PhD Topics in Macroeconomics

Lecture 10: misallocation, part two

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This lecture

Hsieh/Klenow (2009) quantification of misallocation

1- Inferring misallocation from measured gaps in marginal products

- efficient benchmark
- aggregation with distortions

2- Hypothetical gains from reallocating capital and labor

- eliminating distortions entirely
- reducing distortions to US level

Hsieh/Klenow overview

- Background: large aggregate TFP differences across countries

  – US manufacturing TFP 2.3× China (in 1996)
  – US manufacturing TFP 2.6× India

- Why is aggregate TFP so low as compared to the US?

  – traditional explanations focus on barriers to technology diffusion

  – misallocation explanation focuses on inefficient use of technologies (licensing regulations, size-dependent policies, SOEs)

- Main findings

  – larger gaps in China and India than US
  – can account for about half of aggregate TFP differences
  – shrinking gaps in China but not India
  – large plants have large marginal products in China and India

Model

- Final output Y a Cobb-Douglas aggregate of industry output

$$\log Y = \sum_{s=1}^{S} \theta_s \log Y_s$$

with expenditure shares θ_s that sum to one

- Industry output a CES aggregate of M_s differentiated products

$$Y_s = \left(\sum_{i=1}^{M_s} Y_{is}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \qquad \sigma > 1$$

- Firms produce with a Cobb-Douglas aggregate of capital and labor

$$Y_{is} = A_{is} K_{is}^{\alpha_s} L_{is}^{1-\alpha_s}, \qquad 0 < \alpha_s < 1 \qquad \text{for each } s = 1, \ldots, S$$

Expenditure

- Cost minimization by representative perfectly competitive producer of final output

$$P_s Y_s = \theta_s P Y$$

and take Y to be the numeraire so that $P = 1$

- Residual demand curves facing monopolistically competitive producers within each industry

$$Y_{is} = \left(\frac{P_{is}}{P_s}\right)^{-\sigma} Y_s$$

Distortions

- Firm-specific (idiosyncratic) distortions

- Individual firm faces two types of distortions

$\tau_{Y,is}$ distortions to marginal product of capital *and* labor
$\tau_{K,is}$ distortions to marginal product of capital *relative to* labor

- Profits for an individual firm

$$\pi_{is} = (1 - \tau_{Y,is})\, P_{is} Y_{is} - wL_{is} - (1 + \tau_{K,is}) r K_{is}$$

maximized by choosing L_{is}, K_{is} taking as given the production function, residual demand, and the effective factor prices

- Distortions to labor can be 'synthesized' as particular combinations of $\tau_{Y,is}$ and $\tau_{K,is}$

Efficient benchmark (no τ)

- Cost function

$$C(y) := \min_{k,l} \left[wl + rk \,\middle|\, Ak^{\alpha} l^{1-\alpha} = y \right]$$

familiar solution

$$C(y) = \left(\frac{r}{\alpha}\right)^{\alpha} \left(\frac{w}{1-\alpha}\right)^{1-\alpha} (y/A) \;=:\; c(w,r,\alpha)\,(y/A)$$

- Individual factor demands

$$rk = \alpha c(w,r,\alpha)(y/A), \qquad wl = (1-\alpha)c(w,r,\alpha)(y/A)$$

- Price is then constant markup over marginal cost

$$p = \frac{\sigma}{\sigma-1} c(w,r,\alpha)/A$$

Aside on factor/income shares

- Cobb-Douglas production function but markup distortion
  $\Rightarrow$ factor shares $\neq$ output elasticities

- Labor share

$$\frac{wl}{py} = \frac{(1-\alpha)c(w,r,\alpha)(y/A)}{\frac{\sigma}{\sigma-1}c(w,r,\alpha)(y/A)} = \frac{1-\alpha}{\frac{\sigma}{\sigma-1}} < 1-\alpha$$

- Capital share similarly

$$\frac{rk}{py} = \frac{\alpha}{\frac{\sigma}{\sigma-1}} < \alpha$$

- Residual is monopoly (economic) profits

$$\frac{\pi}{py} = 1 - \frac{wl+rk}{py} = \frac{1}{\sigma}$$

Efficient benchmark (no τ)

- So with no distortions, firms have

$$P_{is} = \frac{\sigma}{\sigma - 1} c(w, r, \alpha_s) / A_{is}$$

$$Y_{is} = (P_{is}/P_s)^{-\sigma} Y_s$$

$$rK_{is} = \alpha_s c(w, r, \alpha_s)(Y_{is}/A_{is})$$

$$wL_{is} = (1 - \alpha_s) c(w, r, \alpha_s)(Y_{is}/A_{is})$$

- Note all firms in same industry s have same capital/labor ratio

$$\frac{K_{is}}{L_{is}} = \frac{\alpha_s}{1 - \alpha_s} \frac{w}{r}, \qquad \text{for all } i \text{ in same } s$$

