ECO 2302 - Networks in Trade and Macroeconomics

Lecture 7 - Industrial Policy in Networks

Motivation

- So far, we have briefly touched on the issue of **efficiency** in production networks
  - given the resource and technological constraints of the economy...
  - is the market equilibrium producing the first-best allocation of resources?
- For example:
  - in Lim (2019), markups in networks distort allocation of labor across firms
  - in Tintelnot et al (2019), firm-to-firm relationship formation is inefficient
- Today we will study the issue of **optimal policy** in networks
  - if the market equilibrium is inefficient, what can policymakers do about it?
- Specifically, we will consider **industrial policy** in a production network:
  - i.e. policies that tax/subsidize specific industries/sectors

Model Overview

- Liu (2018), "Industrial Policies in Production Networks"
- As before, we will develop a model with:
  - N sectors
  - input-output linkages between sectors
  - inelastic labor supply
  - perfect competition
- However, the model will now incorporate both **distortions** χ and **policies** τ
- Distortions χ are a reduced-form way of capturing market inefficiencies
  - specifically, they will distort prices relative to the efficient outcome
- Policies τ are taxes/subsidies on consumption/input expenditures
- The **optimal policy** problem will then be as follows:
  - taking distortions χ in the economy as given...
  - what policies τ maximize aggregate consumption?
- In particular, focus on how production network structure shapes optimal policy

Production

- N sectors
- Production technology for firms in sector i:

$$Q_i = z_i F_i \left[L_i, \{M_{ij}\}_{j=1}^{N} \right]$$

  - Q_i: output
  - z_i: TFP
  - L_i: labor input
  - M_{ij}: intermediate inputs from sector j
- F_i is assumed to satisfy the following properties:
  - continuously differentiable
  - increasing and concave in its arguments
  - constant returns to scale

Market Imperfections

- To model market imperfections, assume that:
  - for each dollar of good j purchased by producer i...
  - need to pay $\chi_{ij} \geq 0$ dollars as "imperfection payments"
  - also refer to $\{\chi_{ij}\}_{i,j=1}^{N}$ as *wedges*
- Possible microfoundations of market imperfections:
  - financial frictions
  - contracting frictions
  - imperfect competition
  - production externalities

Market Imperfections

- As an example, consider how financial frictions might generate distortions
  - seller j requires buyer i to pay fraction δ_{ij} of transaction value upfront
  - buyer i finances this by borrowing working capital at interest rate r
  - lenders face some disutility cost of monitoring borrowers
  - interest rates are perfectly competitive, so that lenders earn zero net utility
- Then $\chi_{ij} = r\delta_{ij}$, where "imperfection payments" are paid to lenders of capital
  - but they generate zero additional utility for lenders
  - and hence are a "deadweight loss" for the economy

Industrial Policy

- To model industrial policy:
  - suppose that government can implement two kinds of subsidies
- Intermediate input subsidies:
  - for every dollar of expenditure by producer i on inputs from supplier j...
  - producer i receives τ_{ij} dollars in subsidies
- Labor input subsidies:
  - for every dollar of expenditure by producer i on labor inputs...
  - producer i receives τ_{iL} dollars in subsidies

Producer Problem

- Conditional on wedges $\{\chi_{ij}\}$ and policies $\{\tau_{ij}, \tau_{iL}\}$...
  - market structure is perfectly competitive
- Cost minimization problem for producers in sector i:

$$P_i = \min_{L_i, \{M_{ij}\}_{j=1}^N} \left\{ \sum_{=1}^{N} \left(1 - \tau_{ij} + \chi_{ij}\right) P_j M_{ij} - \left(1 - \tau_{iL}\right) W L_i \right\}$$

$$\text{s.t. } z_i F_i \left[L_i, \{M_{ij}\}_{j=1}^N \right] = 1$$

- Note that both wedges and subsidies distort prices $\{P_i\}$
- However, there is a key difference between wedges and subsidies:
  - wedges $\{\chi_{ij}\}$ *remove* resources from the economy
  - subsidies $\{\tau_{ij}, \tau_{iL}\}$ only *redistribute* resources in the economy
- Total deadweight loss in the economy:

$$\Delta = \sum_{i=1}^{N} \sum_{j=1}^{N} \chi_{ij} P_j M_{ij}$$

Government Budget

- Total cost of government subsidies to sector i:

$$S_i = \sum_j \tau_{ij} P_j M_{ij} + \tau_{iL} W L_i$$

- Also allow government to have consumption G of final consumption good
- To finance expenditure, government levies lump-sum tax T from consumers
- Hence, government budget constraint is:

