Distribution Costs &
The Size of Indian Manufacturing Establishments

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Selling manufactured goods involves costs of distribution:
- Variable: Freight/shipping, insurance, commissions
- Fixed: Finding and contracting with distributors

1. **How does low productivity in distribution sectors affect manufacturing firms in developing countries?**
   - 2005 India-US TFP gap in Distribution sectors \( \approx 8\times \)
   - 2005 India-US TFP gap in Manufacturing sectors \( \approx 4\times \)

2. **Can low productivity in distribution sectors explain survival of small plants in India?**
   - Median manufacturing employment in India \( \approx 1 \) (47 in US)
   - Constrain larger plants \( \Rightarrow \) enable inefficient plants to survive
Indian Distribution

- Poor infrastructure quality
  - But large investments in recent years (GQ)

- Indian distribution sector highly fragmented
  - Wholesalers & retailers tend to be small and local
  - Large firms work with hundreds of distributors

- Tim Cook (July 24, 2012):
  
  “I love India, but I believe Apple has some higher potential ... in some other countries. ... The multi-layered distribution really adds to the cost of getting products to market.”
**Recent Trends**

**Figure:** Sectoral TFP (1995 = 1)

**Figure:** (Distribution Costs / Sales) in Manufacturing

- Rapid productivity growth in distribution sectors
- Declining as share of sales in manufacturing
1. **New finding: distribution costs / sales \(↑\) in plant size**
   - Unique measurement of plant-level distribution expenses in India

2. **2-Sector GE Model with Heterogeneous Firms**
   - Manufacturing firms ‘ship’ goods to consumers across space
   - Shipping further requires more distribution services
     - Increasing relationship between size and distribution share
     - Distribution costs ‘constrain’ larger plants more
   - In GE, small plants survive

3. **Preliminary Quantitative Exercises**
   - TFP increase in distribution \(→\) manufacturing
**Literature**

- Firm-size distribution and development

- Intranational Trade Costs

- Model:
  - Melitz (2003), Arkolakis (2010)
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Data and Empirical Results

Model

Simple Quantitative Exercise
Data: Indian Annual Survey of Industries

- Survey of formal Indian manufacturing plants (1993-2011)
  - Representative sample > 10 workers

- Unique measurement of outward distribution costs:
  ‘i.e. outward freight, rebate, commission, transit insurance of goods sold, packing fees etc’

- Includes variable costs
- Excludes fixed costs: finding distributors, advertising, etc...

- Distribution share \( (ds) = \frac{\text{distribution expenses}}{\text{sales (net of taxes)}} \)
  - Average share = 2.2%
Distribution Share vs Size (Log-Scale)
Interpretation

- Rationalize this finding with 2 observations
  1. Larger plants ship further (Holmes & Stevens (2012))
  2. Marginal distribution costs increasing in distance

- Larger plants use distribution services more extensively.
  → particularly affected by productivity in distribution sector.

- Key features we incorporate in our model.
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DATA AND EMPIRICAL RESULTS

MODEL

SIMPLE QUANTITATIVE EXERCISE
Continuum of consumers & heterogeneous firms

- Firms differentiated by *quality*

Firms choose set of consumers (and sales per consumer):

- Selling to consumer $\Rightarrow$ fixed cost & variable distribution cost
- Distribution cost $\uparrow$ in distance from consumer
- $\Rightarrow$ high quality firms:
  - $\uparrow$ sales, $\uparrow$ consumers, $\uparrow$ distribution costs / sales

$\uparrow$ rate at which distribution costs increase:

- PE: firms sell to smaller set of consumers
- GE: low-quality firms can survive
**Environment**

- Two sectors: Distribution (D) & Production (Q)
  - D: perfect competition, technology: \( D = A^D L \), price: \( p^D \)
  - Q: monopolistic competition, heterogeneous firms

- Continuum of consumers & firms uniformly distributed on circle:
  - Circumference = 1

- At each point on the circle:
  - Mass L of identical consumers (exogenous)
  - Mass J of heterogeneous firms (endogenous)
  - Consumers and firms symmetric at every point

- Free entry condition at each point
**Consumer’s Problem**

- Consumer \((l)\) has CES preferences over available varieties \(\Omega_l\)

\[
\max_{c(\omega)} \left( \int_{\omega \in \Omega_l} \psi(\omega) c(\omega)^\frac{\sigma-1}{\sigma} \, d\omega \right)^\frac{\sigma}{\sigma-1} \quad \text{s.t.} \quad \int_{\omega \in \Omega_l} p(\omega) c(\omega) d\omega \leq w + \pi
\]

