality

   *The potential outcomes framework for causal inference.*

   - Holland (1986) "Statistics and Causal Inference"
   - Little and Rubin (2000) "Causal Effects in Clinical and Epidemiological Studies via Potential Outcomes"
   - Sekhon (2004b): "Quality Meets Quantity: Case Studies, Conditional Probability and Counterfactuals"

   Extra reading:

   - Winship and Morgan (1999) "The Estimation of Causal Effects from Observational Data"

2. Statistical Modeling: Foundations and Limitations

   - Freedman Chapter 1 (Freedman 1995): "Some Issues in the Foundations of Statistics: Probability and Model Validation."
   - Freedman Chapter 2 (Freedman 2003): "Statistical Assumptions as Empirical Commitments."
   - Freedman Chapter 3 (Freedman 1991): "Statistical Models and Shoe Leather."

   For extra readings see the rest of the Freedman volume, especially:

   - Freedman Chapter 20 (Freedman 2008c): "On Types of Scientific Inquiry: The Role of Qualitative Reasoning."
   - Freedman Chapter 14 (Freedman and Humphreys 1996): "The Grand Leap" (of graphical models).
   - Freedman Chapter 15 (Freedman 2004): "On Specifying Graphical Models for Causation, and the Identification Problem."

3. Randomized Experiments and Controlling Bias in Observational Studies

   *Properties of experiments, basic implementations, and illustrations of observational studies based on approximate experimental design.*

   - Neyman (1923/1990): "On the Application of Probability Theory to Agricultural Experiments. Essay on Principles. Section 9." *Statistical Science* 5, 465–472.
   - Rubin (1990) "Comment: Neyman (1923) and Causal Inference in Experiments and Observational Studies," *Statistical Science* 5, 472-480.
   - Rubin (2006) Chapters 1 and 2:
     "William G. Cochran's Contributions to the Design, Analysis and Evaluation of Observational Studies"
     Cochran and Rubin (1973): "Controlling Bias in Observational Studies: A Review"

- Rosenbaum (2002b) Chapter 2

Extra readings:

- Przeworski (In Press) "Is the Science of Comparative Politics Possible?"
- Cox (1958): *Planning of Experiments*. Chapters 1 and 2.
- Cochran (1965): "The Planning of Observational Studies of Human Populations"
- Cochran (1983): Chapters 1 and 7

4. Randomization Inference

   *Fisherian and permutation Inference, and the Lady Tasting Tea*

   - Fisher (1935, ch 1–2): *Design of Experiments*. `http://tinyurl.com/c9tj2hy`
   - Rosenbaum (2002b, ch 2): *Observational Studies*
   - Rosenbaum (2002a): "Covariance adjustment in randomized experiments and observational studies." *Statistical Science* 17 286–327 (with discussion).

   Extra reading:

   - Freedman Chapter 8: "What is the Chance of an Earthquake?"
   - Bowers and Panagopoulos (2011): "Fisher's Randomization Mode of Statistical Inference, Then and Now."
   - Attributable effects: Rosenbaum (2002b, 188–194).
   - Pitman (1937b): "Significance Tests Which May be Applied to Samples From any Populations"
   - Pitman (1937a): "Significance Tests Which May be Applied to Samples from any Populations. II. The Correlation Coefficient Test"
   - Pitman (1938): "Significance Tests which can be Applied to Samples from any Populations. III. The Analysis of Variance Test"
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5. Univariate Matching Methods for Controlling Bias in Observational Studies

   *Experimental and observational studies where assignment to treatment is done on observables. Stratification and matching.*

   - Rubin (2006) Chapters 3 to 5:
     "Matching to Remove Bias in Observational Studies" Rubin (1973a)
     "The Use of Matched Sampling and Regression Adjustment to Remove Bias in Observational Studies" Rubin (1973b)
     "Assignment to a Treatment Group on the Basis of a Covariate"
   - Rosenbaum (2002b) Chapter 3.1–3.3

6. The Propensity Score

   *Logistic regression and the fundamentals of propensity score matching*

   - Handout on general linear models

- Rubin (2006) Chapters 10, 11 and 14 all with Paul R. Rosenbaum:
  "The Central Role of the Propensity Score in Observational Studies" Rosenbaum and Rubin (1983)
  "Assessing Sensitivity to an Unobserved binary Covariate in an Observational Study with Binary Outcome"
  "The Bias Due to Incomplete Matching"
- Sekhon (2004c): The Varying Role of Voter Information Across Democratic Societies
- Morgan and Harding (2006): "Matching Estimators of Causal Effects: Prospects and Pitfalls in Theory and Practice"

Also see Rosenbaum and Rubin (1984); Rubin and Thomas (2000).