Industry productivity A_s

- Productivity for industry s is defined by

$$A_s := \frac{Y_s}{K_s^{\alpha_s} L_s^{1-\alpha_s}}$$

where K_s and L_s are industry capital and labor

- Summing input demands over firms

$$K_s := \sum_{i=1}^{M_s} K_{is} = \frac{\alpha_s c(w, r, \alpha_s)}{r} \sum_{i=1}^{M_s} \frac{Y_{is}}{A_{is}}$$

$$L_s := \sum_{i=1}^{M_s} L_{is} = \frac{(1 - \alpha_s) c(w, r, \alpha_s)}{w} \sum_{i=1}^{M_s} \frac{Y_{is}}{A_{is}}$$

Industry productivity A_s

- Taking the geometric average and simplifying

$$K_s^{\alpha_s} L_s^{1-\alpha_s} = \sum_{i=1}^{M_s} \frac{Y_{is}}{A_{is}}$$

- So industry productivity is a harmonic mean of firm productivities with weights given by *quantity* shares

$$\frac{1}{A_s} = \frac{K_s^{\alpha_s} L_s^{1-\alpha_s}}{Y_s} = \sum_{i=1}^{M_s} \frac{1}{A_{is}} \frac{Y_{is}}{Y_s}$$

- Using the demand curves for individual products

$$\frac{1}{A_s} = \sum_{i=1}^{M_s} \frac{1}{A_{is}} \left(\frac{P_{is}}{P_s} \right)^{-\sigma}$$

Now need to use relative prices in terms of relative productivities

Industry price index P_s

- Revenue shares sum to one

$$1 = \sum_{i=1}^{M_s} \frac{P_{is} Y_{is}}{P_s Y_s} \quad \Rightarrow \quad P_s = \left(\sum_{i=1}^{M_s} P_{is}^{1-\sigma} \right)^{1/(1-\sigma)}$$

- So plugging in for individual prices

$$P_s = \frac{\sigma}{\sigma - 1} c(w, r, \alpha_s) \left(\sum_{i=1}^{M_s} A_{is}^{\sigma-1} \right)^{1/(1-\sigma)}$$

- Therefore producer relative prices are just

$$\frac{P_{is}}{P_s} = \frac{1}{A_{is}} \left(\sum_{j=1}^{M_s} A_{js}^{\sigma-1} \right)^{1/(\sigma-1)}$$

Decomposition into A_s and P_s

- Finally plugging this expression for relative prices back into our expression for A_s and solving gives

$$A_s = \left(\sum_{i=1}^{M_s} A_{is}^{\sigma-1} \right)^{1/(\sigma-1)}$$

- Given this solution, can legitimately say that indeed

$$P_s = \frac{\sigma}{\sigma-1} c(w, r, \alpha_s)/A_s$$

so that for every i in s

$$P_{is}A_{is} = P_s A_s = \frac{\sigma}{\sigma-1} c(w, r, \alpha_s)$$

Relative prices (in same s) are reciprocals of relative productivities

Now with distortions

- With the capital distortion the firm's cost function becomes

$$C(y) := \min_{k,l} \left[wl + (1+\tau_K) rk \,\middle|\, Ak^{\alpha} l^{1-\alpha} = y \right]$$

$$= c(w, (1+\tau_K)r, \alpha)(y/A)$$

$$= c(w, r, \alpha)(1+\tau_K)^{\alpha}(y/A)$$

where $c(\cdot)$ is the same function as in the non-distorted case above

- Implies individual factor demands

$$(1+\tau_K)rk = \alpha c(w, r, \alpha)(1+\tau_K)^{\alpha}(y/A)$$

$$wl = (1-\alpha)c(w, r, \alpha)(1+\tau_K)^{\alpha}(y/A)$$

Pricing with revenue distortion

- With revenue tax, problem of a firm is now to choose y to max

$$\pi = (1-\tau_Y)py - C(y)$$

subject to the residual demand curve

- Firm sets *after-tax* price as constant markup over marginal cost

$$(1-\tau_Y)p = \frac{\sigma}{\sigma-1}C'(y)$$

- With distorted cost function from above

$$p = \frac{\sigma}{\sigma-1}\frac{c(w,r,\alpha)}{A}\frac{(1+\tau_K)^\alpha}{1-\tau_Y}$$

