Industrial Policies in Production Networks

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Introduction

- Industrial policies: *selective* intervention into key economic sectors
  - widely adopted: Japan, South Korea, China

- How to conduct industrial policies? Cross-sector linkages are important (Hirschman 1958)
  - “strategic” and “pillar industries”
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  - a simple measure, *distortion centrality*, should guide policies
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  - sectors with high distortion centrality tends to be upstream
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- This paper: a framework to analyze study policy intervention in networks
  - a simple measure, *“distortion centrality”*, should guide policies
  - sectors with high distortion centrality tends to be *upstream*
  - quantitative policy evaluations & counterfactuals using simple regressions
Model

- Representative consumer, exogenous factor supply $L$, one final consumption good

- $N$ intermediate sectors, CRTS production $F_i \left( L_i, \{M_{ij}\}_{j=1}^N \right)$ with input-output linkages
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- Market imperfections $\{ \chi_{ij} \}$:
  - financial constraints, contracting frictions, market power, externalities...
  - distort expenditure shares away from production elasticities:

\[
(1 + \chi_{ij}) \left( \frac{P_j M_{ij}}{P_i Q_i} \right) = \frac{\partial \ln F_i \left( L_i, M_{ij} \right)}{\partial \ln M_{ij}}
\]

- input expenditure share
- production elasticity
Model

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- Labor
- Market Imperfections
- Market Imperfections
Distortion centrality: the ratio between two standard centrality measures

Standard centrality measures

- “Influence” $\mu_i \equiv \frac{d \ln GDP}{d \ln TFP_i}$: the importance of sectoral TFP
- “Sales share” $\gamma_i \equiv \frac{Sales_i}{GDP}$: sectoral size
- Vertical network: downstream is largest / most influential
Distortion centrality: the ratio between two standard centrality measures

Standard centrality measures

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▶ “Sales share” $\gamma_i \equiv \frac{Sales_i}{GDP}$: sectoral size

▶ Vertical network: downstream is largest / most influential

Definition. **Distortion centrality** is influence over sales $\xi_i \equiv \frac{\mu_i}{\gamma_i}$.

▶ In a frictionless economy, $\xi_i = 1$ in all sectors (Hulten 1978)

▶ In a vertical network, upstream has the highest distortion centrality

\[ \xi' \propto \left( \frac{1 + \chi_2}{1 + \chi_3} \right) \left( \frac{1 + \chi_3}{1} \right) \]

- \( \chi_1 \): Market Imperfections
- \( \chi_2 \): Sector 1
- \( \chi_3 \): Sector 3
Distortion centrality: captures the value of government subsidies

- Consider sector-specific input subsidies $\{\tau_{ij}\}$

\[
(1 - \tau_{ij} + \chi_{ij}) \frac{P_j M_{ij}}{P_i Q_i} = \frac{\partial \ln F_i (L_i, M_{ij})}{\partial \ln M_{ij}}
\]

- Subsidies expand sectoral expenditures, but cost government resources
  - balanced subsidies by lump-sum taxes $T \equiv \sum_{i=1}^{N} \left( \sum_{j=1}^{N} \tau_{ij} P_j M_{ij} + \tau_i^L W L_i \right)$
Distortion centrality: captures the value of government subsidies

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**Theorem.** Distortion centrality \( \xi_i \) is a sufficient statistic for the social value of policy spending:

\[
\left. \frac{dGDP}{dT} \right|_{\tau=0} = \frac{dGDP}{d\tau_{ij}} \bigg|_{\tau=0} = \xi_i - 1 \quad \text{for all } j = 1, \ldots, S, L.
\]

- A general equilibrium spending multiplier; “bang for the buck”
Distortion centrality: quantitatively useful for policy evaluation & counterfactual

\( \xi_i \): the *social value* of government intervention, incorporating general equilibrium effects

\( \xi_i > 1 \iff \text{subsidizing sector } i \text{ raises aggregate output} \)
Distortion centrality: quantitatively useful for policy evaluation & counterfactual

- $\xi_i$: the \textit{social value} of government intervention, incorporating general equilibrium effects
  - $\xi_i > 1 \iff$ subsidizing sector $i$ raises aggregate output

\textbf{Proposition.} Distortion centrality averages to one across sectors ($E[\xi] = 1$).

- Uniformly promoting all sectors is ineffective; \textit{selective intervention} is key.
Distortion centrality: quantitatively useful for policy evaluation & counterfactual

- $\xi_i$: the social value of government intervention, incorporating general equilibrium effects
  - $\xi_i > 1 \iff$ subsidizing sector $i$ raises aggregate output

**Proposition.** Distortion centrality averages to one across sectors ($\mathbb{E} [\xi] = 1$).

- Uniformly promoting all sectors is ineffective; selective intervention is key

**Proposition.** The aggregate gain from sectoral subsidies is

$$
\frac{\Delta GDP}{GDP} = \text{Cov} (\xi_i, s_i) + O \left( \max_{i,j} \{ \tau_{ij}^2 \} \right);
$$

where $s_i$ is the total subsidy spending per value-added in sector $i$ ($s_i = \sum_{j=1}^{N} \frac{\tau_{ij} P_j M_{ij} + \tau_{ij}^L W_{Li}}{W_{Li}}$).

