Growth and the Fragmentation of Production

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Cowles Summer Conference in International Trade
June 7, 2021

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Motivation

What are the drivers of economic growth?

• Factor accumulation, technological progress
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• Adam Smith: Increased specialization

“The greatest improvement in the productive powers of labour [...] seem to have been the effects of the division of labour.” (Wealth of Nations, Chapter 1, 1776)
Motivation

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“The greatest improvement in the productive powers of labour [...] seem to have been the effects of the division of labour.” (Wealth of Nations, Chapter 1, 1776)

This paper: specialization in value chain among plants and growth

1. Empirical facts about organization and performance using manufacturing data from India
   • macro: vertical specialization ⇔ income per capita
   • micro: vertical specialization ⇔ plant size

2. Key components of a quantitative model

3. (in the future) estimation + counterfactuals
Division of labor and productivity:

- **Theory:** Young (1928), Stigler (1951), Rosen (1978), Baumgardner (1988), Becker and Murphy (1992), Rodriguez-Clare (1996), Chaney and Ossa (2013)

Smithian Growth:


Indian Trade Liberalization:

- Panagariya (2004), Sivadasan (2009), Khandelwal and Topalova (2010), Goldberg et al. (2010), Peter and Ruane (2020)
Manufacturing Plants in India

Data: Indian Annual Survey of Industries, 1989/90-2014/15 (with gaps)

- Plant-level panel survey of formal manufacturing plants
  - All plants that have 100+ employees
  - 1/5 of all plants between 20 (10 if using power) and 100 employees

Most important part of the survey:

- Quantities, unit values & 5-digit product codes for all manufacturing output and intermediate inputs (domestic and imported)

Example product codes: Silk yarn, bleached (61222), beryllium copper wire (72246), aluminium ingots (73107)

<table>
<thead>
<tr>
<th></th>
<th>min</th>
<th>p25</th>
<th>p50</th>
<th>p75</th>
<th>max</th>
<th>count</th>
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<tbody>
<tr>
<td># 5-digit Inputs</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>117</td>
<td>595460</td>
</tr>
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</table>
Within narrow industries, firms use different inputs.

(a) Input mixes for Bleached Cotton Cloth (63303)

(b) Input mixes for Polished Diamonds (92104)
Measuring the vertical span of production (Boehm & Oberfield, 2020)

Two steps:

1. Define a **vertical distance** $d_{\omega\hat{\omega}}$ of an input from an output (varies at product-pair level)
   
   • Rough diamonds are more distant from polished diamonds than cut diamonds
   • Similar to upstreamness of Alfaro et al. (2019)

2. Construct each plant’s **vertical span**: how far are the plant’s inputs from the output?

   $$\text{span}_{jt} = \sum_{\hat{\omega}} \frac{X_{j\hat{\omega}}}{\sum \tilde{\omega} X_{j\tilde{\omega}}} d_{\omega\hat{\omega}}$$
Figure 1: Input mixes for Polished Diamonds (92104)
Macro facts: Vertical specialization is positively correlated with development within industry x year:

Plants in richer districts are on average more vertically specialized.

Holds also in the time dimension: Indian states that grow faster are those where plants are v. specializing more.

Binscatter with n=50. Y and X variable de-meaned by industry x year. SP plants only.
Within industry × year:

Plants with **higher sales** tend to have **shorter vertical span**

Holds also in the **time dimension**: Plants that v. specialize more grow faster.
Indian Trade Liberalization to get at causality

- Until end of 80s: India in near-autarky
  - Very high tariffs (average ~80%).
  - Large variation (up to 355%). Was set in the 1950s.
- 1992-1997: Tariffs come down to average of 35%, ending up fairly uniform.
- TARIFF CHANGE WAS DETERMINED IN THE 50’S, uncorrelated with 1992 industry characteristics

See also Panagariya (2004), Sivadasan (2009), Khandelwal and Topalova (2010), Goldberg et al. (2010).

