INTRODUCTION TO CAUSAL INFERENCE

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Introduction and course organization

TODAY

1. What is causal inference?
2. Causal inference within empirical social research
3. A roadmap for causal inference
4. Course goals and learning outcomes
5. Requirements and grading
6. Course materials

WHAT IS CAUSAL INFERENCE?

THE SHORT ANSWER FOR NOW

It's the attempt to learn about causal relations between at least two variables from empirical data.

(see Heckman, 2000)

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Importantly, claiming that X has a causal effect on Y doesn't mean that there are no other causes of Y, only that X is one of its (potentially countless number of) causes.

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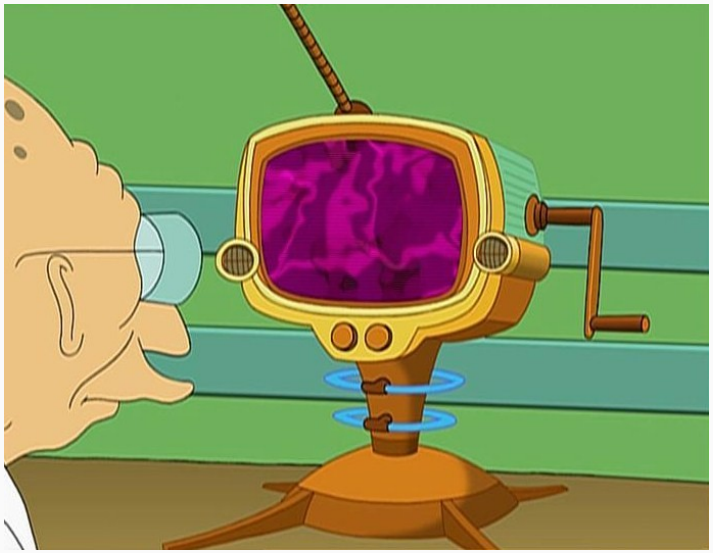
CAUSAL INFERENCE TRIES TO BUILD THE “WHAT-IF-MACHINE”

Source:
`http://futurama.wikia.com/wiki/What-If_Machine`



The What-If Machine was an invention created by Professor Hubert J. Farnsworth. The device resembled a television set, and could predict the outcome of any “What if?” phrased question, though it can only do this three times a year. The machine is made of gold and the method of activating is never the same.

“Alright, Professor! Lets do it. Make that machine show me what would happen if I was a little more impulsive. Just a little... Not too much.”

—Leela

“What if I never fell into that freezer-doodle and came to the future-jiggy?”

—Fry

“I wanna know what would happen if I were human. I mean, being a robot’s great, but we don’t have emotions and sometimes that makes me very sad.”

—Bender

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Being precise about the population of interest is crucial in empirical social research, no less so in causal inference.

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CAUSAL INFERENCE WITHIN EMPIRICAL SOCIAL RESEARCH

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There are at least two other important goals for which researchers study empirical data.

1. Description: involves using data to answer questions about the occurrence or prevalence of phenomena and statistical relations between phenomena
2. Statistical prediction: involves using statistical relations found in empirical data to predict occurence or prevalence of phenomena elsewhere or at a different time

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- Is the rate of mental illness in a country higher, the higher the extent of income inequality?

RESEARCH QUESTIONS INVOLVING STATISTICAL PREDICTION

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- Which people are likely to engage in criminal behavior?
- How many people are likely to die of the flue in the coming winter?

SOME QUESTIONS FOR YOU

1. What's your name?
2. Where did you attain your BA?
3. What was the topic of your BA thesis?
4. Would you say the main question of your thesis was a causal question, a descriptive question, a question involving prediction, or something else?

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Therefore, causal inference is to be sharply distinguished from other (important!) tasks of empirical social research like description, exploration, and statistical/prediction forecasting.

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When we ask whether the number of trees affects neighborhood safety, we want to know whether changing the number of trees would result in a change in neighborhood safety.

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But we would still observe an association between number of trees and safety in neighborhoods.

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But we would still observe an association between class attendance and grades.