$$\sum_{i=1}^{N} S_i + G = T$$

Demand

- Representative household supplies L units of labor inelastically
- Preferences:

$$U = U\left[\{Y_i\}_{i=1}^N\right]$$

  - Y_i: final consumption of good i
- For simplicity, assume that final goods are produced without distortions
- Take consumer price index as numeraire (instead of the wage)
- Hence, household's cost minimization problem is:

$$1 = \min_{\{Y_i\}_{i=1}^N} \sum_{i=1}^N P_i Y_i$$

$$\text{s.t. } U\left[\{Y_i\}_{i=1}^N\right] = 1$$

- Budget constraint:

$$C = WL - T$$

Aggregation

- Let Y denote aggregate consumption (households + government):

$$Y \equiv C + G$$

- Substituting household and government budget constraints:

$$Y = WL - \sum_{i=1}^{N} S_i$$

- In what follows we will take Y as the objective function
- Y differs from totat output of consumption good Y^G due to deadweight loss:

$$Y = Y^G - \Delta$$

- Note: Δ can be interpreted as consumption by lenders with financial frictions

Policy Analysis Goal

- The goal of our policy analysis will now be to answer the following:
  - taking wedges $\{\chi_{ij}\}_{i,j=1}^N$ as given ...
  - how do subsidies $\{\tau_{ij}\}_{i,j=1}^N$ and $\{\tau_{iL}\}_{i=1}^N$ affect aggregate consumption Y?
  - in particular, which sectors should be subsidized?
- We will develop some first-order results
  - starting from the **decentralized equilibrium** with $\tau = 0$

Efficient Equilibrium

- As a benchmark, first consider the **efficient equilibrium** with $\chi = 0$ and $\tau = 0$
- Let γ_i denote the Domar weight of sector i:

$$\gamma_i \equiv \frac{P_i Q_i}{WL}$$

- Let $\Omega \equiv \{\omega_{ij}\}_{i,j=1}^{N}$ denote the matrix of intermediate input production shares:

$$\omega_{ij} \equiv \frac{P_j M_{ij}}{P_i Q_i}$$

- Let β_i denote the share of household expenditure spent on sector i consumption:

$$\beta_i \equiv \frac{P_i Y_i}{\sum_{J=1}^{N} P_j Y_j}$$

- Let $\Sigma \equiv \{\sigma_{ij}\}_{i,j=1}^{N}$ denote matrix of production function elasiticities:

$$\sigma_{ij} \equiv \frac{\partial \log F_i}{\partial \log M_{ij}}$$

Efficient Equilibrium

- From our discussion of Acemoglu et al (2012), we know that:

$$\frac{d \log WL}{d \log z_i} = \mu_i$$

where μ_i is the i^{th}-element of the **influence vector** of the economy

$$\mu = \left(I - \Sigma'\right)^{-1} \beta$$

- In the efficient equilibrium, influence coincides with the Domar weight of a sector

$$\mu_i = \gamma_i$$

- This is a restatement of Hulten's Theorem

Optimal Policy in Decentralized Economies

- Now consider the effect of subsidies in a decentralized economy

Proposition 1

The first-order effects of subsidies in a decentralized economy are:

$$\left.\frac{d\log Y}{d\log \tau_{ij}}\right|_{\tau=0} = \underbrace{\omega_{ij}}_{\substack{\textit{input}\\ \textit{share}}} \times \Big(\underbrace{\mu_i}_{\textit{influence}} - \underbrace{\gamma_i}_{\substack{\textit{Domar}\\ \textit{weight}}} \Big)$$

Optimal Policy in Decentralized Economies

$$\left.\frac{d\log Y}{d\log \tau_{ij}}\right|_{\tau=0} = \omega_{ij}\left(\mu_i - \gamma_i\right)$$

- A higher subsidy τ_{ij} affects aggregate output $Y = WL - \sum_{i=1}^{N} S_i$ in two ways:
  - it increases factor income WL (like a positive TFP shock)
  - it increases total costs of subsidies $\sum_{i=1}^{N} S_i$ (in all sectors)
- Intuition for Proposition 1:
  - marginal benefit of subsidies to sector i captured by influence μ_i
  - marginal cost of subsidies to sector i captured by Domar weight γ_i
  - cost-benefit scaled by input share ω_{ij} (subsidy only targets input j)

Optimal Policy in Decentralized Economies

$$\left.\frac{d \log Y}{d \log \tau_{ij}}\right|_{\tau=0} = \omega_{ij} \left(\mu_i - \gamma_i\right)$$