- Useful for policy evaluation & counterfactual
Distortion centrality: importance of upstreamness

- Should not promote the most distorted / influential / large sectors
  - In a vertical network, promoting upstream brings the most “bang-for-the-buck”
  - even though upstream is the smallest, least influential, and least distorted
Distortion centrality: importance of upstreamness

- Should not promote the most distorted / influential / large sectors
  
  - In a vertical network, promoting upstream brings the most “bang-for-the-buck”
  
  - even though upstream is the smallest, least influential, and least distorted

- Result applies to other policy instruments, e.g. subsidized credit
  
  - cross-sector dispersion in interest rate ≠ misallocation
Measuring distortion centrality

Distortion centrality in arbitrary networks:

$$\xi_j = \delta \times \Omega_j^C + \sum_{i=1}^{N} \left\{ \frac{\xi_i}{N} \times (1 + \chi_{ij}) \times \Omega_{ij} \right\}$$

- High $\xi$ sectors supply disproportionately to distorted sectors, direct or indirectly

Matrix notation:

$$\xi' \propto \Omega'^C (I - D \circ \Omega)^{-1}$$
Measuring distortion centrality

Distortion centrality in arbitrary networks:

\[
\xi_j = \delta \times \frac{1}{\Omega_j^C} + \sum_{i=1}^{N} \xi_i \times (1 + \chi_{ij}) \times \frac{\Omega_{ij}}{\text{fraction of good } j \text{ sold to consumer}} \text{ \sum across all buyers} \times \frac{\text{fraction of good } j \text{ sold to buyer } i}{\text{}}
\]

- High \( \xi \) sectors supply disproportionately to distorted sectors, direct or indirectly.

Matrix notation:

\[
\xi' \propto \Omega^{C'} (I - D \circ \Omega)^{-1}
\]

- \( \Omega \) and \( \Omega^C \) can be derived from input-output tables, but...

- Empirical challenge: how to measure market imperfections \( D \equiv [1 + \chi_{ij}] \)?
$\xi_i^{10\%}$: distortion centrality with constant distortion $\chi_{ij} = 0.1$
$\xi_i^{10\%} \colon$ distortion centrality with constant distortion $\chi_{ij} = 0.1$

<table>
<thead>
<tr>
<th>Panel A: Simulated $\chi_{ij}$'s</th>
<th>South Korea in 1970</th>
<th>China in 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pearson's $r$</td>
<td>Spearman's $\rho$</td>
</tr>
<tr>
<td>$N(0.1, 0.1)$</td>
<td>0.95</td>
<td>0.93</td>
</tr>
<tr>
<td>$U[0, 0.1]$</td>
<td>0.98</td>
<td>0.97</td>
</tr>
<tr>
<td>$Exp(0.1)$</td>
<td>0.95</td>
<td>0.94</td>
</tr>
</tbody>
</table>

| Panel B: Estimated $\chi_{ij}$'s |                      |               |               |
|---------------------------------|---------------------|---------------|
| De Loecker and Warzynski        | -                   | -             | 0.99            | 0.99 |
| Foreign firms as controls       | -                   | -             | 0.98            | 0.98 |
| Rajan and Zingales              | 0.98                | 0.97          | 0.98            | 0.98 |
| Self-reported financial costs    | -                   | -             | 0.92            | 0.92 |
| Sectoral profit share           | 0.91                | 0.91          | 0.99            | 0.98 |
| “Upstreamness” by Antras et al. (2012) | 0.96            | 0.96           | 0.98            | 0.97 |
Measuring distortion centrality

- **Hierarchical networks**: extensions of vertical networks
  - relatively upstream sectors supply disproportionately to other relatively upstream sectors
  - formal definition: IO matrix exhibits decreasing partial column sums

- $\xi$ tends to align with upstreamness (Antras et al. 2012) in hierarchical networks
Korea’s input-output table in 1970
Korea’s input-output table in 1970 — sectors ordered by $\xi^{10\%}$

- Testing for hierarchical property: among >1 million unique inequalities,
  - 84% holds true (90% if small violations <0.01 are tolerated)
South Korea in the 1970s promoted sectors with high distortion centrality

“Heavy-Chemical Industry Drive” (1973-1979): promoted six broad “strategic” sectors:

- steel, non-ferrous metals, shipbuilding, machinery, electronics, petrochemicals

![Graph showing input-using and input-supplying industries](image)

- The input-using industry was targeted by HCI drive
- All others
Input-output table of China in 2007 — sectors ordered by $\xi^{10\%}$

- Testing for hierarchical property: among >1 million unique inequalities,
  - 85% holds true (90% if small violations <0.01 are tolerated)
Which Chinese industries have high / low distortion centralities?

