Introduction

AES Summer School in Structural Estimation

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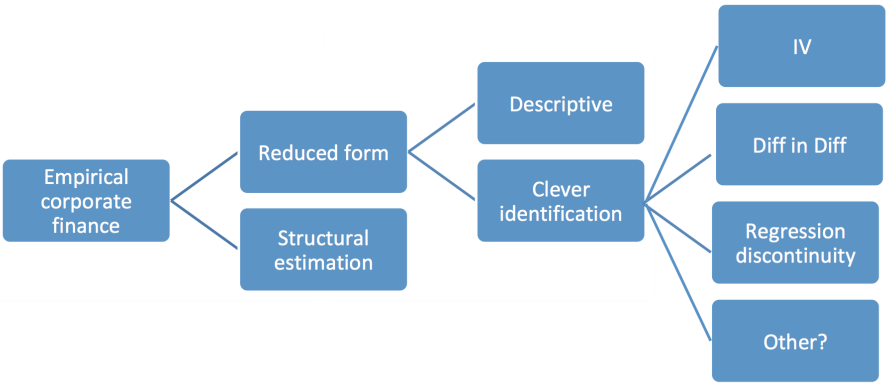
The big picture



First, some terminology

- I am not a big fan of the phrase “structural model.”
- All economic models are “structural.”
- Usually when people say “structural model,” they really mean “dynamic model.”
- It makes a lot of sense to talk about “structural” versus “reduced-form” estimation.

Statistical and Economic Models

- A statistical model describes the relation between two or more random variables:

$$y = x\beta + u$$

- An economic model starts with assumptions about
  - agents' preferences
  - constraints
  - firms' production functions
  - some notion of equilibrium, etc.
- Then it makes predictions about the relation between observable, often endogenous variables.

Structural Estimation

- Structural estimation is an attempt to estimate an economic model's parameters and assess model fit.

- Parameters to estimate often include

  - Preference parameters (e.g., risk aversion coefficient)
  - Technology parameters (e.g. production function's curvature)
  - Other time-invariant institutional features (e.g. agents' bargaining power, financing frictions)

What is Structural Estimation?

- Structural estimation ascertains whether optimal decisions implied by a model resemble actual decisions by firms.

- Structural estimation may or may not require a dynamic—as opposed to a static—model.
  - Hennessy and Whited (2005) $\longrightarrow$ dynamic
  - Albuquerque and Schroth (2010) $\longrightarrow$ static

What Kind of Model to Use

- The model has to be an economic rather than a statistical model
- Should produce realistic magnitudes and distributions
  - No two-state, “profits-are-either-hi-or-lo” models
  - Usually no two- or three-period models
  - Model should usually be fully dynamic

What Kinds of Econometrics

- GMM
- MLE
- SMM (SMD)
- SMLE
- Indirect Inference
- All of the two-step methods used by the structural IO folks.

Moments and Likelihoods

- The moment estimators ascertain whether model-implied moments in the data resemble real-data moments.
- The likelihood estimators use economic models to construct the likelihoods for MLE.
- In both cases
  - The simulation estimators are used with models without closed-form estimating equations.
  - GMM and MLE are used with models with closed-form estimating equations.

Calibration versus Structural Estimation

- Calibration:
  - Take many parameter values from other papers
  - Usually have more parameters than moments—model isn't identified, can't put standard errors on parameters
  - Mainly a theoretical exercise

- Structural estimation:
  - Infer parameter values from the data
  - Get standard errors for parameters
  - **An empirical exercise**

Calibration versus Structural Estimation

- Both:
  - Can assess how well model fits the data—no statistical tests with calibration
  - Can use model to ask counterfactual questions:
  - What would happen if we shocked this variable?
  - How would world look if we changed this parameter's value?
- Picking 5 parameters arbitrarily and then estimating 5 more is not estimation.

