

PMAP 8131 Applied Research Methods II

Causality

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Outline

- 1 Epistemology
- 2 Causation
- 3 Validity
 - Threats to validity

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- 1 Epistemology
- 2 Causation
- 3 Validity
 - Threats to validity

Epistemology

- Popper's falsification principle
- Kuhn's paradigm shift
- Lakatos research paradigm

Epistemology

Popper's falsification principle

- Logical asymmetry of verification and falsification

Epistemology

Modus ponens

- Premise I: *All dogs bark.*
- Premise II: *Tyson is a dog.*
- Conclusion: *Tyson barks.*

Modus tollens

- Premise I: *All dogs bark.*
- Premise II: *Tyson doesn't bark.*
- Conclusion: *Tyson is not a dog.*

Epistemology

Modus ponens

1. $D \rightarrow B$
2. D
3. B = Implication: 1,2

Epistemology

Modus tollens

1. $D \rightarrow B$
2. $\neg B$
3. $\neg D$ = Implication: 1,2

Epistemology

- Logical asymmetry of verification and falsification
 - One negative obs is *enough* to invalidate a theory
 - No number of positive obs would *ever* validate a theory
- Demarcationist stance
 - Falsification *demarcates* science from pseudo-science
 - Difference between statements is *logical*, not empirical

Epistemology

Duhem-Quine Thesis

1. $(T1 \wedge T2 \wedge T3) \rightarrow O$
2. $\neg O$
3. $\neg(T1 \wedge T2 \wedge T3)$

Epistemology

Kuhn's scientific revolutions: Popper + Duhem-Quine

- Local vs global confutations
 - Theories are bundles of propositions $T = \{T_1, \dots, T_n\}$
 - Local confutations do not prove a theory false
- Normal science vs revolutionary science
 - Normal science is *puzzle-solving* of local confutations and never *discovers* anything new

Epistemology

Lakatos' research paradigms: Marx + Hegel

- Science as “struggle of theories”
 - Theories: $T^1 = \{T_1^1, \dots, T_n^1\}, \dots, T^n = \{T_1^n, \dots, T_n^n\}$
 - A *progressive/regressive* theory generates *more/less* successes, on average, than competitor theories
- Theories as “paradigms”
 - Sub-theories layer up onto theories, only *upper layer* theories brought to the fore of evidence

Epistemology

Falsification: Regression example

- **Hypothesis.** Male-female math achievement gap due to institutional features (X_i), does not reflect genetics
- **Experimentum crucis.** Sequential regression models:

$$MATH_i = \beta_0 + \beta_1 Female_i + \epsilon_1 \quad (1)$$

$$MATH_i = \beta_0 + \beta_1 Female_i + \beta_2 X_i + \epsilon_1 \quad (2)$$

Epistemology

Falsification: Regression example

- **Hypothesis.** Male-female math achievement gap due to institutional features (X_i), does not reflect genetics
- **Experimentum crucis.** Sequential regression models:

$$MATH_i = \beta_0 + \beta_1 Female_i + \epsilon_1 \quad (1)$$

$$MATH_i = \beta_0 + \beta_1 Female_i + \beta_2 X_i + \epsilon_1 \quad (2)$$

- **Decision rule:** Reject hypothesis if β_1 significant in model 1), but insignificant in model 2)

Epistemology

Falsification: Regression example (Guiso et al., 2008)

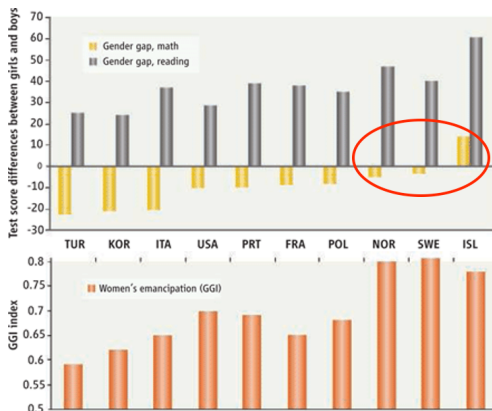


Figure: Female-male gap reverts in countries with greater gender parity

Epistemology

Human subjects

- *Act in such a way that you treat humanity, whether in your own person or in the person of another, **always at the same time as an end** and never simply as a means* (Immanuel Kant)

Human subjects: Violations

- Violence on experimentees
- Framing of questions
- Omission of information
- Interaction with experimentees

Epistemology

Data management

- *There are three kinds of lies: Lies, Damned Lies, and Statistics* (Mark Twain)

Data management: Violations

- Addition or removal of observations
- “P-hacking”
- Framing of findings
- Uncommented code!!!