<table>
<thead>
<tr>
<th>Top 10</th>
<th>Bottom 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke making</td>
<td>Canned food products</td>
</tr>
<tr>
<td>Nonferrous metals and alloys</td>
<td>Dairy products</td>
</tr>
<tr>
<td>Ironmaking</td>
<td>Other miscellaneous food products</td>
</tr>
<tr>
<td>Ferrous alloy</td>
<td>Condiments</td>
</tr>
<tr>
<td>Steelmaking</td>
<td>Drugs</td>
</tr>
<tr>
<td>Metal cutting machinery</td>
<td>Meat products</td>
</tr>
<tr>
<td>Chemical fibers</td>
<td>Grain mill products</td>
</tr>
<tr>
<td>Electronic components</td>
<td>Liquor and alcoholic drinks</td>
</tr>
<tr>
<td>Specialized industrial equipments</td>
<td>Vegetable oil products</td>
</tr>
<tr>
<td>Basic chemicals</td>
<td>Tobacco</td>
</tr>
</tbody>
</table>
In China, $\xi_i$ predicts sectoral credit, taxes, and SOE subsidies

<table>
<thead>
<tr>
<th></th>
<th>Int. Rate (1)</th>
<th>Debt Ratio (2)</th>
<th>Tax Break (3)</th>
<th>Tax Rate (4)</th>
<th>SOE Share (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi_i$</td>
<td>-0.987***</td>
<td>2.726***</td>
<td>2.911**</td>
<td>-1.589***</td>
<td>7.577**</td>
</tr>
<tr>
<td></td>
<td>(0.223)</td>
<td>(0.622)</td>
<td>(1.412)</td>
<td>(0.431)</td>
<td>(2.963)</td>
</tr>
<tr>
<td>adj. $R^2$</td>
<td>0.301</td>
<td>0.231</td>
<td>0.097</td>
<td>0.176</td>
<td>0.066</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td># Obs.</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
<td>79</td>
</tr>
</tbody>
</table>

- In sectors with high distortion centrality,
  - firms pay lower interest rates and have more external debt
  - firms pay lower taxes
  - more state-owned enterprises

- Pattern survives after controlling for other potential reasons for intervention
  - capital intensity, profit share, scale of industry, export intensity
To first-order, industrial policies in China account for 5.7% gain in GDP. Chinese sectoral policies in credit, taxes, and government subsidies to SOEs have all contributed to aggregate efficiency gains.

<table>
<thead>
<tr>
<th>Distortion centrality specification</th>
<th>sd (ξ)</th>
<th>Credit</th>
<th>Taxes</th>
<th>SOEs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benchmark (ξ^{10%})</td>
<td>0.22</td>
<td>1.69</td>
<td>0.64</td>
<td>1.27</td>
<td>3.60</td>
</tr>
<tr>
<td>De Loecker and Warzynski</td>
<td>0.42</td>
<td>3.07</td>
<td>1.19</td>
<td>2.39</td>
<td>6.65</td>
</tr>
<tr>
<td>Foreign firms as controls</td>
<td>0.25</td>
<td>1.69</td>
<td>0.67</td>
<td>1.16</td>
<td>3.51</td>
</tr>
<tr>
<td>Rajan and Zingales</td>
<td>0.11</td>
<td>1.01</td>
<td>0.36</td>
<td>0.65</td>
<td>2.02</td>
</tr>
<tr>
<td>Sectoral profit share</td>
<td>0.17</td>
<td>1.20</td>
<td>0.47</td>
<td>0.95</td>
<td>2.62</td>
</tr>
</tbody>
</table>
Counterfactuals

Targeting sectors by capital intensity, size, or value-added is unlikely to be effective

<table>
<thead>
<tr>
<th>Specification for $\xi$</th>
<th>% GDP gains</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi^{10%}$</td>
<td>DLW</td>
</tr>
<tr>
<td>Real-world interventions</td>
<td>3.60</td>
</tr>
<tr>
<td>Counterfactual policy target</td>
<td></td>
</tr>
<tr>
<td>Sales $\gamma$</td>
<td>-1.42</td>
</tr>
<tr>
<td>Consumption share</td>
<td>-2.56</td>
</tr>
<tr>
<td>Export intensity</td>
<td>1.13</td>
</tr>
<tr>
<td>Sectoral value-added</td>
<td>-1.30</td>
</tr>
<tr>
<td>Interm. exp. share</td>
<td>1.34</td>
</tr>
<tr>
<td>Optimal Assignment</td>
<td>5.33</td>
</tr>
</tbody>
</table>
Conclusion

- **Distortion centrality**: the ratio between sectoral influence and sales share
  - a sufficient statistic for social value of sectoral spending
  - can be used to assess welfare impact of sectoral intervention

- Distortions accumulate upstream through backward demand linkages
  - distortion centrality is stable in hierarchical networks

- Many arguments against industrial policies:
  - my theory abstracts away from political economy factors

- Yet, evidence suggests that certain aspects of Korean and Chinese industrial strategy might be motivated by a desire to subsidize sectors that create positive network effects