Micro Data for Macro Models

Topic 1: Productivity Dispersion, Aggregation, and Misallocation

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January 7th, 2019

Plan for this Topic

1. Document large and persistent dispersion of firms' productivity

2. Show benchmark irrelevance result: without frictions to inputs, economy still has representative firm

3. Measure input frictions using reduced form "misallocation" measures

    - Substantial frictions at micro-level
    - Implies large differences in the aggregate

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Definitions of Productivity

- Productivity is the amount of **output produced per unit of inputs**
- Depends on unit of analysis:
    1. Establishment: A business or production unit at a single location
    2. Firm: A collection of establishments under common legal control
- Depends on input:
    1. Labor productivity: output per labor input $\frac{y_{it}}{n_{it}}$
    2. Capital productivity: output per capital input $\frac{y_{it}}{k_{it}}$
    3. Total factor productivity: output per composite of inputs $\frac{y_{it}}{k_{it}^{\alpha} n_{it}^{1-\alpha}}$

What Is Productivity?

- Productivity is **anything that influences output other than measured inputs**
  - A useful measure of our ignorance

- What could it be?
  1. Technology
  2. Efficiency
  3. Managerial skill
  4. Market conditions
  5. Regulation
  6. Utilization

Measuring Productivity in Practice

$$z_{it} = \log(y_{it}) - \alpha \log(k_{it}) - (1 - \alpha) \log(n_{it})$$

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1. **Estimate output elasticity** α
   - Factor shares method: with Cobb-Douglas and perfect competition, $1 - \alpha =$ labor share
   - Production function estimation: have to deal with endogeneity problem

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2. **Construct measures of** y_{it}**,** k_{it}**, and** n_{it}
   - y_{it}: usually gross output (sales) or value added (sales - materials)
   - k_{it}: book value, replacement value, perpetual inventory
   - n_{it}: number of workers, hours worked, wage bill

Stylized Facts About Productivity (Syverson 2011)

1. **Enormous dispersion across establishments, even within narrowly-defined sector**
    - Within average sector, 90th percentile firm is 2 times as productive as 10th
    - SD of this range across sectors is 0.17

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    - Annual autocorrelation 0.6 - 0.8

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2. **Productivity is persistent**
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3. **Productivity matters**
   - Correlated with outcomes like hiring, investment, survival

A Case Study: Castro, Clementi, and Lee (2015)

- A nice illustration of computing TFP using Census data: Annual Survey of Manufactures (ASM)
  - Standard data source for computing productivity (main alternative is Compustat)
  - Confidential; need approved project proposal
- Advantages
  - Measures of output, labor, and capital
  - Panel dimension allows for fixed-effect analysis
  - Long time sample: since late 1970s
- Disadvantages
  - Only covers manufacturing, a declining share of economy
  - Measurement error a potential problem

Variable Definitions and Measurement

$$z_{ist} = \log(y_{ist}) - \alpha^k_{st} \log(k_{ist}) - \alpha^n_{st} \log(n_{ist}) - \alpha^m_{st} \log(m_{ist})$$

- Output y_{ist}: gross revenue divided by 4-digit SIC price deflator from NBER
- Capital k_{ist}: constructed using perpetual inventory method

$$k_{is0} = \text{book value}, k_{ist+1} = (1 - \delta_{st})k_{ist} + \frac{i_{ist}}{p^i_{st}}$$

  - i_{ist}: total capital expenditures
  - δ_{st}: 2-digit depreciation rates from BEA
  - p^i_{st}: 4-digit investment price deflator from NBER

Variable Definitions and Measurement

$$z_{ist} = \log(y_{ist}) - \alpha^k_{st} \log(k_{ist}) - \alpha^n_{st} \log(n_{ist}) - \alpha^m_{st} \log(m_{ist})$$

- Labor n_{ist}: total hours of production and nonproduction workers

$$n_{ist} = \text{hours}^{\text{prod}}_{ist} + \frac{\text{wage bill}^{\text{nonprod}}_{ist}}{\text{wage bill}^{\text{prod}}_{ist}} \text{hours}^{\text{prod}}_{ist}$$

- Materials m_{ist}: total materials cost deflated by 4-digit deflator from NBER
- Labor and material elasticities α^n_{st} and α^m_{st}: revenue shares at 4-digit sector
  - Capital elasticity α^k_{st}: $\alpha^k_{st} = 1 - \alpha^n_{st} - \alpha^m_{st}$

Shocks to TFP

$$z_{ist} = \mu_i + \mu_{st} + \rho_s z_{ist-1} + \beta_s \log(\text{size})_{ist} + \sum_{j=1}^{3} \Psi_{sj} D_{istj} + \varepsilon_{ist}$$

where

- Firm fixed effect μ_i
- Sector-time fixed effect μ_{st}
- Autocorrelation by sector ρ_s
- Size by industry β_s
- Plant age effects D_{istj}

The residual ε_{ist} is the unforcastable shock to TFP

Shocks to TFP

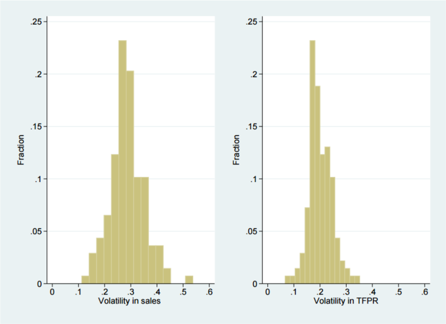

Figure 1: Histogram of idiosyncratic risk by sector.

