Industrial Policies in Production Networks

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(QJE, 2019)

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Networks and innovation reading group with Professor Hopenhayn
UCLA, May 5th, 2023

Motivation

Selected industries, government interventions, and Industrial Policies have been widely observed in the past, but there is no clear argument for choosing a specific sector (leaving aside political economy). Then, **how to target industrial policies?**

What this paper does:

(a) Builds a model to analyze policy interventions in production networks.

(b) Use the framework to evaluate industrial observed policies.

Key takeaway : Distortions accumulate upstream through backward demand linkages, making upstream sector interventions cost-efficient.

Model: Setup

A Representative consumer exogenously provides factor supply L and consumes a unique good, Y.There are S sectors with CRTS that trade between them.

Sectors produce using factors and intermediate inputs (M) which are subject to market imperfections (e.g., Credits constraints):

$$P_i = \min_{\ell_i, m_{i,i-1}, k_i} \left(P_{i-1} m_{i,i-1} + W\ell_i + rk_i\right)$$

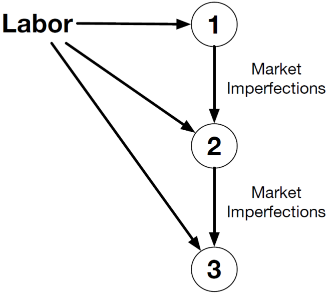
$$\text{s.t. } z_i F_i\left(\ell_i, m_{i,i-1}\right) \geq 1, \quad \delta_i P_{i-1} m_{i,i-1} \leq k_i$$

P_i is the market price of good i, W is the factor price, and δ_i value of transaction paid upfront. For every dollar producer i spends on input j, he must pay $\chi = \lambda\delta_{ij}$, where λ is the interest rate.

Model: Network example

Market with only three sectors:

- upstream (sector 1): $Q_1 = z_1\ L_1$
- midstream (sector 2): $Q_2 = z_2\ L_2^{1-\sigma_2}\ M_{21}^{\sigma_2}$
- downstream (sector 3): $Q_3 = z_3\ L_3^{1-\sigma_3}\ M_{32}^{\sigma_3}$
- final good is produced linearly from good 3



Model: Sectoral allocations in decentralized economy

Assume a decentralized economy; there are inneficiencies but no government intervention.

$\Sigma = [\sigma_i]$ is the N x N matrix of equilibrium intermediate production elasticities:

$$\sigma_i = \frac{\partial \ln F_i(L_i, M_{i,i-1})}{\partial \ln M_{i,i-1}}$$

Distortions affect sectoral expenditure shares:

$$P_i \ M_{i,i-1} = \frac{\sigma_i}{1 + \chi_{i,i-1}}$$

Distortion payments are assumed to be deadweight losses; interest payments are "quasi-rent" (eliminated in terms of the consumption good)

Model: Influence, sales, and distortion centrality (1)

β is be the N x 1 expenditure share for producing the consumption good, $\beta_j = \frac{P_j Y_j}{\sum_i P_i Y_i}$

Sectoral influence $\mu_i \equiv \frac{d \ln Y}{d \ln z_i} = \beta'(I - \Sigma)^{-1}$ is the elasticity measure of sectoral importance:

$$\mu' \propto (\underbrace{\sigma_2 \sigma_3}_{\substack{\text{upstream} \\ \text{sector 1}}} , \underbrace{\sigma_3}_{\substack{\text{midstream} \\ \text{sector 2}}} , \underbrace{1}_{\substack{\text{downstream} \\ \text{sector 3}}})$$

The Leontief inverse in the expression captures the infinite rounds of the network effects; how productivity shocks to one sector affect prices in another, taking all higher-order effects into account

Model: Influence, sales, and distortion centrality (2)

Sectoral sales share $\gamma_i = \frac{p_i Q_i}{Y}$ is a measure of equilibrium sector size:

$$\gamma' \propto (\underbrace{\frac{\sigma_2}{1+r\delta_2} \cdot \frac{\sigma_3}{1+r\delta_3}}_{\text{upstream sector 1}}, \underbrace{\frac{\sigma_3}{1+r\delta_3}}_{\text{midstream sector 2}}, \underbrace{1}_{\text{downstream sector 3}})$$

Distortion centrality: influence over sales $\xi_i = \frac{\mu_i}{\gamma_i}$

Upstream has the highest distortion centrality (inefficient economies $\mu_i = \gamma_i$, $\xi_i = 1$).

