Gov2001: Quantitative Social Science Methods I

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Substantive questions in empirical scientific and policy research are often causal. Does voter outreach increase turnout? Are job training programs effective? Can a universal health insurance program improve people's health? This class will introduce students to both theory and applications of causal inference. As theoretical frameworks, we will discuss potential outcomes, causal graphs, randomization and model-based inference, sensitivity analysis, and partial identification. We will also cover various methodological tools including randomized experiments, regression discontinuity designs, matching, regression, instrumental variables, difference-in-differences, and dynamic causal models. The course will draw upon examples from political science, economics, education, public health, and other disciplines.

1   Contact Information

Instructor
NAME: Kosuke Imai
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OFFICE HOURS: Wednesdays 10:30pm – noon (sign up at https://tinyurl.com/KosukeOfficeHours)
             or by an appointment

Teaching Fellows

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2   Logistics

LECTURES	Mondays and Wednesdays	3:00–4:15pm	CGIS Knafel 354
TF SECTION 1	Thursday	5:30–6:30pm	CGIS South 001
OFFICE HOURS 1	Thursday	6:30–8:00pm	CGIS South 001
TF SECTION 2	Friday	2:30–3:30pm	CGIS Knafel 354
OFFICE HOURS 2	Friday	3:30–5:00pm	CGIS Knafel 354

3   Prerequisites

This course assumes the solid knowledge of

- probability and statistical theory (based on calculus)

- linear models (based on matrix algebra)

- data analysis using R

at the level of Gov2002 taught in Fall 2023 (https://mattblackwell.github.io/gov2002-f23/)

4   The Instructional Tools

We use a variety of instructional tools to run this course.

- **Course website** (https://canvas.harvard.edu/courses/132754): This is the entry point to all the course materials. The links to the review questions and problem sets will be posted here too.

- **Course calendar** (http://tinyurl.com/gov2001calendar): For your convenience, class meetings and TF sections as well as various deadlines are made available through this Google calendar.

- **Perusall** (https://app.perusall.com/courses/gov-2001-quantitative-social-science-methods-i-611183953/): This platform will host lecture videos and lecture slides. You can also ask questions about their contents by annotating relevant parts of the lecture slides and videos rather than directly emailing an instructional staff. We encourage you to watch their Getting Started video and learn about how to ask questions if you are new to Perusall. You can enter the Perusall course site from Canvas.

- **Ed** (https://edstem.org/us/courses/50176): This platform will host all assignments and their solutions. Questions about assignments should be posted here rather than directly emailing an instructional staff. You may find this user guide helpful to orient yourself to the platform.

- **Gradescope** (https://www.gradescope.com/courses/685507): This is where you will submit all of your assignments. The grades for the assignments will be available here as well. There is a student guide you can check for any questions about the workflow.

5   The Structure of the Course

This course is structured to make productive use of in-person class meetings. The course is divided into 10 modules. Each module is centered around a particular theme, and is roughly based on the following basic structure.

- **Pre-module assignments**: Watch video lectures available at Perusall *before* the class meetings of each module. *We will assume that you have watched these videos and asked questions you have about them at Perusall.* We also strongly recommend that you use the reading assignments for better understandings of the materials covered in each module.

- **Review Questions**: These questions are designed to better understand the materials presented in the pre-module video lectures. You may also find the assigned readings useful solving Review Questions. Review Questions are not graded, and you are not required to submit your answers. The solutions of these Review Questions wil be made available before the next class meeting.

- **Class Meetings**: For each module, the first class meeting will begin with a short summary of video lectures. We assume that students have watched the assigned the video lecture already. Students are then given an opportunity to ask any remaining questions about these lectures. Then, you will spend some time working together with your partner on REVIEW QUESTIONS with the help of the instructional team. The meeting will end with another short lecture. Before the second class meeting, you should solve REVIEW QUESTIONS though no submission is required. During the second class meeting, the instructor will give a lecture on additional materials of the module.

- **Problem Sets**: There is one problem set for each module. You are required to complete a minimum of five problem sets throughout the semester.

- **TF sections**: There will be two optional TF sections each week. One reviews the materials from the video and in-person lectures, and the other covers the materials useful for problem sets. The section attendance is optional, but students are encouraged to attend both sections.

- **Additional materials**: Kyla Chasalow who took an iteration of this course and also served as an TF has prepared the extensive notes for the course. Many students have found this material useful. Her notes are available at https://github.com/kchaz/CausalCourseNotes/

6   Course Requirements

The final grade is based on the following components:

- **Class participation** (10% of the course grade): We evaluate the level of your engagement during the in-person class meetings and TF sections as well as Perusall and Ed online discussions.

- **Problem Sets** (30% of the course grade): You and your partner should choose a total of 5 modules out of 10 modules, for which you are to submit your answers to the selected questions from PROBLEM SETS. Each module will be weighted equally. If you decide to submit the solutions to additional exercises, we will take your best scores among those submitted. The following rules apply to all problem sets:

  - *Collaboration policy.* Students are allowed to discuss the problem sets with the instructional staff and any other students in class. Each of you, however, must write up your own solutions and make a separate submission. **Under no circumstances may you copy someone else's answer including computer code, mathematical derivation, and substantive interpretation.**

  - *Genarative AI policy.* ChatGPT and other generative AI should not be used when working on problem sets except for the purpose of debugging your computer code.

  - *Online help and office hours.* You are strongly encouraged to reach out to the instructional staff through Perusall, Ed, and office hours about any questions you might have about the course materials. Students should also feel free to ask questions and answer the questions posed by others at Perusall and Ed, which will count towards class participation.