- \(\psi(\omega)\) = quality of variety (firm) \(\omega\)
- \(\Omega_l\) determined in equilibrium

Demand: \(c(\omega) = P^{\sigma-1}(w + \pi) \, \psi(\omega)^\sigma \cdot p(\omega)^{-\sigma}\)

Details
Active Firm’s Problem

2 steps

1. Maximize profits in each market $N \in [0, N^*]$
2. Choose $N^* \in [0, 1/2]$
Active Firm’s Problem

- 2 steps
  1. Maximize profits in each market $N \in [0, N^*]$ 
  2. Choose $N^* \in [0, 1/2]$

1. In each market $N$

$$\pi^*(\psi, N) = \max_{q,l,d} p(q(\psi, N))q(\psi, N) - wl(\psi, N) - p^D d(\psi, N) - wf(N)$$

s.t. 
\begin{align*}
  l(\psi, N) &= q(\psi, N) \\
  d(\psi, N) &= (1 + \epsilon N)q(\psi, N) \\
  f(N) &= f (1 - 2N)^{-\beta}
\end{align*}
Active Firm’s Problem

- 2 steps
  1. Maximize profits in each market $N \in [0, N^*]$ 
  2. Choose $N^* \in [0, 1/2]$

1. In each market $N$

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\]

s.t. \( l(\psi, N) = q(\psi, N) \)

\[
d(\psi, N) = (1 + \epsilon N)q(\psi, N)
\]

\[
f(N) = f (1 - 2N)^{-\beta}
\]

2. $N^*(\psi)$ solves \( \pi^*(\psi) = \max_{N^*(\psi)} \int_{0}^{N^*(\psi)} 2\pi^*(\psi, N) dN \)
Entry & Exit:

1. Entrant pays sunk cost $w f_E$
2. Draw $\psi$ from distribution $g(\psi)$
3. If $\pi^*(\psi) \geq 0$ produce, otherwise endogenously exit (defines $\psi$)
4. Active firms exit with exogenous probability $\delta$

Focus on stationary equilibria in which
- Mass of successful entrants = mass of exiting firms

Free entry condition: expected profits from entry = $w f_E$
Set $\beta = 0$ for closed-form solutions.

- Constant fixed cost of accessing new markets

$$N(\psi)^* = \frac{1}{\varepsilon} \left( \frac{A_D}{w} \left( \frac{\sigma - 1}{\sigma} \right) \left( \frac{L}{f \sigma} \right)^{\frac{1}{\sigma - 1}} \psi^{\frac{\sigma}{\sigma - 1}} - (A_D + 1) \right)$$

→ Higher $\psi$ firms reach more consumers.
Low $\varepsilon$ drives out low TFP firms

$$N(\psi)^* = \frac{1}{\varepsilon} \left( \frac{A_D}{w} \left( \frac{\sigma - 1}{\sigma} \right) \left( \frac{L}{f\sigma} \right)^{\frac{1}{\sigma-1}} \psi^{\frac{\sigma}{\sigma-1}} - (A_D + 1) \right)$$

- Lower $\varepsilon$
  - All active firms sell a further distance
  - $w \uparrow$ to restore labor market clearing

$$\psi = w \left( 1 + \frac{1}{A_D} \right)^{\frac{\sigma-1}{\sigma}} \left( \frac{\sigma f}{L} \right)^{\frac{1}{\sigma}} \left( \frac{\sigma}{\sigma - 1} \right)^{\frac{\sigma-1}{\sigma}}$$

- $\psi \uparrow$: low quality firms driven out of the market
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Data and Empirical Results

Model

Simple Quantitative Exercise
1. Calibrate $\varepsilon$, $\beta$ and $A_D$ to match:
   - Aggregate and average distribution share of sales
   - Elasticity of distribution expenses wrt size

2. Effect of ↓ $\varepsilon$ within the model
   - Reduction in cost of shipping longer distances
     - Improving highway network

3. Improvements in productivity of distribution sector ($A_D$):
   - Model predictions for distribution share
   - $\varepsilon = 0$ vs $\varepsilon > 0$
Calibrate 3 main parameters (11 total) to match 3 key moments.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate Distribution Costs $↑$ With Distance</td>
<td>$\varepsilon$</td>
</tr>
<tr>
<td>Productivity of Distribution Sector</td>
<td>$A_D$</td>
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<td>Rate Fixed Costs $↑$ With Distance</td>
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<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Model</th>
</tr>
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<tbody>
<tr>
<td>Elasticity of distribution costs wrt size</td>
<td>1.20</td>
<td>1.21</td>
</tr>
<tr>
<td>Aggregate distribution share</td>
<td>3.5%</td>
<td>3.5%</td>
</tr>
<tr>
<td>Average distribution share</td>
<td>2.2%</td>
<td>2.0%</td>
</tr>
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</table>
IMPACT OF $\varepsilon$
1995-2009: “$A_D$” increased by $\approx 51\%$