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Causation

Causation

- 1 Correlation
- 2 Time-order
- 3 Non-spuriousness

Causation

1 Correlation

$$\rho(X, Y) = \frac{\sigma_{XY}}{\sigma_X \sigma_Y} \approx \frac{COV_{XY}}{SD_X SD_Y} \approx \frac{\sum (X - \bar{X})(Y - \bar{Y})}{SD_X SD_Y}$$

• Correlation: Examples

- Size of left and right foot
- Watching football and earnings
- Leap year and Olympic Games

Causation

- 2 Non-spuriousness
 - Relationship between X and Y spurious to Z
- Non-spuriousness: Examples
 - Air conditioning and IQ test score (Z : Temperature)
 - Suicide and Reddit engagement (Z : Depression)
 - Car usage and individual longevity (Z : Income)

Causation

- ③ Time-order
 - X comes before Y (Beware: reverse causation!)

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Validity

Experiment

- Subject features
- Experimental conditions
- Experimental stimulus

Validity

- Internal validity
 - Equality of treated and controls
- External validity
 - Equality of experimentees and outer population

Validity

- Internal validity
 - Equality of treated and controls
 - Observables and unobservables features of treatments that affect the outcome match features of controls
- External validity
 - Equality of experimentees and outer population
 - Experimental conditions and stimulus match inputs in the real world

Threats to Validity

- Threats to internal validity
 - History
 - Maturation
 - Instrumentation
 - Regression to the mean
 - Self-selection
 - Differential mortality

Threats to Validity

- Threats to external validity
 - Measuring
 - Testing
 - General equilibrium effects
 - Multiple treatments
 - Self-selection

Threats to Validity

History. *Treatment effect are attributable to the passing of time.*

- Example: Federal policies and economic growth rates
 - Economy follows own short- and long-run trends
 - Political cycle overlaps with economy, does not cause it

Threats to Validity

Stock market growth and jitters: The Dow Jones index

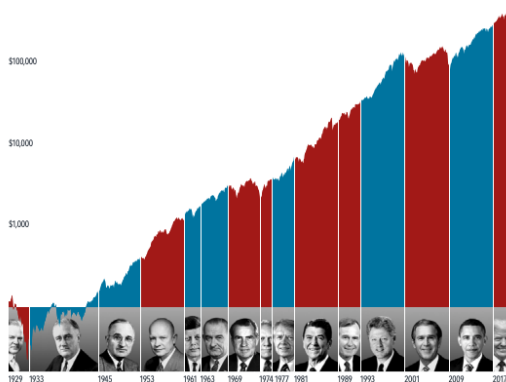


Source: Bloomberg. Last update: 2 November 2020

BBC

Threats to Validity

GROWTH OF \$100
FAMA/FRENCH TOTAL US MARKET RESEARCH INDEX
March 4, 1929–June 30, 2020



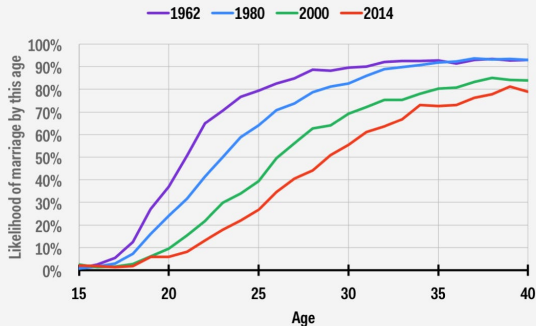
Threats to Validity

Maturation. *Treatment effect are attributable to the aging of subjects.*

- Example: Welfare programs and marital outcomes
 - People more likely to marry and have kids as they age

Threats to Validity

Odds of being married at least once by age



Source: Business Insider tabulations of University of Minnesota Population Center CPS-IPUMS

BUSINESS INSIDER

Threats to Validity

Instrumentation. *The effect is measured with instrumental and nonrandom error.*

- Example: Domain knowledge tests
 - Test measures test-taking ability, not domain knowledge