- This implies that to predict first-order effects of policy, only need to know:
  - intermediate input shares ω_{ij}
  - elasticities σ_{ij} and final consumption shares β_i (to calculate μ_i)
  - Domar weights γ_i
- In particular, first-order policy effects can be predicted...
  - without parametric assumptions on production/utility functions
- Note also that since $\mu_i = \gamma_i$ in the efficient equilibrium...
  - policy has zero first-order effect on welfare if there are no distortions
  - a restatement of the fact that the equilibrium is efficient

Distortion Centrality

- Which sectors should policymakers prioritize in implementing subsidies?
- Proposition 1 implies that policymakers should target sectors in which...
  - the difference between influence μ_i and Domar weight γ_i is large
- Equivalently, targeted sectors should have high **distortion centrality**:

$$\xi_i \equiv \mu_i/\gamma_i$$

- Note that optimal sectors for targeting are not necessarily those with...
  - the strongest distortions χ_{ij} - why? missing input-output linkages
  - the greatest influence μ_i - why? ignores fiscal cost of subsidies
  - the smallest size γ_i - why? ignores benefit of subsidies

Distortion Centrality

- To further illustrate role of distortion centrality...
  - consider the following thought experiment
- Suppose government holds taxes T fixed
  - then financing subsidies to increase private consumption C requires...
  - reducing public consumption G
- To maximize aggregate consumption $C + G$, subsidies should then target...
  - sectors in which $dC/d\tau_{ij}$ is high relative to $-dG/d\tau_{ij}$

Proposition 2

In a decentralized economy, the social value of policy expenditure on τ_{ij} is:

$$SV_{ij} \equiv - \left. \frac{dC/d\tau_{ij}}{dG/d\tau_{ij}} \right|_{\tau=0, T \ constant} = \xi_i$$

- Hence, ξ_i also reflects *tradeoff between private and public consumption*

Distortion Centrality

- Finally, consider the aggregate effects of multiple simultaneous subsidies
- Let $s_i \equiv S_i/WL_i$ denote subsidy expenditure per unit of value-added in sector i

Proposition 3

Aggregate gains from subsidies in a decentralized economy are approximately:

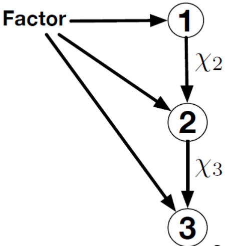
$$\Delta \log Y \approx cov\left(\xi_i, s_i\right)$$

where the covariance is taken across sectors using value-added shares as weights.

- Again, policymakers should:
  - subsidize sectors with high distortion centrality
  - avoid subsidizing (or tax) sectors with low distortion centrality
- In particular, Proposition 3 implies that *uniform* subsidies have no effect
  - why? because they do not redistribute resources across sectors
  - equivalent to lump-sum transfer between government and consumers

Example: Vertical Production Network

- As an example, consider a simple model with three sectors in a vertical production network:



Production Functions

$$Q_1 = L_1$$

$$Q_2 = L_2^{1-\sigma_2} M_{21}^{\sigma_2}$$

$$Q_3 = L_3^{1-\sigma_3} M_{32}^{\sigma_3}$$

$$Y^G = Y_3$$

Source: Liu (2018).

Calculating Influence

- What is the influence μ_i of each sector?
- Production function elasticities:

$$\Sigma = \begin{bmatrix} 0 & 0 & 0 \\ \sigma_2 & 0 & 0 \\ 0 & \sigma_3 & 0 \end{bmatrix}$$

- Final consumption shares:

$$\beta = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix}^T$$

- Influence vector:

$$\begin{aligned} \mu &= \left(I - \Sigma'\right)^{-1} \beta \\ &= \begin{bmatrix} 1 & \sigma_2 & \sigma_2\sigma_3 \\ 0 & 1 & \sigma_3 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \\ &= \begin{bmatrix} \sigma_2\sigma_3 & \sigma_3 & 1 \end{bmatrix}^T \end{aligned}$$