Structural versus Reduced-Form Estimation

- Reduced-form:
  - What is the (causal) effect of X on Y?
- Structural
  - Why does X affect Y?
  - What are the magnitudes of the parameters?
    - "Parameters" $=$ economic primitives
    - "Parameters" $\neq$ slopes, correlations
  - How well does theory line up with the data?
  - How would the world look if one of the parameters (counterfactually) changed?
  - What would happen if you (counterfactually) shocked the system?

Structural versus Reduced-Form Terminology

- Dynamic models often imply one or many "reduced-forms," meaning statistical models that describe the relation between the observables generated by the model.

- Example from "Debt Dynamics." One reduced-form prediction from the model:

$$\text{Leverage}_{it} = \beta_0 + \beta_1 Q_{it} + \beta_2 \pi_{it} + u_{it}$$

  The regression slopes β are nonlinear functions of the model's structural parameters.

- The true (no u_{it}) reduced-form may actually be nonlinear in π_{it} and Q_{it}.

Motivating a Structural Paper

- Structural estimation imposes large costs on the reader.
- Any structural paper must put great effort into convincing reader that it's worth going structural

Structural Estimation Buys You Three Things

From least to most interesting

1. Estimates of interesting economic primitives

2. Deep tests of theory:
   - Formal, joint tests of multiple predictions (e.g., test of overidentifying restrictions in GMM/SMM)
   - Testing quantitative, not just directional, predictions
   - "Seeing where models fail opens doors to future research"
     Example: Hansen and Singleton (1982) and Mehra and Prescott (1985), equity premium puzzle

3. Can answer interesting counterfactual questions

Example from Taylor (2010): "Why are CEOs Rarely Fired?"

- Estimates of interesting economic primitives:
  "I estimate a parameter that quantifies CEO entrenchment: Directors' disutility from firing a CEO"

- Deep tests of theory:
  Model does a good job fitting most moments but struggles to fit (1) changes in profitability in the year after CEOs fired, and (2) the high rate at which CEOs are fired in their first 2 years in office

- Can answer interesting counterfactual questions:
  How much would firm value change if we eliminated CEO entrenchment?
  Set the entrenchment parameter to zero $\longrightarrow$ firm value increases by 3%.

Example: Warusawitharna and Whited (2016) "Equity Market Misvaluation, Financing, and Investment"

Question: How does equity market misvaluation affect firm policies?

	Reduced-form	Structural
Approach	Regress investment, etc. on a proxy for misvaluation	Estimate structural parameters by SMM. Use counterfactual analysis to measure effects of misvaluation on policies
Data challenges	Difficult to measure misvaluation	Use observed data on firm decisions viewed through the lens of a model
Identifying assumptions	Exogenous variation in equity market misvaluation	Model is "true" enough to capture the determinants of relevant firm policies

The structural approach complements existing reduced-form research by
(1) overcoming certain data challenges
(2) imposing a different type of identifying assumption.

How to Referee a Structural Paper[1]

- Am I convinced that we need structural estimation?
  - Why won't a reduced-form approach work?
- Is the economic question important?
  - Or are we using a large hammer to hit a small nail?
- Is the identification clear, or is it a black box?
  - Which features of the data identify each parameter, and why/how?
- Is model fitting the data reasonably well?
  - If not, what can we learn from its failure?
  - Usually not a deal-breaker

[1] And how to write your own!

How to Referee a Structural Paper

- Are moments contaminated by important omitted economic forces?
  - If so, how could the omission bias the estimates?
- Have authors explored interesting heterogeneity in the parameters?
  - E.g, estimate model in subsamples
- Enriches paper, provides useful consistency checks
- Does the paper take full advantage of counterfactual exercises?

Pros and Cons

- Reduced-form
  - "Fewer" assumptions?[2] Results more convincing?
  - Easier to do. Much lower start-up costs.
  - Easier to understand: larger audience
- Structural
  - Often the only feasible option for answering certain important questions
  - Tough to find good instruments or natural experiments
  - The connection between theory and tests of theory is extremely tight, which allows more transparent interpretation of any results. In structural, we "put the model first" and make it explicit.
  - Results generalize better.
  - For job market: Makes you look smart

[2] Kahn and Whited (2018): just as many assumptions.

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