Threats to Validity

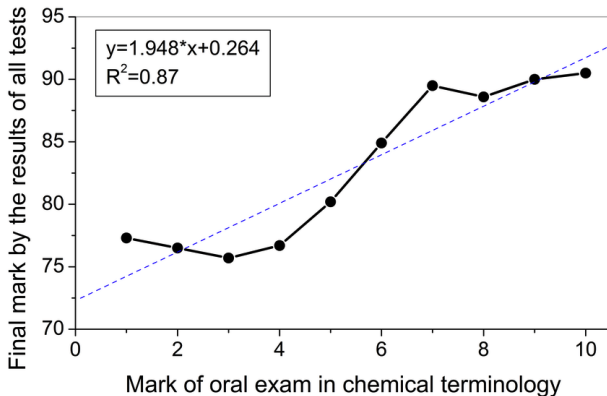


Figure: Correlation of chemistry test scores and other tests (Gryshchenko et al., 2021)

Threats to Validity

Regression to the mean. *Treatment is observed at a point below or above their average value.*

- Example: Job training programs
 - Trainees likely to get back to workforce anyways

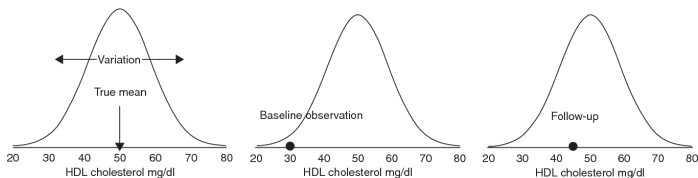


Figure: Regression to baseline cholesterol (Barnett et al., 2005)

Threats to Validity

Self-selection. *Features of experiment drive selection into treatment group.*

- Example: Immigrant earnings
 - Migrants systematically different from those who stay

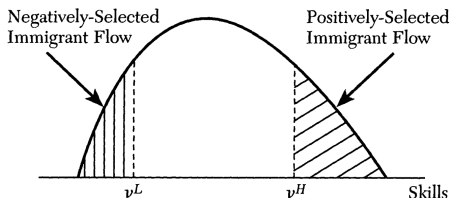


Figure: Immigrant self-selection (Borjas, 1994)

Threats to Validity

Differential mortality. *Treatment and control exit experiment at different and nonrandom rates.*

- Example: Welfare programs
 - Burdensome paperwork forfeits unmotivated treatments

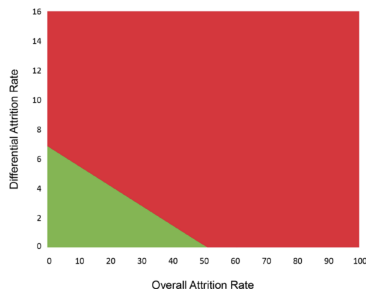


Figure: Maximum differential attrition (Mathematica, 2015)

Threats to Validity

Measuring. *Reaction to measuring affects the outcome.*

- Example: Observing experimentees
 - Behaviors change when we know we are being measured

Threats to Validity

Testing. *Reaction to testing affects the outcome.*

- Example: Pre-testing
 - Pre-testing increases test-taking skills

<i>Group</i>	<i>Pretest</i>	<i>Treatment</i>	<i>Posttest</i>
1	O_1	X	O_2
2	O_1	—	O_2

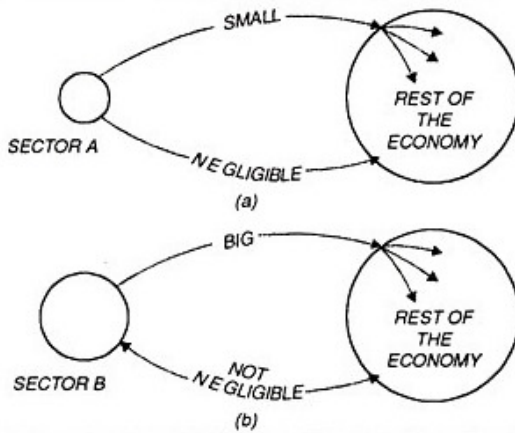
Time ►

Threats to Validity

General equilibrium effects. *Generalization of treatment to population forfeits local effects.*

- Example I: The “paradox of schooling”
 - If I get an A, I stand out. If everyone gets an A, no one stands out
- Example II: Government spending
 - If I get a subsidy, I am better off. If everyone gets a subsidy, inflation makes us all worse off

Threats to Validity



Threats to Validity

Multiple treatments. *Treatment effect does not generalize if treatment is administered jointly with a second treatment.*

- Example: Psychological counseling
 - If counseling involves commutes, treatment effect is the joint effect of counseling and taking time off work

Threats to Validity

Self-selection. *Features of experiment drive selection into experimental group.*

- Example: Student evaluations of professors
 - Students leave evaluations when very happy or unhappy