

Analysis with Simulated Data

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Some cool simulations

Simulation models

- Simulation models are fully specified data generating processes (DGP)
 - Mathematically: system of equations
 - Takes inputs: exogenous variables
 - Returns outputs: endogenous variables
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- Asteroid hitting the ocean
 - Global map of wind, weather, and ocean
 - OG macroeconomy
 - Tax Cuts and Jobs Act

What is simulation?

- the imitation of the operation of a real-world process or system over time, usually with a computational or mathematical model
- System can generate synthetic data

When do we use simulation?

- ① when experiments on human subjects are unethical
 - Do economies recover faster from recessions if the government provides no extra help to the poor?
 - University of Iowa “Monster Study”

When do we use simulation?

University of Iowa “Monster Study”

The Monster Study was a stuttering experiment on 22 orphan children in Davenport, Iowa, in 1939 conducted by Wendell Johnson at the University of Iowa. Johnson chose one of his graduate students, Mary Tudor, to conduct the experiment and he supervised her research. After placing the children in control and experimental groups, Tudor gave positive speech therapy to half of the children, praising the fluency of their speech, and negative speech therapy to the other half, belittling the children for every speech imperfection and telling them they were stutterers. Many of the normal speaking orphan children who received negative therapy in the experiment suffered negative psychological effects and some retained speech problems during the course of their life. Dubbed “The Monster Study” by some of Johnson’s peers who were horrified that he would experiment on orphan children to prove a theory, the experiment was kept hidden for fear Johnson’s reputation would be tarnished in the wake of human experiments conducted by the Nazis during World War II. The University of Iowa publicly apologized for the Monster Study in 2001.

When do we use simulation?

- ① when experiments on human subjects are unethical
- ② when no past data is available
 - How effective is massive monetary policy injection (TARP) in the face of a global equities crisis stemming from the U.S. housing market?
 - Does the use of VR headsets in K-12 education increase mathematics performance and global competitiveness?
- ③ when no past data is observable or has a lot of measurement error
 - Does happiness increase when a population becomes more equal (in terms of income)?
- ④ when real-world experiments are prohibitively expensive
 - black hole dynamics
 - estimating effects of all presidential candidate's tax policies

Simulation requires data generating process

True data generating process

The complete set of actors, forces, exogenous shocks, etc. that combine to make some observable phenomenon

Model data generating process

The incomplete and stylized set of actors, forces, exogenous shocks, etc. that combine to make some observable phenomenon

- The goal in modeling is to:
 - make the model DGP match the true data
 - incorporate the most important factors from the true process into the model process
- Simulation allows us to perform experiments

Machine Learning and simulation

Gross simplification of ML definition

- Infer relationships among variables
 - Highly nonlinear underlying model (hard to interpret)
 - Can be used for prediction, even simulation, but hard to interpret
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- Interpretability might be important for simulation
 - ML is good if you only care about predictive accuracy
 - Many fields still working on reconciling these two

Example: Moretti (2002) simulation in sociology

Moretti, Sabrina, "Computer Simulation in Sociology: What Contribution?" *Social Science Computer Review*, 20:1 (Spring 2002), pp. 43-57.

- [Assignment 3](#) questions
- System dynamics, multiagent systems, cellular automata, genetic algorithms
- How could we simulate or use simulation in one of the non-economic questions we have studied so far?

Example: How much will you earn?

- How much will you earn after you graduate?
- Talk about paper estimating the process from IRS data
- Look at [Assignment 3](#)

Which comes first: Data or Theory?

Sherlock Holmes [quoted in Mankiw (2012), p. 17]

“It is a capital mistake to theorize before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to fit facts.”

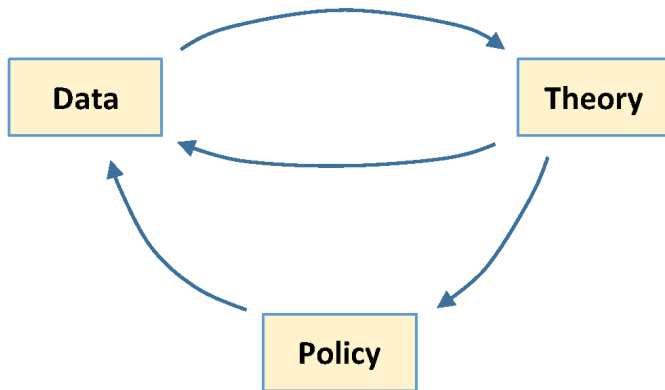
Michael Keane (2005), pp. 29-30

“...[W]e cannot even begin the systematic assembly of facts and empirical regularities without a preexisting theoretical framework that gives the facts meaning, and tells us which facts we should establish.”

Multiple approaches to research

- Workshop speaker (Oct. 26), Santo Fortunato:
 - Data follow a parabolic pattern or power rule
 - What theory would predict this
- Start with data and build to theory
- Start with theory and test the data
- Interplay of policy between data and theory (see figure)

Data and Theory and Policy



Limits of inference without theory

Definition: **statistical inference**

The process of deducing parameters θ of a model $f(\mathbf{x}|\theta)$ from data.