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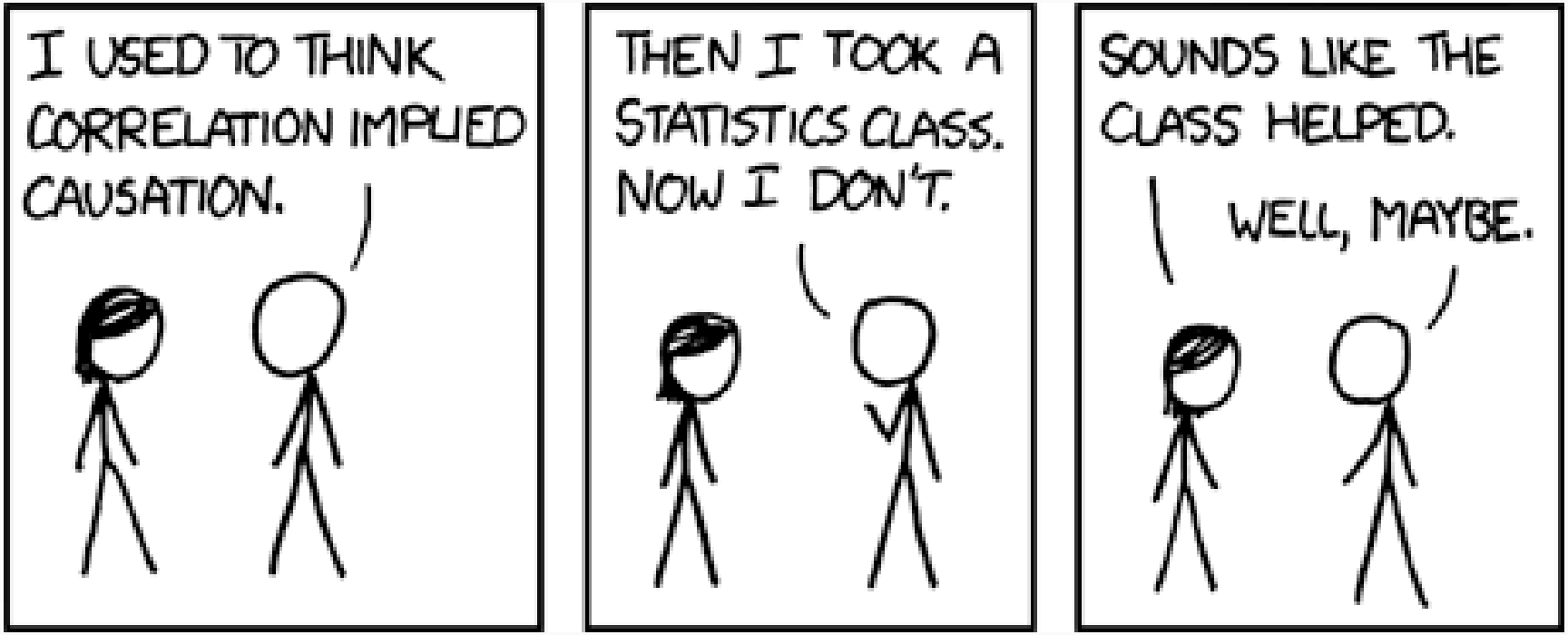
Can you think of some questions or problems for which we need knowledge about causal relations?



Source: `http://imgs.xkcd.com/comics/correlation.png`

Saying that correlation doesn't imply causation is true, but what now?

The course goes beyond this mantra and aims to equip you with tools to decide when causal claims in the literature, the media, or in everyday life are believable and when they aren't.

A ROADMAP FOR CAUSAL INFERENCE

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To rigorously study causal relations it is helpful to follow specific steps.

Petersen and van der Laan (2014) proposed what they call a roadmap for causal inference.

The whole course is organized along this roadmap.

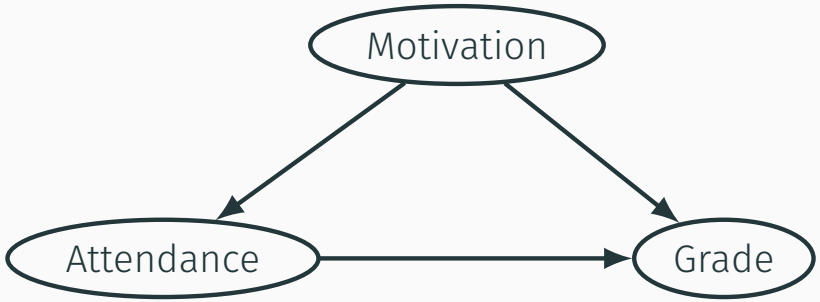
FIRST STEP

Specify a causal model (or possibly multiple alternative models)

- Causal models express knowledge, theory, and assumptions about the processes that generated the data that we can observe.
- They are models of how the world works (i.e., how we think it works).
- Causal models are not based on statistical relations in empirical data.
- But they imply statistical relations that we should be able to observe in empirical data (if the causal model is true).

(Petersen and van der Laan, 2014)

A SIMPLE EXAMPLE



This causal model expresses my belief that

- motivation may cause both class attendance and grades,
- class attendance may cause grades,
- there are no other common causes of motivation, class attendance, and grades.

SECOND STEP

Define the causal question of interest

- Which causal relation(s) in the model is(are) of interest?
- What is the specific change whose consequences are to be studied?
- What is the target population?