About 80% of total variation in ε_{ist} is specific to the establishment

$\rightarrow$ Most volatility is micro volatility!

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   - Substantial frictions at micro-level
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Aggregation with Productivity Dispersion

Consider production side of economy in time t with:

- Heterogeneous firms $i \in [0, 1]$ with production function

$$y_{it} = e^{z_{it}} k_{it}^{\alpha_k} n_{it}^{\alpha_n}, \alpha_k + \alpha_n \leq 1$$

- Perfect competition in factor markets
    - Rent capital at rate r_t
    - Hire labor at rate w_t

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- Perfect competition in factor markets
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Can we represent this structure with an aggregate production function?

$$Y_t = e^{Z_t} F(K_t, N_t) \text{ where } K_t = \int k_{it} di, N_t = \int n_{it} di, \text{ and } Y_t = \int y_{it} di$$

Decreasing Returns, $\alpha_k + \alpha_n < 1$

Claim: aggregates Y_t, K_t, and N_t are same with representative firm

$$Y_t = e^{Z_t} K_t^{\alpha_k} N_t^{\alpha_n} \text{ with } Z_t = \log\left(\int (e^{Z_{it}})^{\frac{1}{1-\alpha_k-\alpha_n}}\right)$$

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- First order conditions for profit maximization of firm i:

$$\alpha_k e^{Z_{it}} k_{it}^{\alpha_k - 1} n_{it}^{\alpha_n} = r_t$$
$$\alpha_n e^{Z_{it}} k_{it}^{\alpha_k} n_{it}^{\alpha_n - 1} = w_t$$

$\rightarrow$ Firms equalize their marginal products

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- Manipulate the FOCs to get

$$k_{it} = (e^{Z_{it}})^{\frac{1}{1-\alpha_k-\alpha_n}} \left(\frac{\alpha_k}{r_t}\right)^{\alpha_k} \left(\frac{\alpha_n}{w_t}\right)^{1-\alpha_k}$$

$$n_{it} = (e^{Z_{it}})^{\frac{1}{1-\alpha_k-\alpha_n}} \left(\frac{\alpha_k}{r_t}\right)^{1-\alpha_n} \left(\frac{\alpha_n}{w_t}\right)^{\alpha_n}$$

$$y_{it} = (e^{Z_{it}})^{\frac{1}{1-\alpha_k-\alpha_n}} \left(\frac{\alpha_k}{r_t}\right)^{\frac{\alpha_k}{1-\alpha_k-\alpha_n}} \left(\frac{\alpha_n}{w_t}\right)^{\frac{\alpha_n}{1-\alpha_k-\alpha_n}}$$

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- Aggregate to get

$$K_t = \int k_{it} di = e^{Z_t} \left(\frac{\alpha_k}{r_t}\right)^{\alpha_k} \left(\frac{\alpha_n}{w_t}\right)^{1-\alpha_k}$$

$$N_t = \int n_{it} di = e^{Z_t} \left(\frac{\alpha_k}{r_t}\right)^{1-\alpha_n} \left(\frac{\alpha_n}{w_t}\right)^{\alpha_n}$$

$$Y_t = \int y_{it} di = e^{Z_t} \left(\frac{\alpha_k}{r_t}\right)^{\frac{\alpha_k}{1-\alpha_k-\alpha_n}} \left(\frac{\alpha_n}{w_t}\right)^{\frac{\alpha_n}{1-\alpha_k-\alpha_n}}$$

$\rightarrow$ Same choices as the representative firm!