Definition: **simulation**

The process of generating synthetic data \mathbf{x} from a model $f(\mathbf{x}|\theta)$ given parameter values θ .

Limits of inference without theory

- Koopmans (1947) essay, “Measurement without Theory”
 - “But, the decision not to use theories of man’s economic behavior, even hypothetically, limits the value to economic science and to the maker of policies, or the results obtained by the methods developed.”
 - Theory helps you know what data you should look for
 - Theory places a hierarchy on the importance of certain relationships between variables

Limits of inference without theory

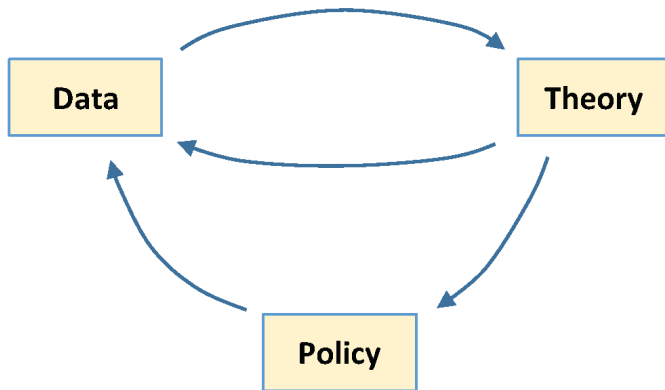
- “The absence of theory in inferential empirical work is pervasive. For example, of all the papers in the January 2009 maiden issue of the new *American Economic Journal: Applied Economics*, all of which were inferential, non contained an explicit model of ‘man’s economic behavior’.”
- “...sharper inferences do indeed result from drawing explicit connections to coherent and relevant theory. The empirical approach, be it structural, quasi-structural, quasi-experimental, or experimental is of secondary importance. Theory provides the only way to fully appreciate the behavioral assumptions that underlie inference from data.”

Theory is No Panacea

- What might be the arguments of empirical/applied researchers against theorists?
- “*All models are wrong, some are useful.*” George E. P. Box (1976, *JASA*)
- “*Everything should be as simple as possible, but no simpler.*” likely Albert Einstein
 - Evans paraphrase: “A model should be as simple as possible to answer the research question, but no simpler.”

Data and Theory and Policy

- How could one neglect theory in this process?
- How should one include theory in this process?



Take theory directly to the data

Simple definition of simulation model

A simulation model $\mathbf{f}(\mathbf{x}|\boldsymbol{\theta}) = 0$ makes explicit the mathematical relationship between:

- data (variables) \mathbf{x}
 - some variables are exogenous (inputs)
 - some variables are endogenous (outputs)
- parameters $\boldsymbol{\theta}$

① Weak calibration

- take parameter values $\boldsymbol{\theta}$ from other studies

② Strong calibration (direct inference, no standard errors)

Take theory directly to the data

② Strong calibration (direct inference, no standard errors)

- Plug data \mathbf{x} into model $\mathbf{f}(\mathbf{x}|\theta) = 0$
- Let $\mathbf{m}(\mathbf{x}|\theta)$ be a set of statistics (moments) generated from the model
- Let $\mathbf{m}(\mathbf{x})$ be a corresponding set of statistics (moments) from the data
- Estimate parameters $\hat{\theta}$ so that model moments are as close as possible to data moments (GMM).

$$\hat{\theta} = \operatorname{argmin}_{\theta} \|\mathbf{m}(\mathbf{x}|\theta) - \mathbf{m}(\mathbf{x})\|$$

③ Estimation (direct inference, standard errors)

- GMM, match moments
- MLE, maximize likelihood
- SMM, simulate data and match moments

Take theory directly to the data

4 Estimation (indirect inference, standard errors)

- Simulate data
- Run separate model on simulated data $\mathbf{g}(\mathbf{x}|\theta)$
- Run separate model on actual data $\mathbf{g}(\mathbf{x})$

$$\hat{\theta} = \operatorname{argmin}_{\theta} \|\mathbf{m}_g(\mathbf{x}|\theta) - \mathbf{m}_g(\mathbf{x})\|$$

Examples

- Income after graduation model, [Assignment 3](#)

$$\ln(\text{inc}_{2018}) = \ln(\text{inc}_0) + \ln(\varepsilon_{2018}) \quad \text{and}$$

$$\ln(\text{inc}_t) = (1 - \rho) \left[\ln(\text{inc}_0) + g(t - 2018) \right] + \rho \ln(\text{inc}_{t-1}) + \ln(\varepsilon_t)$$

for $2019 \leq t \leq 2057$

- Direct inference
 - Indirect inference
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- [FiveThirtyEight.com Methodology](#)

Simulation and tax policy

- **Theory, predictions of taxes and investment:** Mankiw ([here](#) and [here](#)), [Mulligan](#), Cochrane ([here](#), [here](#), and [here](#)), [Summers](#), Furman, [Landsburg](#) tweet/blog storm
- Baker, Bejarano, Evans, Judd, Phillips (2016), “[A Big Data Approach to Optimal Sales Taxation](#)”
- DeBacker and Evans 2018 [TCJA analysis](#)