Calculating Domar Weights

- What is the Domar weight γ_i of each sector?
- Sector 2 spends fraction σ_2 of total costs on sector 1 input:

$$(1+\chi_2)\, P_1 Q_1 = \sigma_2 P_2 Q_2$$

- Sector 3 spends fraction σ_3 of total costs on sector 2 input:

$$(1+\chi_3)\, P_2 Q_2 = \sigma_3 P_3 Q_3$$

- Since only sector 3 produces final consumption goods, Domar weight is:

$$\gamma_3 \equiv \frac{P_3 Q_3}{VA} = 1$$

- Hence, Domar weight for sector 2 is:

$$\gamma_2 \equiv \frac{P_2 Q_2}{VA} = \frac{\sigma_3}{1+\chi_3}$$

and Domar weight for sector 1 is:

$$\gamma_1 \equiv \frac{P_1 Q_1}{VA} = \frac{\sigma_2}{1+\chi_2} \cdot \frac{\sigma_3}{1+\chi_3}$$

Calculating Distortion Centralities

- What is the distortion centrality of each sector?
- Since distortion centrality is the ratio of influence to Domar weight:

$$\xi_1 = \mu_1/\gamma_1 = 1$$
$$\xi_2 = \mu_2/\gamma_2 = 1 + \chi_3$$
$$\xi_3 = \mu_3/\gamma_3 = (1 + \chi_2)(1 + \chi_3)$$

Example: Vertical Production Network

$$
\begin{array}{lcccccc}
 & & & \text{Upstream} & \text{Midstream} & \text{Downstream} & \\
\text{(Influence)} & \left(\mu_1,\ \mu_2,\ \mu_3\right) & \propto & \Big(\quad \sigma_2\sigma_3, & \sigma_3, & 1 & \Big), \\
\text{(Domar weights)} & \left(\gamma_1,\ \gamma_2,\ \gamma_3\right) & \propto & \Big(\quad \frac{\sigma_2}{(1+\chi_2)} \cdot \frac{\sigma_3}{(1+\chi_3)}, & \frac{\sigma_3}{1+\chi_3}, & 1 & \Big), \\
\text{(Distortion centrality)} & \left(\xi_1,\ \xi_2,\ \xi_3\right) & \propto & \Big(\quad (1+\chi_2)(1+\chi_3), & (1+\chi_3), & 1 & \Big),
\end{array}
$$

- Sector rankings in terms of influence/Domar weights are:

$$
\mu_3 > \mu_2 > \mu_1
$$
$$
\gamma_3 > \gamma_2 > \gamma_1
$$

- Sector 3 has the greatest influence
  - why? because shocks to sector 3 affect value of labor in all sectors
- Sector 3 is also the largest sector
  - why? because it adds value to output from sectors 1 and 2

Example: Vertical Production Network

$$
\begin{array}{lcccccc}
 & & & \text{Upstream} & \text{Midstream} & \text{Downstream} & \\
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\text{(Distortion centrality)} & \left(\xi_1,\ \xi_2,\ \xi_3\right) & \propto & \Big(\quad (1+\chi_2)(1+\chi_3), & (1+\chi_3), & 1 & \Big),
\end{array}
$$

- However, sector rankings in terms of distortion centrality are reversed!

$$\xi_1 > \xi_2 > \xi_3$$

- Sector 1 has the highest distortion centrality
  - because distortions in sectors 2 and 3 accumulate in sector 1...
  - through backward demand linkages
- Simple example highlights that:
  - **upstreamness** is closely related to distortion centrality
  - targeting sectors based on influence or size could result in subsidizing the least cost-effective sector

Distortions vs. iceberg trade costs

- Note that distortions $\{\chi_{ij}\}_{i,j=1}^{N}$ also seem to resemble *iceberg trade costs*
  - i.e. to ship 1 unit of good j to firms in i, need to produce χ_{ij} units
- Under both scenarios, prices are related by:

$$
\begin{aligned}
P_1 &= W \\
P_2 &= W^{1-\sigma_2}\left[\left(1+\chi_2\right)P_1\right]^{\sigma_2} \\
P_3 &= W^{1-\sigma_3}\left[\left(1+\chi_3\right)P_2\right]^{\sigma_3}
\end{aligned}
$$

- This raises a bit of a puzzle:
  - a model with iceberg trade costs is *constrained efficient*
  - i.e. there is no scope for subsidies to improve welfare
  - so why is the model with χ_{ij} labeled as “distortions” inefficient?
- Key: distortions directly reduce the amount of the final consumption good

Distortions vs. iceberg trade costs

- With iceberg trade costs, market clearing conditions are:

$$P_3X_3 = WL$$
$$P_2X_2 = \frac{\sigma_3}{1+\chi_3}P_3X_3$$
$$P_1X_1 = \frac{\sigma_2}{1+\chi_2}P_2X_2$$