(Petersen and van der Laan, 2014)

THIRD STEP

Link the causal model to the available empirical data

- Which variables of the causal model are measured in the data and which aren't?
- What happened during data collection?

(Petersen and van der Laan, 2014)

FOURTH STEP

Assess whether the causal relation of interest can be identified with the available data

- Does the data include the variables necessary to learn about the causal relation of interest?
- If so, which statistical relation can be used to (approximately) estimate the causal relation?
- If not, which additional information (or assumptions) are necessary to identify the causal relation of interest?

(Petersen and van der Laan, 2014)

FURTHER STEPS

Only now, statistical methods (e.g., regression) come in!

5. Specify the statistical model used to estimate the statistical parameter
6. Estimate the statistical parameter (for example, using *Stata*)
7. Interpret the results
   Important: for causal interpretation of results (from any statistical method) causal model must be (approximately) true!

(Petersen and van der Laan, 2014)

A ROADMAP FOR CAUSAL INFERENCE!

1. Specify the causal model
2. Define the causal parameter of interest (along with the target population)
3. Link the causal model to the available empirical data
4. Assess whether the causal parameter of interest can be identified with the available data and define the respective statistical parameter
5. Specify the statistical model used to estimate the statistical parameter
6. Estimate the statistical parameter
7. Interpret the results and discuss assumptions

(Petersen and van der Laan, 2014)

COURSE GOALS AND LEARNING OUTCOMES

LEARNING GOALS AND OUTCOMES

1. Formalize a research question about causal relations using causal graphs and counterfactuals. This includes
   - ⋆ translating theoretical arguments about causal relations into a corresponding graphical model,
   - ⋆ specifying the causal relation of interest and defining this relation in terms of counterfactual contrasts,
   - ⋆ being able to conceptually distinguish this causal relation from statistical association.

→ Roadmap 1 & 2

LEARNING GOALS AND OUTCOMES

2. Use graphical models to devise strategies for identifying the causal relation of interest. For this, students
   - ⋆ demonstrate that they are capable to derive empirical implications from a graphical causal model,
   - ⋆ understand the theoretical assumptions necessary to test these implications,
   - ⋆ critically evaluate whether these assumptions hold in applied social research.

→ Roadmap 3 & 4

LEARNING GOALS AND OUTCOMES

3. Estimate the causal relation of interest and, if feasible, test underlying assumptions. To do so, students
   - ⋆ adapt existing *Stata* code for their purposes,
   - ⋆ correctly interpret the resulting estimates,
   - ⋆ understand and perform tests of the validity of the analyses.

→ Roadmap 5–7

COURSE STRUCTURE AND CONTENT

After a refresher on statistical relations (next week) and an introduction to graphical causal models (in two weeks) we will follow the roadmap for causal inference to study

1. total effects (Oct 30–Nov 27)
2. direct and indirect effects (Dec 4–Dec 18)
3. cumulative effects (Jan 8–Jan 22).

REQUIREMENTS AND GRADING

FINAL GRADE

1. 60-min exam on January 29, 2018 (60 points), based on required readings and class contents (not the lecture slides alone!)
2. max. of 30 bonus points by completing three labs (10 points each), in which you implement the roadmap for causal inference to study (1) total effects (2) direct and indirect effects (3) cumulative effects using empirical data

!DON'T FORGET TO REGISTER FOR THE EXAM ON TIME!

GRADING

Points from labs are added to exam points until you reach max. 60 points

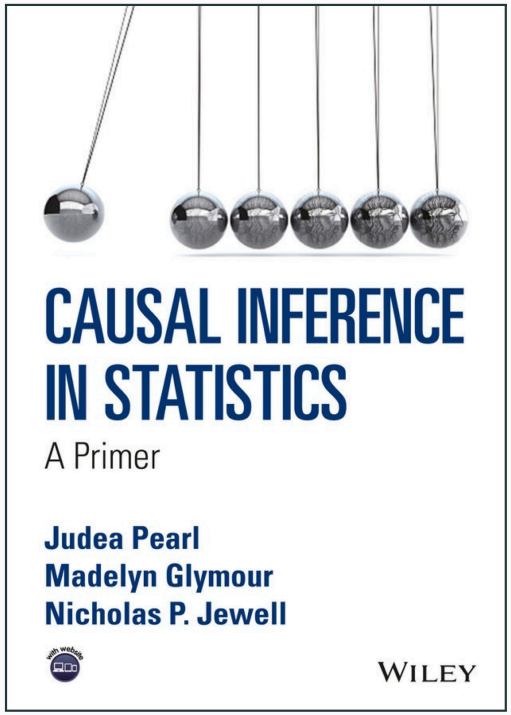
Grades are awared as follows:

1.0: $60 \geq \text{points} \leq 58$
1.3: $58 > \text{points} \leq 55$
1.7: $55 > \text{points} \leq 51$
2.0: $51 > \text{points} \leq 48$
2.3: $48 > \text{points} \leq 45$
2.7: $45 > \text{points} \leq 42$
3.0: $42 > \text{points} \leq 39$
3.3: $39 > \text{points} \leq 36$
3.7: $36 > \text{points} \leq 33$
4.0: $33 > \text{points} \leq 30$
n.p.: $30 > \text{points} \leq 0$

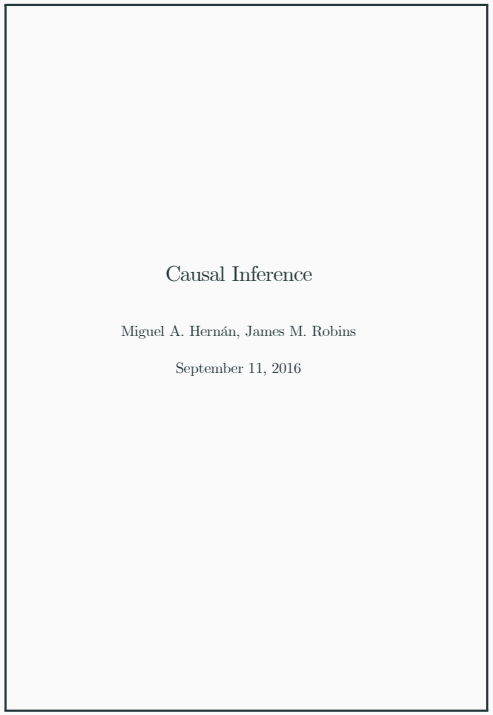
COURSE MATERIALS

TEXTBOOKS AND REQUIRED READINGS

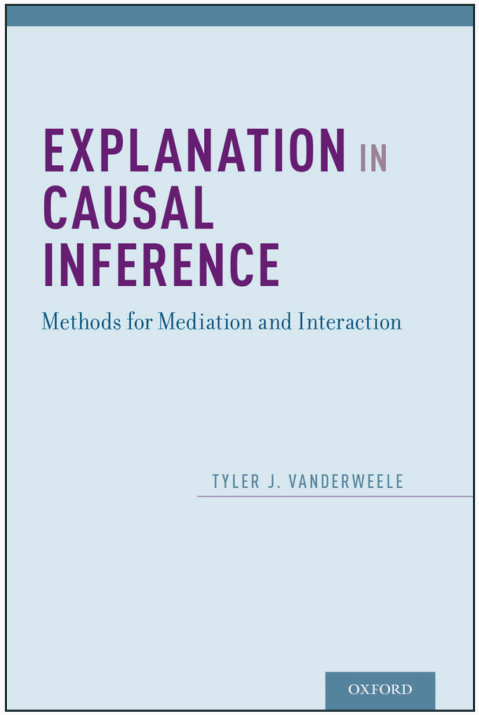
PGJ



HR



VDW



Please use PGJ with errata!

Other required readings (and some further readings) on *Ilias*

ILIAS

- course materials (readings, slides, data etc.)
- submission of completed labs
- short quizzes
- forum for questions and discussion
  Please use this forum for all questions regarding course organization and content that are possibly of general interest to course members and use email only for personal matters such as office hour appointments, illness, and questions regarding grading.

NEXT WEEK: STATISTICAL RELATIONS AND THEIR INTERPRETATION

1. Variables and distributions
2. Conditioning and conditional distributions
3. Statistical dependence and independence
4. Statistical models
5. Simpson's Paradox and the data generating process

THANK YOU FOR YOUR ATTENTION!

REFERENCES

Heckman, J. J. (2000). Causal parameters and policy analysis in economics: A twentieth century retrospective. *Quarterly Journal of Economics*, 115, 45–97.

Pearl, J. (2009). Causal inference in statistics: An overview. *Statistics Surveys*, 3, 96–146.

Petersen, M. L. and van der Laan, M. J. (2014). Causal models and learning from data: Integrating causal modeling and statistical estimation. *Epidemiology*, 25(3), 418–426.

Shalizi, C. R. (2016). *Advanced Data Analysis from an Elementary Point of View*. Cambridge University Press, New York. URL `http://www.stat.cmu.edu/~cshalizi/ADAfaEPoV/ADAfaEPoV.pdf`.

Get these slides from

`https://osf.io/jgrsy/`

The METROPOLIS theme was created by Matthias Vogelgesang and is available from

`https://github.com/matze/mtheme`