  - *Submission policy.* All answers including the math and computer code are encouraged to be incorporated into the Rmarkdown file provided by the instructional staff. Handwritten math answers are acceptable once merged into one pdf document. For the exercises, each

student should submit the pdf file electronically to Gradescope. Once you upload the PDF file, you will see a list of the questions in the assignment and thumbnails of your file. For each assigned question, click the PDF page(s) that contains your answer. No late submission will be accepted unless you obtain a prior approval from the instructor.

- **Mid-term and final take-home exams** (60% of the course grade): The midterm and final will be 24-hour take-home exams and will consist of both analytical and empirical questions. They cover the first and second half of the materials, respectively, and are equally weighted. You should not consult with anyone including the instructional team. Clarifying questions can be asked by emailing the instructional team. Detailed instructions will be given later in the semester.

7 Textbook

The required textbook for this course is,

- Imbens, Guido W. and Rubin, Donald B. (2015). *Causal Inference for Statistics, Social, and Biomedical Sciences: An Introduction*, Cambridge University Press.

In addition, you may find the following books useful,

- Angrist, Joshua D. and Pischke, Jörn-Steffen. (2009). *Mostly Harmless Econometrics: An Empiricist's Companion*, Princeton University Press.

- Hernán M. A., Robins James M. (2020). Causal Inference. Boca Raton: Chapman & Hall/CRC. Available free at https://www.hsph.harvard.edu/miguel-hernan/causal-inference-book/

8 Course Plan

This course provides a brief introduction to the following 10 topics in causal inference. The problem set for each module is due by noon on the day listed.

Module 1 Introduction

Class 1 (1/22) Overview of the course

Video lecture Potential outcomes

Reading Imbens & Rubin, Chapter 1 (Optional Chapter 2)

Class 2 (1/24) Potential outcomes

Problem Set 1 January 31

Module 2 Permutation Test

Video lecture Permutation test

Reading Imbens & Rubin, Chapter 5 (Optional Chapter 4)

Class 1 (1/29) Inverting permutation tests

Class 2 (1/31) Conditional randomization tests

Problem Set 2 February 7

Module 3 Inference for Average Treatment Effects

VIDEO LECTURE Average treatment effects

READING Imbens & Rubin, Chapters 6, 9 (Skip 9.6–9.7), and 10 (Skip 10.6–10.7)

CLASS 1 (2/5) Evaluation of individualized treatment rules

CLASS 2 (2/7) Stratified experiments

PROBLEM SET 3 February 14

Module 4 Linear Regression and Randomized Experiments

VIDEO LECTURE Simple linear regression

READING Imbens & Rubin, Chapters 7, 9 (9.6–9.7), and 10 (10.6–10.7)

CLASS 1 (2/12) Cluster randomized trials

CLASS 2 (2/14) Covariate adjustment in randomized experiment

PROBLEM SET 4 February 21

Module 5 Instrumental Variables

VIDEO LECTURE Noncompliance in randomized experiments

READING Imbens & Rubin, Chapters 23 and 24

CLASS 1 (2/21) Instrumental variables

CLASS 2 (2/26) Two stage least squares

PROBLEM SET 5 March 4

Module 6 Regression Discontinuity Designs

VIDEO LECTURE Sharp regression discontinuity designs

READING

CLASS 1 (2/28) Diagnostics of regression discontinuity design

CLASS 2 (3/18) Fuzzy and other regression discontinuity designs

PROBLEM SET 6 March 25

Midterm Exam

REVIEW SESSION I March 4

REVIEW SESSION II March 6

MIDTERM Released on March 7, 24-hour take-home submitted by 5pm on March 10

Spring Break

Module 7 Observational Studies

VIDEO LECTURE Regression with observational data

READING Imbens & Rubin, Chapters 21 and 22

CLASS 1 (3/25) Sensitivity analysis

CLASS 2 (3/27) Partial identification

PROBLEM SET 7 April 3

VIDEO LECTURE Directed acyclic graphs and backdoor criterion

READING

CLASS 3 (4/1) Proxy and frontdoor criterion

Module 8 Matching and Weighting

VIDEO LECTURE Matching and weighting methods

READING Imbens & Rubin, Chapters 13, 15, and 18 (Optional Chapters 12, 14, and 19)

CLASS 1 (4/3) Optimal matching and weighting methods

CLASS 2 (4/8) Semiparametric causal inference

PROBLEM SET 8 April 15

Module 9 Causal Mechanisms and Heterogeneity

VIDEO LECTURE Controlled Direct Effects, Natural Direct and Indirect Effects

READING

CLASS 1 (4/10) Causal mediation analysis

VIDEO LECTURE Causal heterogeneity

Class 2 (4/15) Heterogeneous treatment effects

PROBLEM SET 9 April 22

Module 10 Fixed Effects, Difference-in-Differences, and Synthetic Control Method

VIDEO LECTURE Difference-in-differences and fixed effects regressions

READING Angrist & Pischke, Chapter 5

CLASS 1 (4/17) Nonlinear difference-in-differences design

CLASS 2 (4/22) Matching and weighting methods for panel data

PROBLEM SET 10 April 29

VIDEO LECTURE Synthetic control method

READING

CLASS 3 (4/29) Difference-in-differences, regression, and synthetic control

Wrap Up TBD

Final Exam

REVIEW SESSION I April 24

REVIEW SESSION II May 1

FINAL EXAM Released on May 2, 24-hour take-home submitted by 5pm on May 9