To summarize, with distortions firms now have

$$P_{is} = \frac{\sigma}{\sigma - 1} \frac{c(w, r, \alpha_s)}{A_{is}} \frac{(1 + \tau_{K,is})^{\alpha_s}}{(1 - \tau_{Y,is})}$$

$$Y_{is} = \left(\frac{P_{is}}{P_s}\right)^{-\sigma} Y_s$$

$$(1 + \tau_{K,is}) r K_{is} = \alpha_s \frac{c(w, r, \alpha_s)}{A_{is}} (1 + \tau_{K,is})^{\alpha_s} Y_{is}$$

$$w L_{is} = (1 - \alpha_s) \frac{c(w, r, \alpha_s)}{A_{is}} (1 + \tau_{K,is})^{\alpha_s} Y_{is}$$

Goal now is to *infer* distortions from producer data

Key to inference

(1) Variation in capital/labor ratio reveals $\tau_{K,is}$

$$1 + \tau_{K,is} = \frac{\alpha_s}{1 - \alpha_s} \frac{wL_{is}}{rK_{is}}$$

(2) Variation in labor share reveals $\tau_{Y,is}$

$$1 - \tau_{Y,is} = \frac{\sigma}{\sigma - 1} \left(\frac{1}{1 - \alpha_s} \right) \frac{wL_{is}}{P_{is}Y_{is}}$$

Data

- **India**: Annual Survey of Industries
  - annual fiscal years 1987/88 – 1994/95
  - census of large manufacturing plants, sample of small plants
  - approx 40,000 plants per year, 400 industries (4 digit)
  - labor compensation, value-added, age, book value capital stock etc

- **China**: Annual Surveys of Industrial Production
  - annual 1998 – 2005
  - census of large nonstate firms plus all state firms
  - grows to approx 200,000 firms in 2005, 400 industries (4 digit)
  - wage payments grossed up to match aggregate labor compensation

Data

- **United States**: Census of Manufactures
  - 1977, 1982, 1987, 1992, 1997
  - census of manufacturing plants
  - approx 160,000 plants per year, 400 industries (4 digit)
  - labor compensation, value-added, book value capital stock etc
- Other sample issues
  - drop industries without close US counterpart
  - trim 1% tails

Measurement / calibration

- Assigned parameters

$r = .1$	real rate 5% + depreciation 5%
$\sigma = 3$	elasticity of substitution across producers within industry
$1 - \alpha_s$	labor share in corresponding US industry (* scaled up)

- Inferred distortions (data objects in blue)

$$1 + \tau_{K,is} = \frac{\alpha_s}{(1-\alpha_s)r} \frac{wL_{is}}{K_{is}}$$

$$1 - \tau_{Y,is} = \frac{\sigma}{\sigma - 1} \left(\frac{1}{1-\alpha_s} \right) \frac{wL_{is}}{P_{is}Y_{is}}$$

- With these inferred distortions, what do we conclude about producer and aggregate productivity?

TFPQ vs. TFPR

- We are interested in physical productivity A_{is} but we can typically only measure *revenue productivity*

- Let TFPQ denote physical productivity and TFPR denote revenue productivity. Define them as follows

$$\text{TFPQ}_{is} := \frac{Y_{is}}{K_{is}^{\alpha_s} L_{is}^{1-\alpha_s}} = A_{is}$$

and

$$\text{TFPR}_{is} := \frac{P_{is} Y_{is}}{K_{is}^{\alpha_s} L_{is}^{1-\alpha_s}} = P_{is} A_{is}$$

- In the efficient benchmark, TFPQ naturally varies across firms with A_{is} but TFPR would be constant across firms (higher productivity firms charging proportionately lower prices)

TFPR

- With distortions, firm-level TFPR is

$$P_{is}A_{is} = \frac{\sigma}{\sigma - 1} c(w, r, \alpha_s) \frac{(1 + \tau_{K,is})^{\alpha}}{1 - \tau_{Y,is}}$$

(inferred objects in red)

- TFPR varies with both distortions

Inferring quantities from revenue

- We observe revenue $P_{is}Y_{is}$ and want to infer Y_{is} and hence A_{is}

- Residual demand $Y_{is} = (P_{is}/P_s)^{-\sigma} Y_s$ so revenue share

$$\frac{P_{is}Y_{is}}{P_sY_s} = \left(\frac{Y_{is}}{Y_s}\right)^{\frac{\sigma-1}{\sigma}}$$

- So TFPQ is inferred to be (data objects in blue)