- With distortions, market clearing conditions are:

$$P_3X_3 = WL + \chi_2 P_1X_1 + \chi_3 P_2X_2$$
$$P_2X_2 = \frac{\sigma_3}{1+\chi_3}P_3X_3$$
$$P_1X_1 = \frac{\sigma_2}{1+\chi_2}P_2X_2$$

i.e. distortion losses $\chi_2 P_1X_1 + \chi_3 P_2X_2$ are subtracted from final output P_3X_3

Distortion Centrality and Network Structure

- In vertical network example, upstream sectors have higher distortion centrality
- What about more general network structures?
- Let θ_{ij} denote the fraction of good j that is used by sector i:

$$\theta_{ij} \equiv \frac{M_{ij}}{X_j}$$

- Let θ_i^F denote the fraction of good i that is consumed by the household:

$$\theta_i^F \equiv \frac{C_i}{X_i}$$

- So market clearing requires:

$$\theta_i^F + \sum_{j=1}^{N} \theta_{ji} = 1$$

Distortion Centrality and Network Structure

Proposition 4

Distortion centralities satisfy:

$$\xi_i = \theta_i^F \delta + \sum_{j=1}^{N} \xi_j \left(1 + \chi_{ji}\right) \theta_{ji}$$

where $\delta \equiv WL/Y^G$ *is determined in general equilibrium.*

- A sector has high distortion centrality if...
  - it sells more ($\theta_{ji} \uparrow$) to sectors that have high distortions ($\chi_{ji} \uparrow$) and high distortion centralities ($\xi_j \uparrow$)

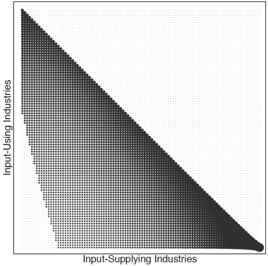
Distortion Centrality and Network Structure

- To compute ξ_i and determine optimal policy, need to know either:
  1. influence μ_i (which requires information on β, Σ) and Domar weights γ_i
  2. demand I-O table $\{\theta_{ij}\}$ and extent of distortions $\{\chi_{ij}\}$
- In case 1, may not be feasible...
  - to estimate production function elasticities Σ for all sector-pairs
- In case 2, may not be feasible...
  - to estimate extent of distortions $\{\chi_{ij}\}$ for all sector pairs
- What can we say about optimal policy if we only know the I-O table $\{\theta_{ij}\}$?
- To make progress, we will restrict attention to a class of networks:
  - in which statistics computed from $\{\theta_{ij}\}$ align with distortion centrality

Hierarchical Networks

- Define a **hierarchical network** as one in which demand I-O shares satisfy:

$$\sum_{k=1}^{K} \theta_{ki} \geq \sum_{k=1}^{K} \theta_{kj}, \quad \forall i < j \text{ and } \forall K \leq N$$



Source: Liu (2018).

- In other words, there is a ranking of sectors such that:
  - higher-ranked sectors supply disproportionately more output...
  - to other higher-ranked sectors

Hierarchical Networks

- Define the **upstreamness** U_i of sector i as:

$$U_i = 1 + \sum_{j=1}^{N} \theta_{ji} U_j$$

or in matrix form:

$$U = \left[I - \Theta'\right]^{-1} \mathbf{1}$$

where $\Theta = \{\theta_{ij}\}$ is the demand I-O matrix.

- In other words, sector i is more "upstream"...
  - if it sells disproportionately more to other "upstream sectors"
- One can then show that in a hierarchical network:

$$U_i \geq U_j \Leftrightarrow i \leq j$$

Hierarchical Networks

- Now let $D \equiv \{\chi_{ij}\}$ denote the distortion matrix
- Suppose that the matrix $D \cdot \Theta$ is also hierarchical
  - e.g. all distortions are the same with $\chi_{ij} = \chi$
- Then in the decentralized economy:

$$\xi_i \geq \xi_j \text{ for all } i < j$$

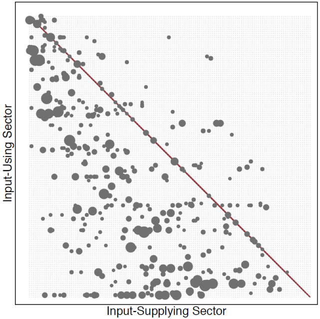
- In other words, if the I-O matrix adjusted for distortions is hierarchical...
  - then sector rankings in upstreamness and distortion centrality are identical
- What does this imply about optimal policy?
  - governments should target upstream sectors

