Empirical Economic Modeling

Industrial organization

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Lecture plan

Central research question in IO: How do firms produce?

- What is the level of returns to scale?
- How do input coefficients on capital and labor change over time?
- How does adoption of a new technology affect production?
- How much heterogeneity is there in measured productivity across firms?
- What explains such productivity differences?
- How does the allocation of firm inputs relate to productivity?

Source: Dan Ackerberg's 2017 AEA mini course (https://www.aeaweb.org/content/file?id=3015)

Olley, G. Steve and Ariel Pakes (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. *Econometrica* 64(6), 1263-1297.

Olley and Pakes (1996 ECMA). Dynamics of Productivity in Telcom

Olley and Pakes (1996 ECMA). Dynamics of Productivity in Telcom

Research question: How to estimate production functions?

(Log) value added production function with labor and capital inputs:

$$va_{jt} = \beta_0 + \beta_l l_{jt} + \beta_k k_{jt} + \omega_{jt} + \varepsilon_{jt}$$

ω_{jt}: Markovian firm productivity (unobserved by economist); $\omega_{jt} = g(\omega_{jt-1}) + \xi_{jt}$

ε_{jt}: transitory shock

What if we estimate this regression with OLS?

Olley and Pakes (1996 ECMA). Dynamics of Productivity in Telcom

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What if we estimate this regression with OLS? Omitted variable bias!

Timing: k_{jt} is predetermined (chosen before t) $\Rightarrow \mathbb{E}[\xi_{jt} \mid k_{jt}] = 0 \quad \Rightarrow \mathbb{E}[\xi_{jt} k_{jt}] = 0$

Olley and Pakes (1996 ECMA). Dynamics of Productivity in Telcom

Research question: How to estimate production functions?

Million dollar idea: use investment to back out productivity

$$i_{jt} = \tilde{i}_t(k_{jt}, \omega_{jt}) \quad \Rightarrow \omega_{jt} = \tilde{i}_t^{-1}(k_{jt}, i_{jt}) \quad \text{if } \tilde{i}_t(\cdot) \text{ is monotonic in } \omega_{jt}$$

$$\Rightarrow va_{jt} = \beta_0 + \beta_l l_{jt} + \underbrace{\beta_k k_{jt} + \tilde{i}_t^{-1}(k_{jt}, i_{jt})}_{\doteq \gamma_t(k_{jt}, i_{jt})} + \varepsilon_{jt}$$

1. Regress va_{jt} on l_{jt}, $f(k_{jt}, i_{jt}) \quad \Rightarrow$ get $\hat{\beta}_l$, $\hat{\gamma}_t(\cdot)$
2. Get $\hat{\beta}_k$ from moment condition $\mathbb{E}[\xi_{jt} k_{jt}] = 0$
   a. Given a guess for β_k, write $\hat{\omega}_{jt}(\beta_k) = \hat{\gamma}_t(k_{jt}, i_{jt}) - \beta_k k_{jt}$
   b. Regress $\hat{\omega}_{jt}(\beta_k)$ nonparametrically on $\hat{\omega}_{jt-1}(\beta_k) \quad \Rightarrow$ get $\hat{\xi}_{jt}(\beta_k)$
   c. Evaluate the sample analogue of the moment condition: $\frac{1}{NT} \sum_{j,t} \hat{\xi}_{jt}(\beta_k)\, k_{jt}$

   Iterate steps a–c until β_k minimizes the sample analogue of the moment condition

Levinsohn, James and Amil Petrin (2003). Estimating Production Functions Using Inputs to Control for Unobservables. *Review of Economic Studies 70*(2), 317-341.

Levinsohn and Petrin (2003 REStud). Estimating Production Functions Using Inputs

Levinsohn and Petrin (2003 REStud). Estimating Production Functions Using Inputs

Investment is likely not monotonic in productivity

If it were, firms with $k_{jt} = k$ and $i_{jt} = 0$ (many in data!) had the same productivity

Research question: How to fix OP?

Million dollar idea: use intermediate inputs instead

$$m_{jt} = \tilde{m}_t(k_{jt}, \omega_{jt}) \quad \Rightarrow \omega_{jt} = \tilde{m}_t^{-1}(k_{jt}, m_{jt})$$

$$\Rightarrow va_{jt} = \beta_0 + \beta_l l_{jt} + \underbrace{\beta_k k_{jt} + \tilde{m}_t^{-1}(k_{jt}, m_{jt})}_{\doteq \gamma_t(k_{jt}, m_{jt})} + \varepsilon_{jt}$$

Estimation is analogous to OP

Extra moment condition for the extra parameter: $\mathbb{E}[(\xi_{jt} + \varepsilon_{jt}) m_{jt}] = 0$

Ackerberg, Daniel A., Kevin Caves and Garth Frazer (2015). Identification Properties of Recent Production Function Estimators. *Econometrica 83*(6), 2411-2451.



Ackerberg, Caves and Frazer (2015 ECMA). Identification of Production Functions



Ackerberg, Caves and Frazer (2015 ECMA). Identification of Production Functions

Labor cannot be chosen independently of capital and intermediate inputs!

$$l_{jt} = \tilde{l}_t(k_{jt}, \omega_{jt}) = \tilde{l}_t(k_{jt}, \tilde{m}_t^{-1}(k_{jt}, m_{jt})) \doteq \tilde{\tilde{l}}_t(k_{jt}, m_{jt})$$

Research question: How to fix OP/LP?

