Summer School in Structural Estimation
Introduction

Toni M. Whited

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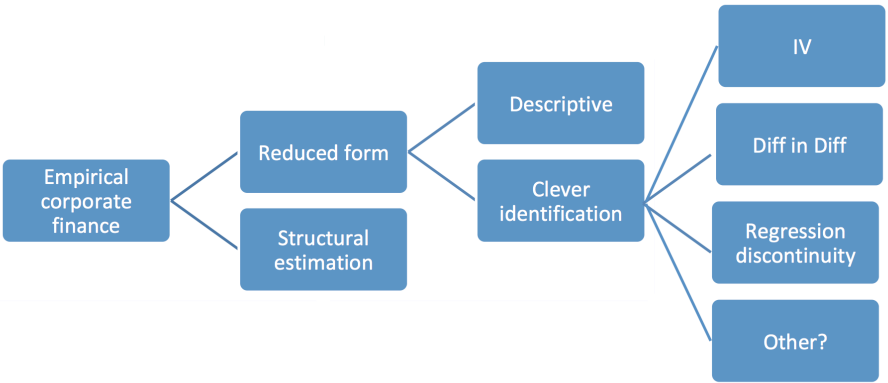
The Plan

- Who's who? (in order of appearance)
  - Toni Whited
  - Stephen Terry
  - Luke Taylor
  - Ellen Longman
  - Mahdi Shahrabi
- Goals
  - Level the "model-solving" playing field so you can all do the project (but this is not a model-solving class)
  - Teach you the econometrics behind full-solution model estimation
  - Give you hands-on practice!!
- Schedule

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 ascertains whether optimal decisions implied by a model resemble actual decisions by agents.
- 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 or banks or individuals.

- 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

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

- Structural models often imply a "reduced-form," meaning a statistical model describing the relation between the observables generated by the model.

- Example from "Debt Dynamics." One reduced-form prediction from the structural 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 is likely nonlinear in π_{it} and Q_{it}.

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
- SMLE
- Indirect Inference
- All of the two-step and demand-estimation methods used by the structural IO folks.

What Kinds of Econometrics

- **GMM**
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- SMLE
- **Indirect Inference**
- Demand estimation and 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
  - The model is underidentified
  - Cannot put standard errors on parameters
  - Mainly a theoretical exercise
  - Useful in a macro model of a single economy

Calibration versus Structural Estimation

- Structural estimation:
  - Infer parameter values from the data
  - Get standard errors for parameters
  - **An empirical exercise**
- Picking 5 parameters arbitrarily and then estimating 5 more is not estimation.

Calibration versus Structural Estimation

- Both:
  - Can assess how well model fits the data—no statistical tests with calibration
  - Can use the model to ask counterfactual questions:
  - What would happen if we shocked this variable?
  - How would the world look if we changed this parameter's value?

Why use complicated simulation estimators?

- "Better data and computing facilities have made sensible things simple.[1]"
- Simulation estimators make transparent the relationship between economic models and the equations used to estimate them.
- It seems odd to call computationally intensive econometric techniques "simple," especially given the all-too-frequent criticism that they are a "black box."
- However, there exists a tension between realism and the sorts of models that can produce closed-form estimating equations.
- Better models that can explain more interesting phenomena may not lend themselves to closed-form solutions.

[1] Pakes (2003)

Closed-Form Structural Example

- If you estimate a closed-form investment Euler equation from a dynamic investment model

$$\begin{aligned}
\text{M.C. of investing today} &= \text{Expected M.C. of waiting until tomorrow} \\
1 + a\frac{I_t}{K_t} &= \beta\mathbb{E}\left(MPK_{t+1} + (1-d)\left(1 + \alpha\frac{I_{t+1}}{K_{t+1}}\right)\right) \\
1 + a\frac{I_t}{K_t} &= \beta\left(MPK_{t+1} + (1-d)\left(1 + \alpha\frac{I_{t+1}}{K_{t+1}}\right)\right) + e_{t+1}
\end{aligned}$$

I_t	investment at time t
K_t	capital stock at time t
MPK_t	marginal product of capital at time t
d	depreciation rate
β	discount factor
$\alpha I_t^2/2K_t$	adjustment costs

- Then α is supposed to measure the magnitude of capital adjustment costs.