Constant Returns, $\alpha_k + \alpha_n = 1$

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- With constant returns, scale of production not pinned down:

$$y_{it} = e^{z_{it}} \left(\frac{\alpha_k}{1-\alpha_k} \frac{w_t}{r_t} \right)^{\alpha_k} n_{it}$$

$\rightarrow$ wage must adjust so highest productivity firm indifferent

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- Need curvature in revenue function for non-degenerate size distribution

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Hsieh and Klenow (2009)

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  1. How disperse are marginal products across firms in the data?
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- Large differences across countries: TFP gains 40% in US vs. 130% in India

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$$y_{it} = e^{z_{it}} k_{it}^{\alpha} n_{it}^{\alpha}$$

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- Representative final good producer $Y_t = \left(\int y_{it}^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}$
  - Firm i monopolistic competitor with CES demand curve $\left(\frac{p_{it}}{P_t}\right)^{-\sigma} Y_t$
  - Alternative way to generate curvature in revenue function

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    - Alternative way to generate curvature in revenue function
- Idiosyncratic distortions to factor prices: $(1 + \tau_{it}^{n})w_t$ and $(1 + \tau_{it}^{k})r_t$
    - τ_{it}^{n}: hiring costs, regulations, search frictions, ...
    - τ_{it}^{k}: adjustment costs, financial constraints, ...

Firm Behavior Given Wedges

- Optimal input choices:

$$\underbrace{\alpha\left(\frac{\sigma-1}{\sigma}\right)\frac{p_{it}y_{it}}{k_{it}}}_{\text{MRPK}_{it}} = (1+\tau^k_{it})r_t$$

$$\underbrace{(1-\alpha)\left(\frac{\sigma-1}{\sigma}\right)\frac{p_{it}y_{it}}{n_{it}}}_{\text{MRPL}_{it}} = (1+\tau^n_{it})w_t$$

$\rightarrow$ τ^n_{it} and τ^k_{it}: how much firms do not equalize marginal products

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$\rightarrow \tau^n_{it}$ and τ^k_{it}: how much firms do not equalize marginal products

- Output:

$$y_{it} = \left(\left(\frac{\sigma-1}{\sigma}\right)\frac{e^{z_{it}}}{\left(\frac{(1+\tau^k_{it})r_t}{\alpha}\right)^{\alpha}\left(\frac{(1+\tau^n_{it})w_t}{1-\alpha}\right)^{1-\alpha}}\right)^{\sigma}$$

Aggregation

- After a lot of algebra (don't worry about it):

$$Y_t = (T_t^p)^{\frac{\sigma}{\sigma-1}}(T_t^k)^{\alpha}(T_t^n)^{1-\alpha}K_t^{\alpha}N_t^{1-\alpha}, \text{ where}$$

$$T_t^p = \left(\int \left(\frac{(1+\tau_{it}^k)^{\alpha}(1+\tau_{it}^n)^{1-\alpha}}{e^{z_{it}}}\right)^{1-\sigma} di\right)^{-1}$$

$$T_t^n = \left(\int \left(\frac{(1+\tau_{it}^k)^{\alpha}(1+\tau_{it}^n)^{-\alpha}}{e^{z_{it}}}\right)^{1-\sigma} \frac{1}{1+\tau_{it}^n} di\right)^{-1}$$

$$T_t^k = \left(\int \left(\frac{(1+\tau_{it}^k)^{\alpha-1}(1+\tau_{it}^n)^{1-\alpha}}{e^{z_{it}}}\right)^{1-\sigma} \frac{1}{1+\tau_{it}^k} di\right)^{-1}$$

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- Compare distribution of wedges in data vs. no wedges

Measuring Wedges and Productivity in the Data

$$
\begin{aligned}
(1+\tau_{it}^{k}) &= \frac{\text{MRPK}_{it}}{r_t} = \frac{1}{r_t} \times \alpha \left(\frac{\sigma-1}{\sigma}\right) \frac{p_{it}y_{it}}{k_{it}} \\
(1+\tau_{it}^{n}) &= \frac{\text{MRPL}_{it}}{w_t} = \frac{1}{w_t} \times (1-\alpha) \left(\frac{\sigma-1}{\sigma}\right) \frac{p_{it}y_{it}}{n_{it}} \\
e^{z_{it}} &= \frac{y_{it}}{k_{it}^{\alpha} n_{it}^{1-\alpha}} = \frac{(p_{it}y_{it})^{\frac{\sigma-1}{\sigma}}}{k_{it}^{\alpha} n_{it}^{1-\alpha}}
\end{aligned}
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Want to infer wedges and productivity from data

Measuring Wedges and Productivity in the Data

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Plant level data from Census of Manufactures

- Revenue $p_{it}y_{it}$ is nominal value added
- Capital k_{it} is book value of capital stock
- Labor n_{it} is wage bill of the plant

Measuring Wedges and Productivity in the Data

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Remaining quantities are calibrated

- Rental rate on capital $r_t = 10\%$
- Elasticity of substitution $\sigma = 3$
- Capital share α as 1 - labor share
- NB: actual implementation in paper complicated by sectoral heterogeneity