7. Regression Discontinuity Design

- Thistlethwaite and Campbell (1960): "Regression-Discontinuity Analysis: An alternative to the ex post facto experiment"
- Lee (2008): "Randomized Experiments from Non-random Selection in U.S. House Elections"
- Caughey and Sekhon (2011): "Elections and the Regression-Discontinuity Design: Lessons from Close U.S. House Races, 1942–2008"
- Hahn, Todd, and van der Klaauw (2001): "Identification and Estimation of Treatment Effects with a Regression-Discontinuity Design"

Extra reading:

- Dunning (2008): "Improving Causal Inference: Strengths and Limitations of Natural Experiments." *Political Science Quarterly* 61(2):282–293 2008.

8. Multivariate Matching

*Mahalanobis distance, Genetic Matching and Equal Percent Bias Reduction*

- Rubin (2006) Chapters 8 and 9:
  "Bias Reduction Using Mahalanobis-Metric Matching" Rubin (1980)
  "Using Multivariate Matched Sampling and Regression Adjustment to Control Bias in Observational Studies" Rubin (1979)
- Diamond and Sekhon (forthcoming): Genetic Matching for Estimating Causal Effects: A General Multivariate Matching Method for Achieving Balance in Observational Studies

9. Genetic Matching

*Automatic balance optimization, evaluating balance and the LaLonde controversy*

- Diamond and Sekhon (forthcoming): "Genetic Matching for Estimating Causal Effects
- Sekhon and Grieve (2012): "A Matching Method for Improving Covariate Balance in Cost-Effectiveness Analyses."
- LaLonde (1986) [ JSTOR ]
- Dehejia and Wahba (1999) [ JSTOR ]
- Smith and Todd (2001)

10. Natural Experiments

    - Sekhon and Titiunik (2012): "When Natural Experiments Are Neither Natural Nor Experiments"

11. Matching Examples Using Observational Data
    Please read the first three of the Political Science examples listed here and any of the others you find of interest. An effort has been made to obtain examples across fields which are pedagogically interesting.
    *Political Science*

    - Gordon and Huber: "The Effect of Electoral Competitiveness on Incumbent Behavior"
    - Gilligan and Sergenti: "Evaluating UN Peacekeeping with Matching to Improve Causal Inference"
    - Lenz and Ladd: "Exploiting a Rare Shift in Communication Flows: Media Effects in the 1997 British Election"
    - Simmons and Hopkins (2005): "The Constraining Power of International Treaties: Theory and Methods"

    *Economics*

    - Galiani, Gertler, and Schargrodsky (2005): "Water for Life: The Impact of the Privatization of Water Services on Child Mortality"
    - Imbens, Rubin, and Sacerdote (2001): "Estimating the Effect of Unearned Income on Labor Earnings, Savings, and Consumption: Evidence from a Survey of Lottery Players"
    - Angrist (1998): "Estimating the Labor Market Impact of Voluntary Military Service Using Social Security Data on Military Applicants."

    *Other*

    - Christakis and Iwashyna (2003): "The Health Impact of Health Care on Families: A matched cohort study of hospice use by decedents and mortality outcomes in surviving, widowed spouses"
    - Rubin (2001): "Using Propensity Scores to Help Design Observational Studies: Application to the Tobacco Litigation"

12. Instrumental Variables (IV)

    - Angrist and Krueger (2001): "Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments"
    - Angrist, Imbens, and Rubin (1996) "Identification of Causal Effects Using Instrumental Variables"
    - Heckman (1997) "Instrumental Variables: A Study of Implicit Behavioral Assumptions Used in Making Program Evaluations"

    Application, and use of randomization inference to correct an issue:

    - Imbens and Rosenbaum (2005): "Robust, Accurate Confidence Intervals with a Weak Instrument: Quarter of Birth and Education," *Journal of the Royal Statistical Society*, Series A, vol 168(1), 109–126.

- Angrist and Krueger (1991): "Does compulsory school attendance affect earnings?" *Quarterly Journal of Economics* 1991; 106: 979–1019.
- Bound, Jaeger, and Baker (1995): "Problems with Instrumental Variables Estimation when the Correlation Between the Instruments and the Endogenous Regressors is Weak," *JASA* 90, June 1995, 443–450.

13. (Regression) Adjustment to Experimental Data

    - Lin (forthcoming): "Agnostic Notes on Regression Adjustments to Experimental Data: Reexamining Freedman's Critique." `http://tinyurl.com/9378kmk`
    - Miratrix, Sekhon, and Yu (forthcoming):Adjusting Treatment Effect Estimates by Post-Stratification in Randomized Experiments

    Extra readings:

    - Freedman (2008a): "On regression adjustments to experimental data."
    - Freedman (2008d): "Randomization does not justify logistic regression"
    - Freedman (2008b): "On regression adjustments in experiments with several treatments"

14. Application: Fixing Broken Experiments and a Controversy

    - Gerber, Alan S. and Donald P. Green. 2000. "The Effects of Canvassing, Telephone Calls, and Direct Mail on Voter Turnout: A Field Experiment." American Political Science Review 94(3): 653 663.
    - Imai, Kosuke. "Do Get-Out-The-Vote Calls Reduce Turnout? The Importance of Statistical Methods for Field Experiments." American Political Science Review
    - Green and Gerber Reply
    - Bowers, Jake and Ben Hansen. 2005. "Attributing Effects to A Cluster Randomized Get-Out-The-Vote Campaign."