Empirical Application

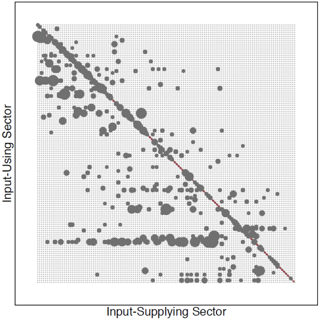
- Now apply theoretical results to evaluate two real-world policies
  - promotion of heavy and chemical industries (HCI) in 1970s South Korea
  - industrial policy in modern-day China
- First, use national input-output tables to compute Θ
- As a benchmark, rank sectors based on distortion centralities $\xi_i^{10\%}$:
  - computed under common distortion $\chi_{ij} = 0.1$
  - hence all variation in $\xi_i^{10\%}$ driven by Θ

Benchmark Distortion Centrality

South Korea, 1970



China, 2007



Source: Liu (2018).

- Both I-O tables look strikingly hierarchical

Benchmark Distortion Centrality

- Formal test of whether hierarchical inequalities hold:

Relax inequalities by ε $\left(\sum_{k=1}^{K} \theta_{ik} \geq \sum_{k=1}^{K} \theta_{jk} - \varepsilon\right)$	Fraction of partial-column-sum comparisons (in Definition 3) that hold true: South Korea	China
0	84.8%	86.0%
0.001	87.2%	87.4%
0.005	89.1%	88.9%

Source: Liu (2018).

- Next, simulate/estimate distortions χ_{ij} using multiple approaches
  - and check correlation with $\xi_i^{10\%}$

Simulating/Estimating Distortions

		Average correlation with benchmark $\xi_i^{10\%}$			
		South Korea in 1970		China in 2007	
Specifications		**Pearson's r**	**Spearman's ρ**	**Pearson's r**	**Spearman's ρ**
Upstreamness by Antras et al. (2012)		0.96	0.96	0.98	0.97
Panel A: Simulated χ_{ij}'s					
A1	constant $\chi_{ij} = 5\%$	1	1	1	1
A2	log-$N(0.09, 0.1)$	0.94	0.92	0.99	0.99
A3	$N(0.1, 0.1)$	0.95	0.93	0.99	0.99
A4	$N(0.2, 0.2)$	0.93	0.94	0.95	0.97
A5	$\max\{N(0.1, 0.1), 0\}$	0.97	0.96	0.99	0.99
A6	$U[0, 0.1]$	0.98	0.97	1	1
A7	$U[0, 0.2]$	0.98	0.97	0.99	0.99
A8	$Exp(0.1)$	0.95	0.94	0.98	0.99
A9	$Exp(0.15)$	0.94	0.94	0.96	0.97

Source: Liu (2018).

Simulating/Estimating Distortions

		Average correlation with benchmark $\xi_i^{10\%}$			
		South Korea in 1970		China in 2007	
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Panel B: Estimated Imperfections					
B1	De Loecker and Warzynski	-	-	0.99	0.99
B2	Foreign firms as controls	-	-	0.94	0.95
B3	Rajan and Zingales	0.98	0.97	0.98	0.97
B4	Sectoral profit share	0.91	0.91	0.99	0.98

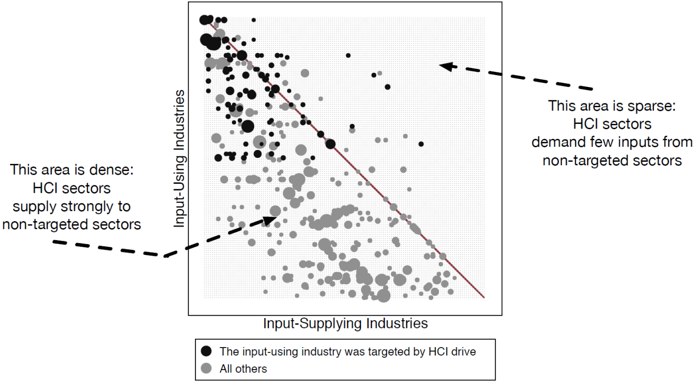
Source: Liu (2018).

Simulating/Estimating Distortions

- Analysis shows that distortion centralities from multiple estimation/simulation methods are:
  - highly correlated with benchmark distortion centrality $\xi_i^{10\%}$
  - highly correlated with upstreamness measure U_i
- Hence, suggests that policy can safely target upstream sectors
  - regardless of how actual distortions are specified

Industrial Policy in South Korea, 1970s

- HCI sectors targeted by South Korean industrial policy in the 1970s were generally upstream with high distortion centralities:



Source: Liu (2018).