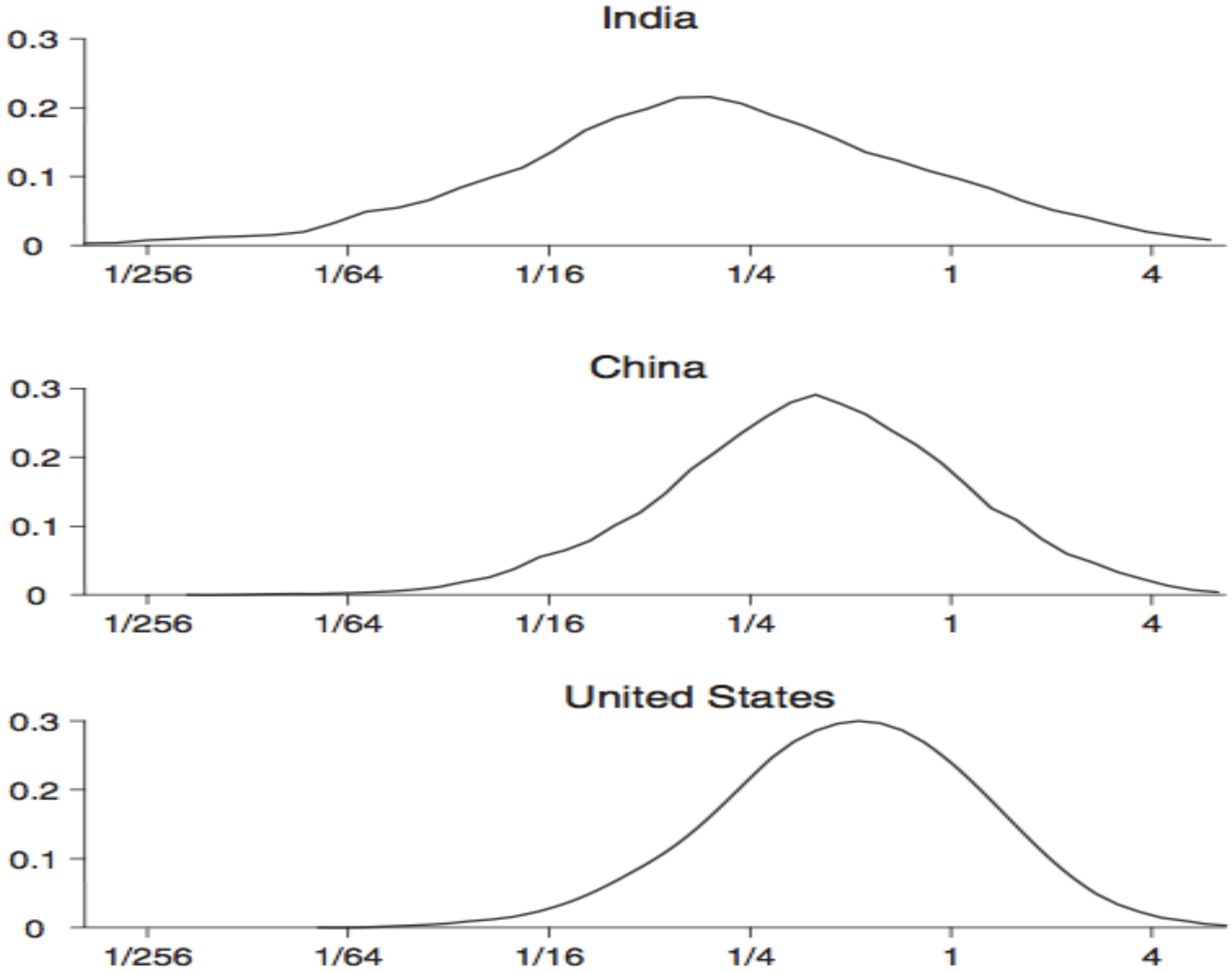
$$A_{is} = \frac{Y_{is}}{K_{is}^{\alpha_s} L_{is}^{1-\alpha_s}} = \kappa_s \frac{(P_{is}Y_{is})^{\frac{\sigma}{\sigma-1}}}{K_{is}{}^{\alpha_s}(wL_{is})^{1-\alpha_s}}$$

where the scalar κ_s absorbs the industry terms

$$\kappa_s := w^{1-\alpha_s} (P_sY_s)^{-\frac{\sigma}{\sigma-1}} Y_s$$

- What matters is *relative* A_{is} across firms, can normalize $\kappa_s = 1$

Distribution of TFPQ ($= A_{is}$)



Distributions for most recent year. Small firms underreported in Chinese data so US and India better comparison. Many more small plants in India.

