Production Functions

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Motivation[1]

The production function is an object of primary economic interest.

- characterize firm's cost function.
- What are returns to scale in an industry?
- How persistent is productivity?
- Do input elasticities change over time?
- What is the impact of new technology?
- What is impact of trade/macro policies on production?
- Is productiviry correlated with exporting, importing, etc?

[1] I borrow from a variety of sources including Victor A's handbook chapter and Paul Grieco's and Peter Newberry's notes from Penn State.

More questions...

- What contributes to economic growth?
- Role of skill-biased tech change.
- Learning-by-doing?
- Do more prodictive firms choose higher quality or charge higher markups?

Fix Ideas

$$Y_{it} = L_{it}^{\alpha} K_{it}^{\beta} U_{it} \tag{1}$$

- U – (total factor) productivity.
    - in contrast to labor productivity: Y/L
- L, K – input choices of firms.
- α – output elasticities.

Fix Ideas – Data

Typical dataset:

- Yearly (usually) data.
- Measure of output: quantity, revenues, value-added (R - cost of materials)
- laborers, capital stock, investment, R&D, materials, energy costs.
- USA: Compustat, US Census Long. Research Database.
- Europe: Panel data from central banks.
- Other: Chile, Columbia...

Firms

- Production is dynamic by its nature.
- Why? Capital (K) requires investment (I) and depreciates.
- Firms engage in other activiites that are state variables.
  - R&D
  - Entry/exit
  - entry into new/export markets
- Unlike in demand estimation, it will be harder to ignore this for estimation.
- Models of industry dynamics rely on heterogeneous (and stochastic) productivity.
  - Jovanovic (1982), Hopanhyan (1992), Melitz (2003)

Econometric Simultaneity

Take logs of Eq 1:

$$y_{it} = \alpha\ell_{it} + \beta k_{it} + \omega_{it} + \varepsilon_{it} \tag{2}$$

- ε is just random and not known at the time of choosing K and L.
- ω_{it} is the "known" (to the firm) productivity.
- ℓ_t or k_t could be chosen with knowledge of ω_t
- Typically we think that k is chosen $t-1$ (as investment, i_{t-1})
- But more productive firms will choose more ℓ.

Classic solutions to the simultaneity problem

Input prices (or other) as instruments:

- Sometime data not available.
- Almost never any variation in data.
- if variation, probably not exogenous.

Fixed Effects:

- Assumption: ω_{it} is really $\omega_i + \varepsilon_{it}$
- Probably not suitable for long panels.
- Assumes no change in firm-specific technology – this rules out some

Classic solutions to the simultaneity problem

Dynamic Panel Methods

- See Arellano and Bond (1991).
- Let's put some structure on TFP.
- $\omega_t = \rho\omega_{t-1} + \xi_t$
- See problem set...

Econometric Selection

- Firms that exit have low productivity draws.
- Or, variable like “export status” will be endogenous.
- We will basically punt on this for now.

Roadmap of Talk

Olley and Pakes

Levinsohn and Petrin

Olley and Pakes (1996)

Propose alternative solution to simultaneity (and selection) problem.

Idea

- Greater (optimal) investment this period implies the firm realized a higher ω_t.
- Use investment (i_t) to "proxy" for TFP (ω_t).
  - Remember: investment does not get used until next period!
- This only works under certain conditions – *which is the innovation in this paper.*

OP - Details[2]

OP1: Information
Firm info set ($\mathcal{I}_t$) includes only current and past ω. ε is exogenous: $E[\varepsilon_t \mid \mathcal{I}_t] = 0$.

OP2: First Order Markov
$p(\omega_{i,t+1} \mid \mathcal{I}_{it}) = p(\omega_{i,t+1} \mid \omega_{it})$

OP3: Timing
Firms accumulate capital according to $k_{it} = \kappa(k_{i,t-1}, i_{i,t-1})$. Labor is not dynamic.

OP4: Scalar Unobservable
Firms investment decisions: $i_{it} = f_t(k_{it}, \omega_{it})$.

OP5: Strict Monotonicity
$f_t(k_{it}, \omega_{it})$is strictly increasing in ω_{it}.

[2] The description here follows ACF.

Marginal Product of Capital and Investment as a Proxy

OP2: First Order Markov
$p(\omega_{i,t+1} \mid I_{it}) = p(\omega_{i,t+1} \mid \omega_{it})$

OP5: Strict Monotonicity
$f_t(k_{it}, \omega_{it})$is strictly increasing in ω_{it}.

These together imply: firms with higher ω_{it} have higher expected marginal product of capital in the future and will invest more.

As ACF point out, proving this is tedious and may not extend to all models, but is general enough for relatively straightforward models with C-D or translog PFs.

Econometric Procedure – First Stage

- Invert investment policy function:

$$\omega_{it} = h(k_{it}, i_{it})$$

  (remember we can do this because i is monotonic in ω!)

- Then plug in for omega in the linear (in logs) production function:

$$y_{it} = \alpha \ell_{it} + \Phi_t(k_{it}, i_{it}) + \varepsilon_{it},$$

  where

$$\Phi_t(k_{it}, i_{it}) = \beta k_{it} + h(k_{it}, i_{it}).$$

Econometric Procedure – First Stage

- First stage regression:
$$y_{it} = \alpha \ell_{it} + \Phi_t(k_{it}, i_{it}) + \varepsilon_{it},$$
where
$$\Phi_t(k_{it}, i_{it}) = \beta k_{it} + h(k_{it}, i_{it}).$$

- Notice that k enters multiple places, and $h()$ is unknown, so the only primitive we can recover is α.

- But we can also recover $\hat{\Phi}(k_{it}, i_{it})$ – treat this non-parametrically.

Econometric Procedure – Second Stage

Roadmap of Talk

Olley and Pakes

Levinsohn and Petrin

Levinsohn and Petrin (2003)