Million dollar idea: drop first stage and express $m_{jt} = \tilde{m}_t(l_{jt}, k_{jt}, \omega_{jt})$

$$va_{jt} = \beta_0 + \beta_l l_{jt} + \beta_k k_{jt} + \omega_{jt} + \varepsilon_{jt}$$

$$\Rightarrow va_{jt} = \underbrace{\beta_0 + \beta_l l_{jt} + \beta_k k_{jt} + \tilde{m}_t^{-1}(l_{jt}, k_{jt}, m_{jt})}_{\doteq \gamma_t(l_{jt}, k_{jt}, m_{jt})} + \varepsilon_{jt}$$

Estimation is analogous to 2nd stage of OP/LP

Extra moment condition for the extra parameter: $\mathbb{E}[\xi_{jt} l_{jt-1}] = 0$

Gandhi, Amit, Salvador Navarro and David A. Rivers (2020). On the Identification of Gross Output Production Functions. *Journal of Political Economy 128*(8), 2973-3016.



Gandhi, Navarro and Rivers (2020 JPE). Gross Output Production Functions



Gandhi, Navarro and Rivers (2020 JPE). Gross Output Production Functions

OP/LP/ACF estimate value added so m_{jt} does not directly enter production

...except if production is Leontief and firms perfectly optimize in each t:

$$va_{jt} = \min\{f(l_{jt}, k_{jt}) + \omega_{jt}, g(m_{jt})\} + \varepsilon_{jt}$$
$$\Rightarrow \text{gross output } go_{jt} = \min\{f(l_{jt}, k_{jt}) + \omega_{jt}, g(m_{jt})\} + m_{jt} + \varepsilon_{jt}$$

This functional form is rather restrictive

Research question: How can we estimate $go_{jt} = f(l_{jt}, k_{jt}, m_{jt}) + \omega_{jt} + \varepsilon_{jt}$?

Gandhi, Navarro and Rivers (2020 JPE). Gross Output Production Functions

Research question: How can we estimate $go_{jt} = f(l_{jt}, k_{jt}, m_{jt}) + \omega_{jt} + \varepsilon_{jt}$?

Million dollar idea: use the firm's first-order condition for identification

With price-taking firms (P_t, R_t) & predetermined labor and capital:

$$\max_{M_{jt}} P_t \, \mathbb{E}_t[F(L_{jt}, K_{jt}, M_{jt}) e^{\omega_{jt} + \varepsilon_{jt}}] - R_t M_{jt}$$

Gandhi, Navarro and Rivers (2020 JPE). Gross Output Production Functions

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$$\max_{M_{jt}} P_t \, \mathbb{E}_t[F(L_{jt}, K_{jt}, M_{jt}) e^{\omega_{jt} + \varepsilon_{jt}}] - R_t M_{jt}$$

$$\rightsquigarrow 0 = P_t \frac{\partial}{\partial M_{jt}} F(L_{jt}, K_{jt}, M_{jt}) e^{\omega_{jt}} \, \mathbb{E}_t[e^{\varepsilon_{jt}}] - R_t$$

$$f(l_{jt}, k_{jt}, m_{jt}) + \omega_{jt} = r_t - p_t - \ln(\mathbb{E}_t[e^{\varepsilon_{jt}}])$$

$$\Rightarrow m_{jt} = \tilde{m}_t(l_{jt}, k_{jt}, \omega_{jt}) \quad \Rightarrow \omega_{jt} = \tilde{m}_t^{-1}(l_{jt}, k_{jt}, m_{jt})$$

Estimation is similar to ACF

Taking stock

Production function estimation is useful everywhere

- Academia: macro, labor, education, …
- Industry: antitrust, litigation, Big Tech, …

Canned estimation packages

- OP/LP/ACF: `prodest` in Stata
- GNR: `gnrprod` in R

Where to find data

Minimize GIGO (garbage in, garbage out)

Search for as granular data as possible

Always explore the raw data first!

Useful micro data sources:

- CERS Databank: go-to source for Hungarian micro data
- National Longitudinal Survey of Youth (NLSY97, NLSY79): US labor data by BLS
- Survey of Income and Program Participation (SIPP) by Census Bureau
- EU Statistics on Income and Living Conditions (EU-SILC) by Eurostat
- Augment with simulated tax data (TAXSIM for US, EUROMOD for EU, TAXBEN for UK)
- Collection of several data sources here (also saved in materials)
- Friends and family

Unified approach in practice

Sidenote

a. Find a broad topic that interests you

b. Find the most granular base data available

c. Identify the strengths of the data
   - Unique information, policy variation, …

d. 0. Formulate a relevant and important research question
   1. Describe the underlying economic behavior
   2. Describe the ideal experiment that could identify the structural parameters
   3. Attempt to reduce the model
   4. Quantify policy implications

Iterate until you have a strong pitch for a paper

Frontiers of IO

Central research question in IO: How do firms produce?

- Production function estimation: we got to the frontier
- …

Other central questions:

- How do firms respond to demand shocks?
- What is the origin and dynamics of product market power?
- How do firms make entry/exit decisions?

Things we do not cover:

- Industry dynamics
- Strategic interactions (empirical games)
- …
- See Sergey Lychagin's syllabus for more