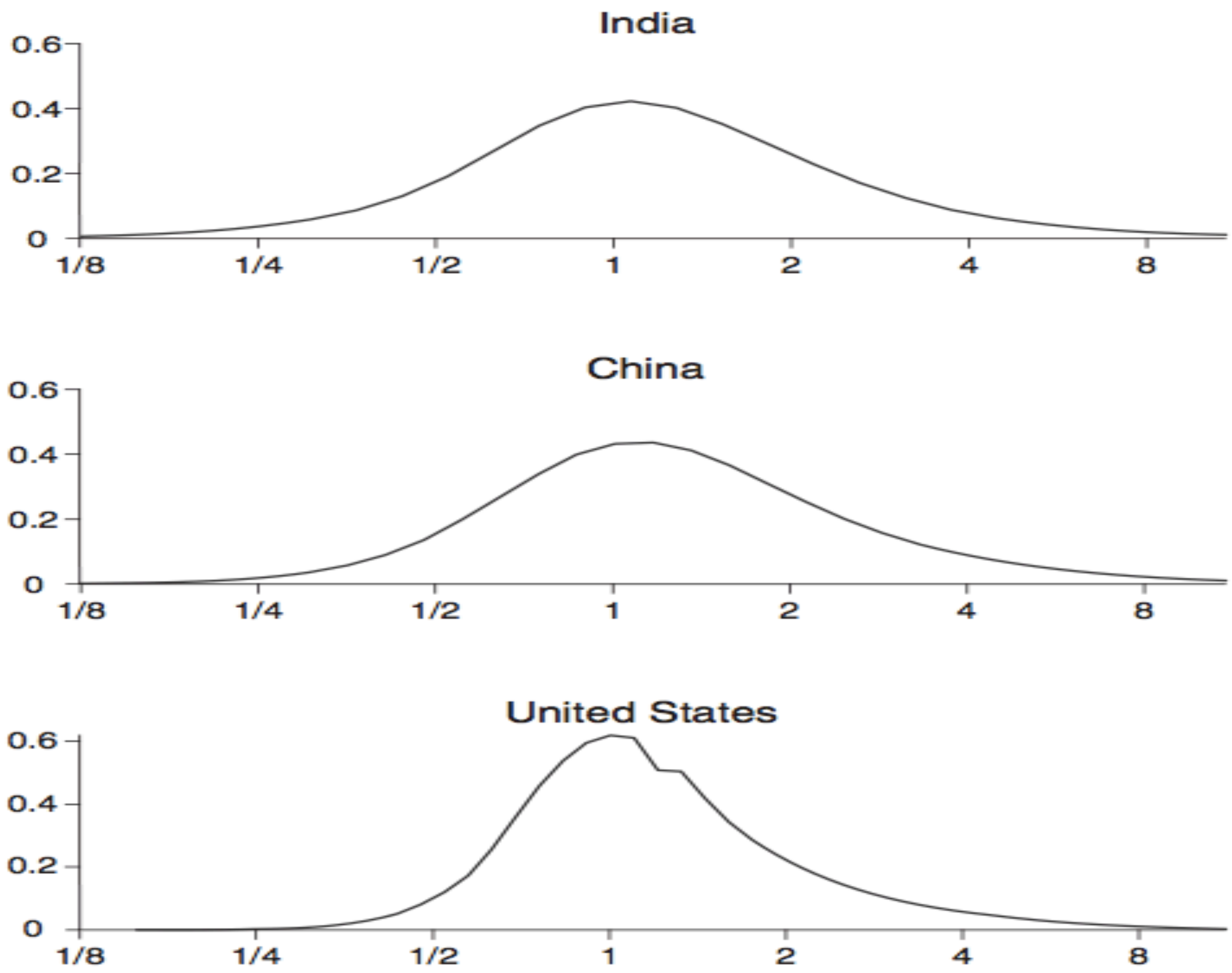
Dispersion of TFPQ

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

Notes. For plant i in industry s, $\text{TFPQ}_{si} \equiv \frac{Y_{si}}{K_{si}^{\alpha_s}(w_{si}L_{si})^{1-\alpha_s}}$. Statistics are for deviations of log(TFPQ) from industry means. S.D. = standard deviation, 75 − 25 is the difference between the 75th and 25th percentiles, and 90 − 10 the 90th vs. 10th percentiles. Industries are weighted by their value-added shares. N = the number of plants.

Dispersion in log TFPQ. For example, $e^{1.60} \approx 5$ means Indian firm at 75th percentile about 5 times larger than 25th percentile in 2005.

Distribution of TFPR ($= P_{is}A_{is}$)



All expressed relative to aggregate TFPR ($= P_s A_s$). Suggestive of larger distortions in India and China as compared to US.

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

Notes. For plant i in industry s, $\text{TFPR}_{si} \equiv \frac{P_{si}Y_{si}}{K_{si}^{\alpha_s}(w_{si}L_{si})^{1-\alpha_s}}$. Statistics are for deviations of log(TFPR) from industry means. S.D. = standard deviation, 75 – 25 is the difference between the 75th and 25th percentiles, and 90 – 10 the 90th vs. 10th percentiles. Industries are weighted by their value-added shares. Number of plants is the same as in Table I.

Sources of TFPR variation within industries

	Ownership	Age	Size	Region
India	0.58	1.33	3.85	4.71
China	5.25	6.23	8.44	10.01

Notes. Entries are the cumulative percent of within-industry TFPR variance explained by dummies for ownership (state ownership categories), age (quartiles), size (quartiles), and region (provinces or states). The results are cumulative in that "age" includes dummies for both ownership and age, and so on.