Drop in tariff on output is negative demand shock (import competition); drop in tariff on inputs is positive supply shock.
Demand shocks affect vertical specialization

<table>
<thead>
<tr>
<th>Dependent variable: $\Delta$ Vertical Span</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta$ log Sales</td>
<td>-0.0158**</td>
<td>-0.0160**</td>
<td>-0.0326*</td>
<td>-0.0536*</td>
</tr>
<tr>
<td></td>
<td>(0.0020)</td>
<td>(0.0020)</td>
<td>(0.013)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>$\Delta$ log$(1 + \bar{\tau}_{\text{input}}{\omega}_t)$</td>
<td>-0.0170</td>
<td>-0.0473</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.044)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Estimator</td>
<td>OLS</td>
<td>OLS</td>
<td>IV</td>
<td>IV</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.00207</td>
<td>0.00208</td>
<td>0.0000365</td>
<td>-0.00419</td>
</tr>
<tr>
<td>Observations</td>
<td>123666</td>
<td>123666</td>
<td>90115</td>
<td>90115</td>
</tr>
</tbody>
</table>

Changes within plant-products
Standard errors in parentheses, clustered at the state-industry level.
$^+ p < 0.10$, $^* p < 0.05$, $^{**} p < 0.01$

Columns (3), (4) instrument $\Delta$ log sales by the change in the log output tariff.

Smith (1776): “The division of labour is limited by the extent of the market”
Trying to find evidence for network economies

Plant $j$ in industry $\omega$
Trying to find evidence for network economies

Plant $j$ in industry $\omega$

$j$’s upstream industries $\hat{\omega}$
Trying to find evidence for network economies

\( \omega \)'s downstream industries, excluding \( \omega \)

Plant \( j \) in industry \( \omega \)

\( j \)'s upstream industries \( \hat{\omega} \)
Trying to find evidence for network economies

1.) output tariff

\( \omega \)'s downstream industries, excluding \( \omega \)

\( j\)'s upstream industries \( \hat{\omega} \)

Plant \( j \) in industry \( \omega \)
Trying to find evidence for network economies

1.) output tariff

Plant $j$ in industry $\omega$

$\hat{\omega}$'s downstream industries, excluding $\omega$

2.) number of producers
Trying to find evidence for network economies

1.) output tariff

\( \hat{\omega} \)'s downstream industries, excluding \( \omega \)

sales impact?

Plant \( j \) in industry \( \omega \)

\( j \)'s upstream industries \( \hat{\omega} \)

2.) number of producers
## Upstream entry and sales

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. log #Producers in Upstream Ind.</td>
<td>0.0466**</td>
<td>0.0383**</td>
<td>0.0384**</td>
<td>0.0383*</td>
<td>0.0613**</td>
<td>0.0618**</td>
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<tr>
<td></td>
<td>(0.0041)</td>
<td>(0.0050)</td>
<td>(0.0050)</td>
<td>(0.017)</td>
<td>(0.017)</td>
<td>(0.017)</td>
</tr>
<tr>
<td>(\log(1 + \tau_{j\omega t}^{\text{input}}))</td>
<td></td>
<td></td>
<td></td>
<td>0.0280</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td>(0.085)</td>
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<td></td>
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<td>0.0293</td>
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<td></td>
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<tr>
<td>Year FE</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Industry × Year FE</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Plant × Industry FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>OLS</td>
<td>OLS</td>
<td>IV</td>
<td>IV</td>
<td>IV</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.942</td>
<td>0.952</td>
<td>0.952</td>
<td>0.00183</td>
<td>0.000631</td>
<td>0.000621</td>
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<tr>
<td>Observations</td>
<td>215805</td>
<td>199039</td>
<td>198727</td>
<td>215805</td>
<td>199039</td>
<td>198727</td>
</tr>
</tbody>
</table>

Standard errors in parentheses, clustered at the industry-year level.