15. Synthetic Cohorts
    *When good matches cannot be found: create a new unit*

    - Abadie and Gardeazabal (2003): "The Economic Costs of Conflict: a Case-Control Study for the Basque Country"

16. Full and Optimal Matching

    - Rosenbaum (1991, 1989)
    - Hansen (2004)

17. Sensitivity Analysis for Hidden Bias and other Helpful Suggestions

18. Application: Voting Irregularities

    - Wand, Shotts, Sekhon, Walter R. Mebane, Herron, and Brady (2001): The Butterfly Did It: The Aberrant Vote for Buchanan in Palm Beach County, Florida
    - Mebane and Sekhon (2004): Robust Estimation and Outlier Detection for Overdispersed Multinomial Models of Count Data

- Herron and Wand (2007): Assessing Partisan Bias in Voting Technology: The Case of the 2004 New Hampshire Recount
- Sekhon (2004a): The 2004 Florida Optical Voting Machine Controversy: A Causal Analysis Using Matching

19. Pre-Test Problems

- Diaconis (1985): "Theories of Data Analysis: From Magical Thinking Through Classical Statistics"
- Freedman (1983): "A Note on Screening Regression Equations"

## References


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Angrist, Joshua D. and Alan B. Krueger. 2001. "Instrumental Variables and the Search for Identification: From Supply and Demand to Natural Experiments." *Journal of Economic Perspectives* 15 (4): 69–85.

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Christakis, Nicholas A. and Theodore I. Iwashyna. 2003. "The Health Impact of Health Care on Families: A Matched Cohort Study of Hospice use by Decedents and Mortality Outcomes in Surviving, Widowed Spouses." *Social Science & Medicine* 57 (3): 465–475.

Cochran, William G. 1965. "The Planning of Observational Studies of Human Populations (with discussion)." *Journal of the Royal Statistical Society, Series A* 128: 234–255.

Cochran, William G. 1983. *Planning and analysis of observational studies*. New York: John Wiley and Sons. Edited posthumously by L. E. Moses and F. Mosteller.

Cochran, William G. and Donald B. Rubin. 1973. "Controlling Bias in Observational Studies: A Review." *Sankhya, Series A* 35 (4): 417–446.

Cox, David R. 1958. *Planning of Experiments*. New York: Wiley.

Dehejia, Rajeev and Sadek Wahba. 1999. "Causal Effects in Non-Experimental Studies: Re-Evaluating the Evaluation of Training Programs." *Journal of the American Statistical Association* 94 (448): 1053–1062.

Diaconis, Persi. 1985. "Theories of Data Analysis: From Magical Thinking Through Classical Statistics." In D. Hoaglin, F. Mosteller, and J. Tukey, editors, *Exploring Data Tables, Trends and Shapes* New York: Wiley. pages 1–36.

Diamond, Alexis and Jasjeet S. Sekhon. forthcoming. "Genetic Matching for Estimating Causal Effects: A General Multivariate Matching Method for Achieving Balance in Observational Studies." *Review of Economics and Statistics*.

Dunning, Thad. 2008. "Improving Causal Inference: Strengths and Limitations of Natural Experiments." *Political Science Quarterly* 61 (2): 282–293.

Fisher, Ronald A. 1935. *Design of Experiments*. New York: Hafner.

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Freedman, David A. 1991. "Statistical Models and Shoe Leather." *Sociological Methodology* 21: 291–313.

Freedman, David A. 1995. "Some Issues in the Foundation of Statistics." *Foundations of Science* 1: 19–39.

Freedman, David A. 2003. "Statistical Assumptions as Empirical Commitments." In Thomas G. Blomberg and Stanley Cohen, editors, *Punishment and Social Control: Essays in Honor of Sheldon Messinger* Aldine de Gruyter. 2nd edition pages 235–254.

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Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky. 2005. "Water for Life: The Impact of the Privatization of Water Services on Child Mortality." *Journal of Political Economy* 113 (1): 83–120.

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Hahn, Jinyong, Petra Todd, and Wilbert van der Klaauw. 2001. "Identification and Estimation of Treatment Effects with a Regression-Discontinuity Design." *Econometrica* 69: 201–209.

Hansen, Ben B. 2004. "Full Matching in an Observational Study of Coaching for the SAT." *Journal of the American Statistical Association* 99 (467): 609–618.

Heckman, James. 1997. "Instrumental Variables: A Study of Implicit Behavioral Assumptions Used in Making Program Evaluations." *The Journal of Human Resources* 32 (3): 441–462.

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