For example, ownership accounts for only 0.6% of the variance in India but about 5% in China. Ownership *and* age account for 1.3% in India and 6.2% in China, etc.

So: how large would the aggregate gains be if the cross-sectional allocation was more efficient?

Aggregation with distortions

- As before, physical productivity for industry s is defined by

$$A_s := \frac{Y_s}{K_s^{\alpha_s} L_s^{1-\alpha_s}}$$

- Aggregating across firms

$$K_s := \sum_{i=1}^{M_s} K_{is} = \frac{\alpha_s c_s}{r} \sum_{i=1}^{M_s} \frac{Y_{is}}{A_{is}} (1 + \tau_{K,is})^{\alpha - 1}$$

$$L_s := \sum_{i=1}^{M_s} L_{is} = \frac{(1 - \alpha_s) c_s}{w} \sum_{i=1}^{M_s} \frac{Y_{is}}{A_{is}} (1 + \tau_{K,is})^{\alpha}$$

where c_s is short for $c(w, r, \alpha_s)$

Aggregation with distortions

- Or in terms of factor shares

$$\Theta_{K,s} := \frac{rK_s}{P_sY_s} = \frac{\alpha_s}{\frac{\sigma}{\sigma-1}} \sum_{i=1}^{M_s} \left(\frac{1-\tau_{Y,is}}{1+\tau_{K,is}}\right) \frac{P_{is}Y_{is}}{P_sY_s}$$

$$\Theta_{L,s} := \frac{wL_s}{P_sY_s} = \frac{1-\alpha_s}{\frac{\sigma}{\sigma-1}} \sum_{i=1}^{M_s} (1-\tau_{Y,is}) \frac{P_{is}Y_{is}}{P_sY_s}$$

- Notice we can also write

$$P_sY_s = \left(\frac{r}{\Theta_{K,s}}\right)^{\alpha_s} \left(\frac{w}{\Theta_{L,s}}\right)^{1-\alpha_s} K_s^{\alpha_s} L_s^{1-\alpha_s}$$

or

$$P_sA_s = \left(\frac{r}{\Theta_{K,s}}\right)^{\alpha_s} \left(\frac{w}{\Theta_{L,s}}\right)^{1-\alpha_s} = \mathrm{TFPR}_s$$

Aggregation with distortions

- Decomposing into price and quantity indexes

$$P_s = \left(\sum_{i=1}^{M_s} P_{is}^{1-\sigma} \right)^{1/(1-\sigma)}$$

$$= \left(\sum_{i=1}^{M_s} \left(\text{TFPR}_{is} / A_{is} \right)^{1-\sigma} \right)^{1/(1-\sigma)}$$

- So we can write

$$A_s = \left(\sum_{i=1}^{M_s} \left(A_{is} \frac{\text{TFPR}_s}{\text{TFPR}_{is}} \right)^{\sigma-1} \right)^{1/(\sigma-1)}$$