+ \(p < 0.10\), * \(p < 0.05\), ** \(p < 0.01\)
Other empirical results

- Vertical specialization comes with a reduction in the number of intermediate inputs
  Demand shocks $\Rightarrow$ Sales $\Rightarrow$ # Inputs

- Tariff supply & demand shocks affect entry.
  Lower output tariffs decreases the number of plants
  Lower input tariffs increases the number of plants.

- Input tariffs affect input adoption.
  Lower input tariffs lead to an increased probability of plants using that input.
Model
Firm produces good $\omega_0$. Two (perf. substitutable) ways of producing:
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- Buying $\omega_1$ from a supplier (‘shirts from cloth’)
- Buying $\omega_2$ and $\omega_3$ from suppliers (‘shirts from yarn & dye’)

Firm produces good $\omega_0$. Two (perf. substitutable) ways of producing:

1. **Buying $\omega_1$ from a supplier (‘shirts from cloth’)**

   Firms search for $\omega_1$ suppliers. Search effort $h_1$.

   Cost of production: $c_{j\omega_0} = \frac{1}{q_j} w^{\alpha_j^0} \left( \tilde{c}_j^1 \right)^{1-\alpha_j^0}$

   Arrival rate of supplier matches + match-specific productivity so that $\tilde{c}_j^1 \sim EV(h_1 v_1, \zeta)$
Firm produces good $\omega_0$. Two (perf. substitutable) ways of producing:

2. Buying $\omega_2$ and $\omega_3$ from suppliers (‘shirts from yarn & dye’)

Firms search for $\omega_2, \omega_3$ suppliers. Search efforts $h_2, h_3$

Cost of production: $c_{j\omega_0} = \frac{1}{q_j} w^{\alpha_0} \left( \frac{1}{b_j} w^{\alpha_1} (\tilde{c}_j^2)^{\alpha_2} (\tilde{c}_j^3)^{\alpha_3} \right)^{1-\alpha_0}$

$\tilde{c}_j^2 \sim EV(h_2 v_2, \zeta), \quad \tilde{c}_j^3 \sim EV(h_3 v_3, \zeta), \quad \chi(\log b_j) = \frac{\Gamma(1-\zeta it)}{\Gamma(1-\alpha_2^1 \zeta it) \Gamma(1-\alpha_3^1 \zeta it)}$
Search problem

- Firm born with productivity $q_j$, make search choice based only on that.
- Profits from sales to households, isoelastic demand, isoelastic search costs:

$$\max_{\{h\}_i} E(\pi_j|q_j, \{h\}_i) - \sum_{i=1,2,3} \frac{k}{1+\gamma} h_i^{1+\gamma}$$

$$A_{\omega_0} q^{\varepsilon-1} E(c_j|q_j, \{h\}_i)^{1-\varepsilon} - \sum_{i=1,2,3} \frac{k}{1+\gamma} h_i^{1+\gamma}$$

$$A_{\omega_0} q^{\varepsilon-1} \left[h_1 v_1 + (h_2 v_2)^{\alpha_2} (h_3 v_3)^{\alpha_3}\right]^{(1-\alpha_i^0) \frac{\varepsilon-1}{\zeta}} - \sum_{i=1,2,3} \frac{k}{1+\gamma} h_i^{1+\gamma}$$

- **Nonhomotheticity**: return from searching in upstream industries (i.e. 2, 3) is more concave than in downstream industry (1).

$\Rightarrow$ Plants born with high $q$ will be more likely to be vertically specialized (use $\omega_1$ rather than $\omega_2, \omega_3$). **Size ↔ Span relationship** in the data
Roadmap / Summary

- **Differentiated vs Standardized Inputs** (preliminary) empirical patterns driven by use of differentiated inputs
- **Profits from firm-to-firm trade**
  - Account explicitly for demand shocks from downstream sectors
  - What is internalized?
- **Identification of scale economies**

**Conclusion:**
Indian Microdata suggests

- Internal economies of scale from search
- Possibly external economies of scale through matching process

Overall, try to make progress on quantitative models of growth. How important is “Smithian” growth?