Sector Distortion Centralities

- Sectors with highest/lowest $\xi_i^{10\%}$ in South Korea, 1970:

Top 10	$\xi_i^{10\%}$	Bottom 10	$\xi_i^{10\%}$
Pig iron	1.43	Tobacco	0.91
Crude steel	1.38	Condiments	0.91
Iron alloy	1.35	Bread and pastry	0.92
Steel forging	1.26	Cosmetics and toothpaste	0.92
Explosives	1.26	Slaughter, meat, and dairy products	0.93
Acyclic intermediates	1.25	Leather goods	0.93
Construction clay products	1.25	Furniture	0.93
Carbides	1.25	Soaps	0.95
Non-ferrous metals	1.24	Other miscellaneous food products	0.95
Machine tools	1.23	Drug	0.96

Source: Liu (2018).

Industrial Policy in South Korea, 1970s

- Can also use model to simulate counterfactuals of targeting "wrong" sectors
  - target same number of sectors as HCI drive
  - but select sectors based on other criteria
  - simulate subsidies in proportion to sector value-added

		Average distortion centrality			Gains Relative to HCI Drive		
		(1)	(2)	(3)	(4)	(5)	(6)
	Specification for ξ_i:	benchmark	B3	B4	benchmark	B3	B4
HCI Drive		1.16	1.12	1.28	100%	100%	100%
Counterfactuals (select sector sorted by...)							
CF1	Domar weight γ	0.98	0.99	0.96	-11%	-9%	-13%
CF2	Consumption share β	0.97	0.94	0.94	-18%	-16%	-22%
CF3	Export intensity	1.07	1.05	1.11	46%	44%	40%
CF4	Sectoral value-added	0.98	0.99	0.98	-10%	-9%	-8%
CF5	Interm. exp. share	1.07	1.04	1.08	41%	36%	28%
CF6	distortion centrality ξ	1.22	1.15	1.30	137%	124%	109%
CF7	Uniform promotion	1	1	1	0%	0%	0%

Source: Liu (2018).

Industrial Policy in Modern-day China

- Multiple examples of industrial policy in modern-day China
- Credit markets:
  - predominantly state-controlled
  - heavily regulated interest rates
  - policy directives for banks to prioritize lending to specific sectors
- Corporate income tax:
  - national standard tax rate
  - but with multiple policy incentives that are predominantly industry-oriented
- State-owned enterprises
  - state directly engages in production through SOEs
  - SOEs receive government subsidies and easy access to credit

Measures of Chinese Industrial Policy

- There is substantial variation in multiple measures of extent of industrial policy:

Sectoral Means (in Percentage Points)	Min	1st Quartile	Median	3rd Quartile	Max	Average	Std. Dev.
Effective interest rate	1.85	3.39	4.12	5.00	12.33	4.45	1.67
Debt ratio	40.91	51.54	54.78	57.04	65.39	54.45	4.82
Fraction of firms with tax incentives	8.70	24.88	30.81	36.55	61.33	31.23	9.84
Effective corporate income tax rate	9.08	15.13	17.48	19.45	24.78	17.29	2.94
Fraction of firms receiving subsidies	6.65	9.62	11.77	13.93	28.83	12.42	3.83
Subsidies / revenue	0.60	0.98	1.36	1.79	4.74	1.57	0.83
SOE Share of sectoral value-added	0.66	4.76	10.67	24.40	74.50	17.32	17.04

Source: Liu (2018).

Measures of Chinese Industrial Policy

- State-owned enterprises also appear to receive more favorable industrial policy:

Variable Means By Ownership	Private Firms	SOEs
Effective interest rate	4.63	2.23
Debt ratio	54.38	63.49
Fraction of firms with tax incentives	31.93	31.48
Effective corporate income tax rate	17.29	14.98
Fraction of firms receiving subsidies	11.46	22.41
Subsidies / revenue	1.56	2.78

Source: Liu (2018).

Sector Distortion Centralities

- Sectors with highest/lowest $\xi_i^{10\%}$ in China, 2007:

Top 10	$\xi_i^{10\%}$	Bottom 10	$\xi_i^{10\%}$
Coke making	1.36	Canned food products	0.62
Nonferrous metals and alloys	1.35	Dairy products	0.65
Ironmaking	1.35	Other miscellaneous food products	0.68
Ferrous alloy	1.33	Condiments	0.69
Steelmaking	1.33	Drugs	0.77
Metal cutting machinery	1.32	Meat products	0.77
Chemical fibers	1.31	Grain mill products	0.78
Electronic components	1.30	Liquor and alcoholic drinks	0.81
Specialized industrial equipments	1.30	Vegetable oil products	0.82
Basic chemicals	1.29	Tobacco	0.83

Source: Liu (2018).