1. Compare predicted effects on distribution share in baseline model.

<table>
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<th>Data</th>
<th>Baseline</th>
<th>$\varepsilon = 0$</th>
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<tr>
<td>$A_D$</td>
<td>$+51%$</td>
<td>$+51%$</td>
<td></td>
</tr>
<tr>
<td>Aggr. distr share</td>
<td>$-35%$</td>
<td>$-31%$</td>
<td></td>
</tr>
<tr>
<td>Elasticity of distr costs</td>
<td>$\approx 0%$</td>
<td>$+0.5%$</td>
<td></td>
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<tr>
<td>Median Employment</td>
<td></td>
<td></td>
<td></td>
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<td>Average Employment</td>
<td></td>
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<tr>
<td>Welfare (TFP)</td>
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<td></td>
<td></td>
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## Increase in $A_D$: Model and Data

1995-2009: “$A_D$” increased by $\approx 51\%$

1. Compare predicted effects on distribution share in baseline model.
2. Compare to model with
   - $\varepsilon = 0$
   - $A_D$ recalibrated to match aggregate distribution share

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<td>−31%</td>
<td>−35%</td>
</tr>
<tr>
<td>Elasticity of distr costs</td>
<td>≈ 0%</td>
<td>+0.5%</td>
<td>−</td>
</tr>
<tr>
<td>Median Employment</td>
<td></td>
<td></td>
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<tr>
<td>Average Employment</td>
<td></td>
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<td>Welfare (TFP)</td>
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- Median Employment: +5.2% 1.8%
- Average Employment: +5.7% 1.8%
- Welfare (TFP): +1.80% 1.79%
CONCLUSION

1. Stylized Fact
   - Distribution costs non-trivial
   - Distribution costs / sales increasing in plant size

2. 2-Sector Model
   - Firms sell to consumers & incur distribution costs
   - Higher quality firms: profitably sell to more distant consumers
     - More customers, ↑ total sales, ↑ distribution share of sales

3. Preliminary Quantitative Results
   - ↓ in rate at which distribution costs increase with distance
     - ↑ in welfare
     - ↑ in median plant size
Next Steps

Focus explicitly on wholesale / retail sector

- Fragmentation $\Rightarrow$ ↑ fixed costs: related to $\beta$  
- How do we get discipline on this?

Use variation across time and geography

- Infrastructure improvements (GQ)
- ‘Fragmentation of distribution sector’
- FDI liberalization in distribution sector 2011
THANK YOU
Robustness

- Robust to measure of size & geographic aggregation

- Not driven by exporters $\Rightarrow$ *intranational* distribution costs
  - Exporters by Decile
  - Distribution Share non-exporters

- Not driven by reporting of 0’s ($\approx 21.5\%$ of plants)
  - Zeros by Decile
  - Distribution Share vs Size

- All components of distribution expenses increase with size
  - Distribution Subcomponents

- Opposite relationship on *inward* freight costs
  - Inward Freight Share vs Size

- Different from other inputs (labor, materials):
  - Labor share *decreasing* with plant size
In India, Distribution is God (Harvard Business Review, 2012):

“In India, because of fragmented distribution networks, it’s difficult for a new venture to get its products to a large audience. In the US, innovative companies can bypass delivery problems by working directly with large consumer-facing hubs such as Wal-Mart (old), Amazon (new), or iTunes (new, new), which allows them to quickly and efficiently reach early adopters”
Aggregate Labor

$$\Pi = J \int_{\psi \in \Psi} \pi(\psi) \mu(\psi) d\psi$$

$$L^D = \frac{J}{A^D} \int_{\psi \in \Psi} d(\psi) \mu(\psi) d\psi$$

$$L^P = J \int_{\psi \in \Psi} (l(\psi) + fN^*(\psi)) \mu(\psi) d\psi$$

$$L^E = f_E \delta M^E$$

- $\mu(\psi) =$ equilibrium quality distribution
- $M^E = $ mass of potential firms
- $N^*(\psi) = $ optimal $N$ for firm of productivity $\psi$
Distribution Share vs Size

![Graph showing the relationship between Distribution Costs/Sales (%) and log output. The graph includes a trend line indicating a positive correlation.](image-url)
Distribution Share vs Size