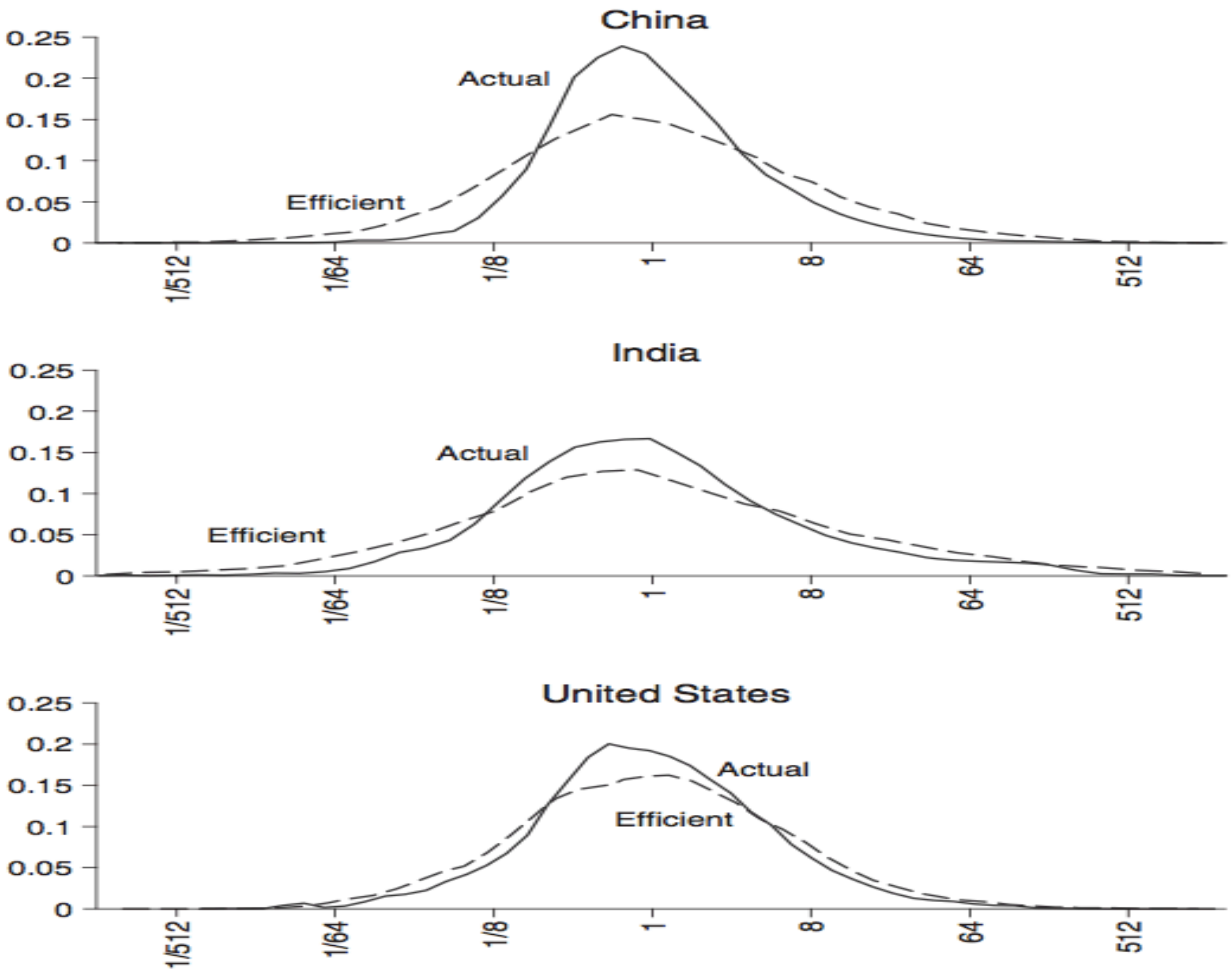
which collapses to the usual formula if no TFPR dispersion

TFP gains from equal 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

Gains from equalizing TFPR across all plants within each industry. Gains have been falling in China, suggesting actual distribution has been improving over time. Not so for India (and the US), at least in this sample.

Distribution of plant size (= value-added)



Efficient distribution has *more dispersed plant size*, fewer middle but more large and more small plants.

Percent of plants, actual size vs. efficient size

China 2005	0–50	50–100	100–200	200+
Top size quartile	7.0	6.1	5.4	6.6
2nd quartile	7.3	5.9	5.3	6.6
3rd quartile	8.5	6.0	5.2	5.4
Bottom quartile	10.5	5.9	4.5	4.2
India 1994	**0–50**	**50–100**	**100–200**	**200+**
Top size quartile	8.7	4.7	4.6	7.1
2nd quartile	10.7	4.6	4.1	5.7
3rd quartile	11.4	5.0	4.0	4.7
Bottom quartile	13.8	3.9	3.3	3.8
United States 1997	**0–50**	**50–100**	**100–200**	**200+**
Top size quartile	4.4	10.0	6.7	3.9
2nd quartile	4.4	9.6	5.8	5.1
3rd quartile	4.5	9.8	5.4	5.4
Bottom quartile	4.7	12.0	4.3	4.1

For example, 7% of Chinese firms in top size quartile have efficient output $<$ 50% of actual output while 6.6% have efficient output more than double their actual output.

TFP gains from equal TFPR, relative to US gains

China	1998	2001	2005
%	50.5	37.0	30.5
India	1987	1991	1994
%	40.2	41.4	59.2

Gains from moving to "1997 US efficiency" (lowest US efficiency). Aggregate manufacturing TFP differences based on Penn World Tables suggest US TFP in 1998 was 2.3 times China and 2.6 times India. So reallocation could account for about $\log(1.5)/\log(2.3) \approx 0.49$ of the difference between China and the US.

Welfare gains would be magnified by endogenous capital accumulation.

TFP by ownership

	TFPR	TFPQ
China		
State	−0.415	−0.144
	(0.023)	(0.090)
Collective	0.114	0.047
	(0.010)	(0.013)
Foreign	−0.129	0.228
	(0.024)	(0.040)
India		
State (central)	−0.285	0.717
	(0.082)	(0.295)
State (local)	−0.081	0.425
	(0.063)	(0.103)
Joint public/private	−0.162	0.671
	(0.037)	(0.085)