- Pro: very close connection between theory and what you want to measure.

Closed-Form Structural Example

- Con: the model is very simple. The parameter α can capture all sorts of other frictions.
- Solutions:
  - Pre-modern-computing.
    - Whited (1992): Parameterize financial frictions. Closed-form estimating equations.
  - Modern-computing era.
    - Hennessy and Whited (2007): Richer model, no closed-form estimating equations, exogenous frictions.
    - Li, Whited and Wu (2016): Richer model, no closed-form estimating equations, endogenous frictions
- This is where simulation estimators come in.

Motivating a Structural Paper

- Structural estimation imposes large costs on the reader.
- Any structural paper must put great effort into convincing a 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%.

Pros and Cons

- Reduced-form
  - “Fewer” assumptions? (Kahn and Whited (2018): just as many assumptions) Results more convincing?
  - Easier to do
  - 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 like a useful coauthor

Reduced Form Example

- Baker, Stein and Wurgler (2003) study the effect of stock market over-valuation on corporate investment.
- "In particular, the model in Stein [1996] implies that those firms that are in need of external equity finance will have investment that is especially sensitive to the nonfundamental component of stock prices."
- Here is the test:

$$\frac{CAPX_{it}}{A_{it-1}} = a_i + a_t + bQ_{it-1} + c\frac{CF_{it}}{A_{it-1}} + u_{it}$$

- Extremely hard to test this hypothesis because misvaluation is by definition unobservable.

Example: Warusawitharna and Whited (2016)

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.

Example: Schroth, Suarez and Taylor (2014), Dynamic Debt Runs

- Question: what factors are quantitatively most important for spurring bank runs?
- Panel data on firms issuing ABCP (short-term debt) in 2007

  Variables:
  - Weekly spreads (i.e. prices) on ABCP
  - Indicator for whether firm is experiencing a run
- How do you answer this question given these data?

Use a Model

- Setting: Continuous time, one borrowing firm, continuum of lenders
- Production function: Asset value follows geometric Brownian motion
- Financing: Firm buys an asset by issuing equity and short-term debt
- Preferences: Risk-neutral lenders optimally choose whether to roll over debt or “run”
- Information: a lender’s decision depends on beliefs about other lenders’ decisions (strategic complementarity)
- Equilibrium: debt is priced in competitive market

Parameters to Estimate

- Asset volatility
- Average debt maturity
- Average asset maturity
- Perceived weakness of firm's backup credit guarantee
- Asset liquidity = recovery rate in default
- Cap on yield spreads
- Investors' discount rate

Assessing the Model's Fit

- Frequency and timing of "recoveries" from runs
- Average debt yields in event time leading up to runs
- Yield volatility and its relation to yield levels
- Probability of future run, given current yield level (forecasting regression)

What Makes a Good Structural Paper

- Do 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? Don't do that.
- Is the paper using an appropriate model for the question?
  - Models are not reality, but are there any critical missing parts?
  - If so, how could the omission bias the estimates?
- Is the identification clear, or is it a black box?
  - Which features of the data identify each parameter, and why/how?
- Is the model fitting the data reasonably well?
  - If not, what can we learn from its failure?
  - Usually not a deal-breaker

What Makes a Good Structural Paper

- 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?

WHY GO STRUCTURAL? BECAUSE YOU GET TO DO IT ALL!

- Write down models, solve models numerically, gather data, do complicated econometrics, . . .
- Going structural may be right for you if...
  - . . .not much on your calendar for next few years
  - . . .emotionally robust

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