Dispersion in TFPQ in Line with Literature

TABLE I
DISPERSION OF TFPQ

China	1998	2001	2005
S.D.	1.06	0.99	0.95
75 – 25	1.41	1.34	1.28
90 – 10	2.72	2.54	2.44
N	95,980	108,702	211,304
India	**1987**	**1991**	**1994**
S.D.	1.16	1.17	1.23
75 – 25	1.55	1.53	1.60
90 – 10	2.97	3.01	3.11
N	31,602	37,520	41,006
United States	**1977**	**1987**	**1997**
S.D.	0.85	0.79	0.84
75 – 25	1.22	1.09	1.17
90 – 10	2.22	2.05	2.18
N	164,971	173,651	194,669

Marginal Products Very Disperse

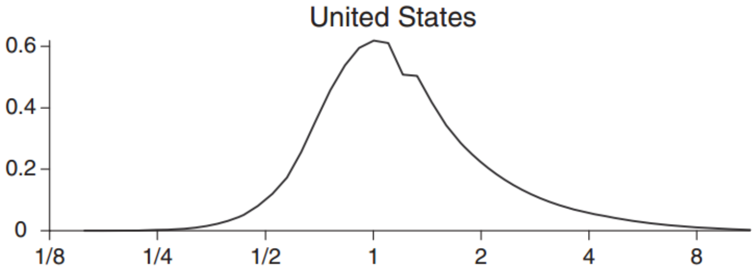


FIGURE II
Distribution of TFPR

$$\text{TFPR}_{it} = \frac{p_{it} y_{it}}{k_{it}^{\alpha} n_{it}^{1-\alpha}} = (\text{MPRK}_{it})^{\alpha} (\text{MRPL}_{it})^{1-\alpha}$$

Marginal Products More Disperse in India and China

TABLE II
DISPERSION OF TFPR

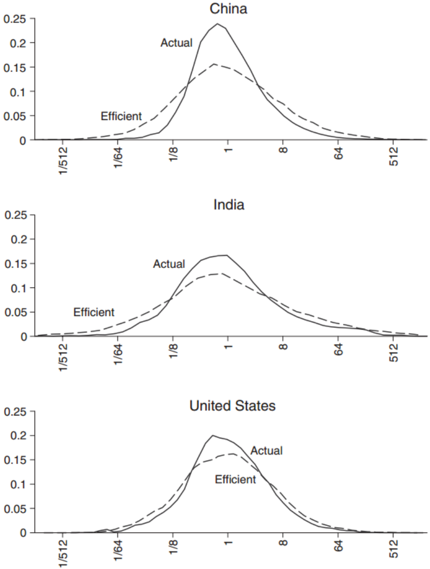
China	1998	2001	2005
S.D.	0.74	0.68	0.63
75 – 25	0.97	0.88	0.82
90 – 10	1.87	1.71	1.59
India	**1987**	**1991**	**1994**
S.D.	0.69	0.67	0.67
75 – 25	0.79	0.81	0.81
90 – 10	1.73	1.64	1.60
United States	**1977**	**1987**	**1997**
S.D.	0.45	0.41	0.49
75 – 25	0.46	0.41	0.53
90 – 10	1.04	1.01	1.19

Large Gains From Equalizing Marginal Products

TABLE IV
TFP GAINS FROM EQUALIZING TFPR WITHIN INDUSTRIES

China	1998	2001	2005
%	115.1	95.8	86.6
India	1987	1991	1994
%	100.4	102.1	127.5
United States	1977	1987	1997
%	36.1	30.7	42.9

Efficient vs. Actual Size Distribution



Takeaways From Topic 1

- Large dispersion in productivity across firms
  - Measurement involves many choices
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    - Firms equalize marginal products to factor prices
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- Even with heterogeneity, representative firm exists if can adjust inputs frictionlessly
  - Firms equalize marginal products to factor prices
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- Misallocation literature provides evidence that world is far away from representative firm
  - Reduced-form wedges indicate firms far away from equal marginal products
  - Dispersion in wedges matters for aggregate outcomes

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$\Longrightarrow$ **The rest of the course is figuring out what these wedges are**

The Rest of the Course

Topic 2: Investment and capital adjustment costs

- Firms' investment decisions are lumpy
- What kinds of frictions do we need to account for these patterns?
- What are the implications for aggregate dynamics?
- Aside: how do we solve models with heterogeneity?

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Topic 3: Financial frictions

- Many decisions depend on firms' financial health
- What kinds of financial frictions fit the data best?
- What are the implications for aggregate dynamics?

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Topic 2: Investment and capital adjustment costs

- Firms' investment decisions are lumpy
- What kinds of frictions do we need to account for these patterns?
- What are the implications for aggregate dynamics?
- Aside: how do we solve models with heterogeneity?

Topic 3: Financial frictions

- Many decisions depend on firms' financial health
- What kinds of financial frictions fit the data best?
- What are the implications for aggregate dynamics?

Topic 4: Entry, exit, and firms' lifecycles

- How do firms enter, grow, and die?
- What are the implications for aggregate dynamics?