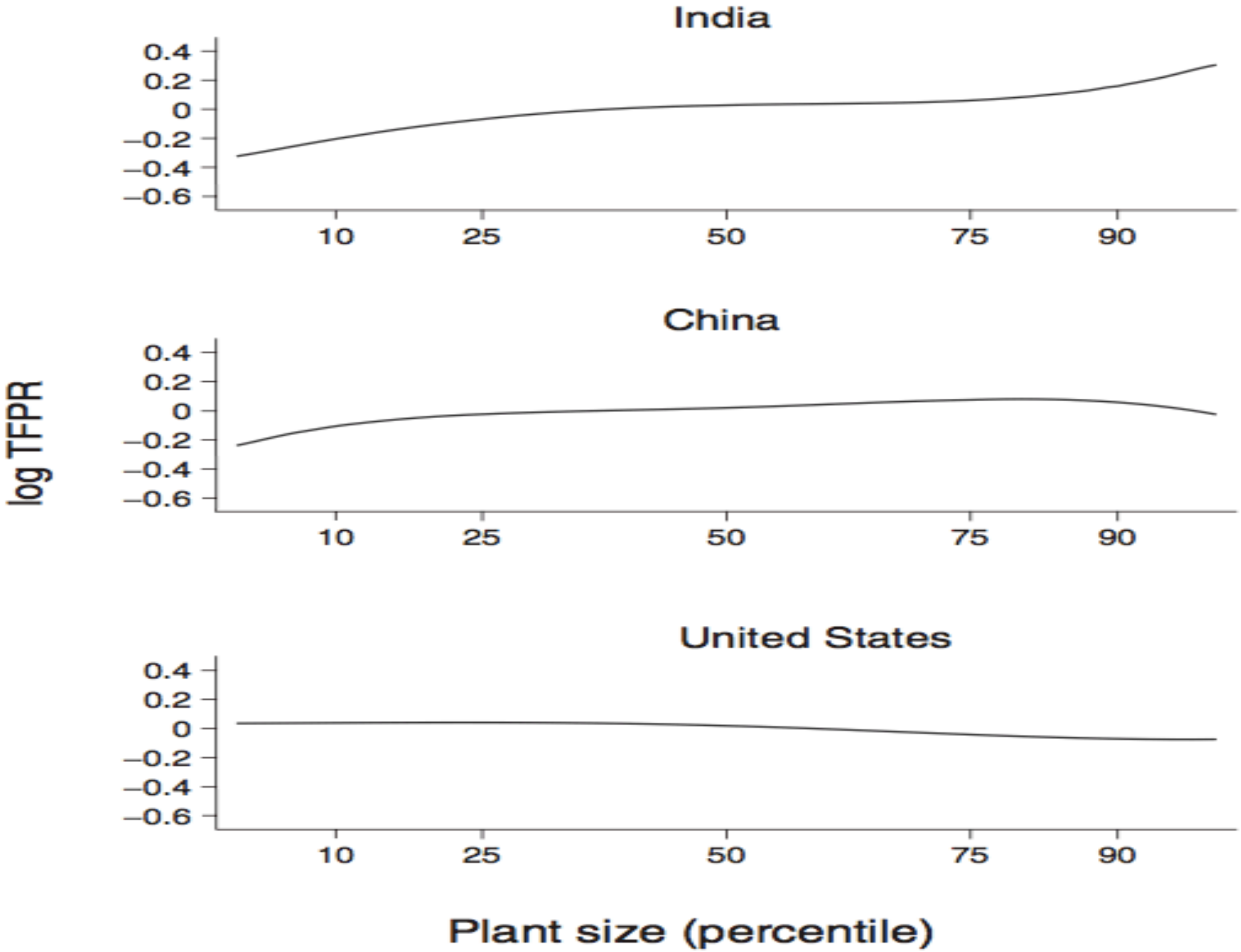
Notes. The dependent variable is the deviation of log TFPR or log TFPQ from the industry mean. The independent variables for China are dummies for state-owned plants, collective-owned plants (plants jointly owned by local governments and private parties), and foreign-owned plants. The omitted group is domestic private plants. The independent variables for India are dummies for a plant owned by the central government, a plant owned by a local government, and a plant jointly owned by the government (either central or local) and by private individuals. The omitted group is a privately owned plant (both domestic and foreign). Regressions are weighted least squares with industry value-added shares as weights. Entries are the dummy coefficients, with standard errors in parentheses. Results are pooled for all years.

Alternative explanations

- Measurement error
- Within-industry markup variation
- Adjustment costs
- Unobserved investments (e.g., R&D)
- Within-industry variation in technology (e.g., in capital intensities)

Key question: Which of these could account for more TFPR dispersion in China and India vs. the US?

TFPR by plant size



If due to variable markups, TFPR should increase with size. Yes for India and maybe for China, but no for US.

Next

- Misallocation, part three

- Endogenous misallocation. Static and dynamic misallocation

  - Peters (2013): Heterogeneous mark-ups, growth and endogenous misallocation, *LSE working paper*.