Industrial Policy and Distortion Centralities

- Now test whether sectors that appear to be targeted by industrial policy...
  - also have high distortion centralities
- Estimate regressions of the following form:

$$[\text{policy measure}]_i = a + b \times \xi_i^{10\%} + \text{controls}_i + \epsilon_i$$

- First restrict sample to private firms only
- Then use SOE share of sector value-added as dependent variable

Industrial Policy and Distortion Centralities

	Effective Interest Rate		Debt Ratio		Tax Break	
	(1)	(2)	(3)	(4)	(5)	(6)
$\xi_i^{10\%}$	-0.895^{***}	-0.987^{***}	2.961^{***}	2.726^{***}	2.861^{**}	2.911^{**}
	(0.222)	(0.223)	(0.556)	(0.622)	(1.323)	(1.412)
Capital intensity		-0.425^{**}		-0.390		0.759
		(0.199)		(0.556)		(1.263)
Lerner index		-0.0247		0.146		-0.559
		(0.173)		(0.481)		(1.092)
Log(fixed assets in starting year)		-0.0273		0.511		-0.559
		(0.204)		(0.568)		(1.290)
Export intensity		-0.682^{***}		0.284		2.824^{**}
		(0.172)		(0.487)		(1.105)
adj. R^2	0.163	0.301	0.260	0.231	0.045	0.097
# Obs.	79	79	79	79	79	79

Source: Liu (2018).

Industrial Policy and Distortion Centralities

	Effective Tax Rate		Recipient of Subsidies		$\frac{\text{Subsidies}}{\text{Revenue}}$	
	(7)	(8)	(9)	(10)	(11)	(12)
$\xi_i^{10\%}$	-1.595^{***}	-1.589^{***}	-0.556	-0.236	-0.210	-0.102
	(0.396)	(0.431)	(0.593)	(0.578)	(0.127)	(0.126)
Capital intensity		-0.253		1.403^{***}		0.284^{**}
		(0.385)		(0.517)		(0.113)
Lerner index		0.0958		0.166		0.00943
		(0.333)		(0.447)		(0.0975)
Log(fixed assets in starting year)		-0.643		1.075^{**}		0.147
		(0.394)		(0.528)		(0.115)
Export intensity		-0.375		1.186^{**}		-0.0977
		(0.337)		(0.452)		(0.0986)
adj. R^2	0.164	0.176	-0.002	0.209	0.022	0.198
# Obs.	79	79	79	79	79	79

Source: Liu (2018).

Industrial Policy and Distortion Centralities

Outcome variable: SOEs' Share of Sectoral Value-Added in 2007

	All SOEs in 2007		SOEs established after year T			
			$T = 2000$	$T = 2001$	$T = 2002$	$T = 2003$
	(1)	(2)	(3)	(4)	(5)	(6)
$\xi_i^{10\%}$	7.577**	7.808***	2.960***	2.549***	2.123***	1.545**
	(2.963)	(2.834)	(1.059)	(0.886)	(0.725)	(0.619)
Capital intensity		0.914	0.774	0.717	0.602	0.199
		(2.535)	(0.947)	(0.792)	(0.649)	(0.554)
Lerner index		−4.622**	−2.191***	−1.997***	−1.611***	−1.148**
		(2.193)	(0.820)	(0.685)	(0.561)	(0.479)
Log(fixed assets in starting year)		6.974***	2.042**	1.632**	1.245*	1.028*
		(2.590)	(0.968)	(0.809)	(0.663)	(0.565)
Export intensity		−5.660**	−2.013**	−1.810**	−1.484**	−1.145**
		(2.218)	(0.829)	(0.693)	(0.568)	(0.484)
adj. R^2	0.066	0.290	0.269	0.284	0.276	0.220
# Obs.	79	79	79	79	79	79

Source: Liu (2018).

Summary and Related Papers

- Studied how networks shape industrial policy in models with distortions
- Key result: subsidies should target sectors with high distortion centrality
  - which depends on both standard network influence and Domar weight
- Empirical application to 1970s South Korea and modern-day China:
  - empirical I-O tables are predominantly hierarchical
  - real-world policy appears to target sectors with high distortion centralities
- Related papers:
  - Huang (2018) - optimal subsidies in economies with innovation networks
- Next week: transportation networks