![Graph showing the relationship between distribution costs/sales and log totvarcost. The graph displays a positive correlation, with data points scattered along a straight line.]
% of Exporters Across Deciles of Market Share

Overall Percentage = 14.3%

% of Exporters vs Decile of Market Share (Labor-Cost Based)
Distribution Share vs Size (Sub-Components)
Distribution Share vs Size (Zeros I)

% of 0's Across Deciles of Market Share

Overall Percentage = 20.7%
Distribution Share vs Size (Zeros II)
Inward Freight Share vs Size
# Indian ASI: Data Cleaning Steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Cleaning</th>
<th># of Dropped Obs</th>
<th>Remaining Obs</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Open plants (1993-2007)</td>
<td>–</td>
<td>547,154</td>
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<tr>
<td>2</td>
<td>Missing key variables</td>
<td>110,035</td>
<td>437,119</td>
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<tr>
<td>3</td>
<td>Missing distribution</td>
<td>17,179</td>
<td>419,940</td>
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<tr>
<td>4</td>
<td>Trimming Extreme Values</td>
<td>3,351</td>
<td>416,589</td>
</tr>
<tr>
<td>5</td>
<td>Consistent Sectoral Definitions</td>
<td>7,216</td>
<td>409,373</td>
</tr>
</tbody>
</table>

- Key variables are:
  - Output, employment, labor cost, intermediates, capital.
Sketching solution

- Free entry
  - average profits $\pi = 0$
  - consumer’s income $w = \text{GDP per capita}$

- Demand for good of quality $\psi$:
  \[
  c(\psi, N) = w \psi^\sigma p(\psi, N)^{-\sigma}
  \]

- Each level of $w$ determines
  - Cut-off productivity $\underline{\psi}$
  - Total sales (and hence labor demand) of firms with $\psi > \underline{\psi}$

- In equilibrium, $w$ is such that
  - $L = L_e + L_p + L_d$
  - Expected operating profits $P(\psi > \underline{\psi}) \bar{\pi}^o = w f_e$
Market Clearing Conditions

1. Aggregate Labor Constraint:

\[ L^D + L^P + L^E = L \]

- \( L^D \) = labor in distribution sector
- \( L^P \) = labor in production sector (variable & fixed)
- \( L^E \) = labor for entry

2. Aggregate Budget Constraint:

\[ wL + \Pi = \int_{l \in [0,1]} \int_{\omega \in \Omega_l} p_l(\omega) c_l(\omega) d\omega \]

- \( \Pi \) = aggregate profits (net of entry costs)
**Equilibrium**

Given a quality distribution $g(\psi)$, an equilibrium is set of:

1. prices $\{p^D, w, P, \{p(\psi, N)\}\}$
2. quantities $\{L^D, L^E, L^P, \{c(\omega)\}, \{q(\psi)\}, \{l(\psi)\}, \{d(\psi)\}, J, M^E\}$

such that

1. Consumers optimize subject to their budget constraint
2. Active firms optimize subject to constraints
3. Production = consumption $\forall \omega$
4. Aggregate constraints hold
5. Free entry condition holds

Focus on stationary distribution of firms:

- Net Entry = 0
Solution to Consumer’s Problem

Demand:

\[ c(\psi, N) = P^{\sigma-1} y\psi^\sigma p(\psi, N)^{-\sigma} \]

Price Index:

\[ P \equiv 1 = \left[ 2J \int_{N\in[0,\frac{1}{2}]} \int_{\psi\in\Psi} \psi^\sigma p(\psi, N)^{1-\sigma} f(\psi, N) d\psi dN \right]^{\frac{1}{1-\sigma}} \]

- Symmetry across all points on the circle → price index identical
Productivity Improvements in Distribution Sector
IMPACT OF $\beta$

The graph illustrates the impact of $\beta$ on various metrics, showing how different parameters change with increasing $\beta$. The $y$-axis represents the percentage changes, while the $x$-axis represents the values of $\beta$. The lines correspond to different metrics:

- **Cutoff $\psi$** (blue line)
- **Welfare** (red line)
- **Median N** (yellow line)
- **Median Employment** (purple line)

As $\beta$ increases, the percentage changes decrease significantly for all metrics, indicating a diminishing impact on these variables.
**CALIBRATION**

- Distribution of $\psi = \text{truncated Pareto} \ (\eta, \psi_{min}, \psi_{max})$

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<td>$\psi_{min}$</td>
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<td>$\delta$</td>
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<td>Pareto Shape Parameter</td>
<td>$\eta$</td>
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<tr>
<td>Elasticity of Substitution</td>
<td>$\sigma$</td>
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