Model: Introducing a government (1)

The government gives sector-specific input subsidies τ_{ij} , for $j = 1, ..., S, L$ which expand sectoral expenditures but are costly for the government.

$$(1 - \tau_{ij} + \xi_{ij}) P_i \; M_i = \sigma P_i \; Q_i$$

The Government budget constraint is $G + B = T$, where G is public consumption, B is total subsidies payments (sectors and factors), and T is a lump sum tax.

Aggregate output is $Y = C + G$

Model: Introducing a government (2)

The elasticity of aggregate output w.r.t. subsidy τ_{ij} is a sufficient statistic to predict subsidies' impact on output in the decentralized economy.

$$\left.\frac{d \ln Y}{d\tau_{ij}}\right|_{\tau=0} = \underbrace{\frac{\sigma_{ij}}{1+\chi_{ij}}}_{\substack{\text{expenditure}\\ \text{share}}} \Big(\underbrace{\mu_i}_{\text{influence}} - \underbrace{\gamma_i}_{\text{sales}} \Big) \text{ for } j = 1, \ldots, S, L.$$

This is s reduced-form formula for non-parametric and ex-ante counterfactuals; the logic is as follows:

- Subsidies raise factor income WL, similar to a factor augmenting productivity shock, escalated by target sector influence, which affects the rest of the (distorted) production network.
- The cost for the government is proportional to total resources at the targeted sector γ_i, only first order.
- Hence, the subsidy aggregated impact is proportional to the distance of the influence and the sector domar weight (γ_i).

Model: Social value of policy expenditure

Identity: $dY = dC + dG$, then the social value of policy expenditure on input subsidy τ_{ij} is

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

Hence, Sectoral distortion centrality ξ_i is a sufficient statistic for the social value of marginal policy spending into the sector: $SV_{ij} = \xi_i$. It captures gains in private consumption per unit reduction of public consumption.

Policy should not target the most important / large / distorted sectors: **Subsidize upstream!**

(a) Indirectly relaxes constraints downstream.

(b) Pushes resources toward efficient allocations

Model: Welfare evaluation and counterfactual

Distortion centrality averages to one: $\mathbb{E}[\xi] = \sum_{i \in S} \xi_i \cdot \frac{L_i}{L} = 1$

Define s_i as the government spending per value-added in sector i, hence the aggregate gain from selective sectoral intervention is:

$\frac{\Delta Y}{Y} = Cov(\xi_i, s_i)$

If sd is the standar deviation of ξ_i, then $\bar{\xi}_i = \xi_i / sd$ is the distortion centrality standardized to unit variance.

By regressing $s_i = \alpha + \beta \bar{\xi}_i + \varepsilon_i$ where each observation is a sector and is weighted by sectoral value-added. Then $\frac{\Delta Y}{Y} = sd \cdot \beta$

- high sd : more dispersion in ξ, more scope for welfare-enhancing policies.
- high β: spendings are better targeted to high-ξ sectors.

Model: Distortion centrality in general production networks

The intermediate expenditure share is the fraction of good j that is sold to sector i, $\omega_{ij} = \frac{M_{ij}}{Q_j}$, captures the importance of sector j as a supplier to i; ω_j^F is the homologous for factors.

Thus, for scalar $\sigma = \frac{WL}{Y}$ the distortion centrality for sector j is:

$$\xi_j = \delta \cdot \omega_j^F + \sum_{i \in S} \xi_i \cdot (1 + \chi_{ij}) \cdot \omega_{ij}$$

or in matrix form ($\mathbf{D} \equiv [1 + \chi_{ij}]$),

$$\xi' \propto \left(\omega^F\right)' (I - \mathbf{D} \circ \Omega)^{-1},$$

With $\Omega = [\omega_{ij}]$ being the IO expenditure share matrix. It formalizes that distortions accumulate through backward demand linkages:

A sector has high distortion centrality if it sells a disproportionate share of its output to other sectors with high distortion centrality and large imperfections.

Hierarchical networks (1)

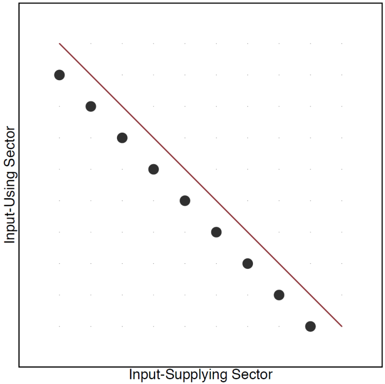
In an arbitrary production network, distortion centrality may depend strongly on the underlying market imperfections and thus correlate poorly with the upstreamness measure.

There is a class of networks- "hierarchical" -in which distortion centrality tends to correlate strongly with the upstreamness measure.

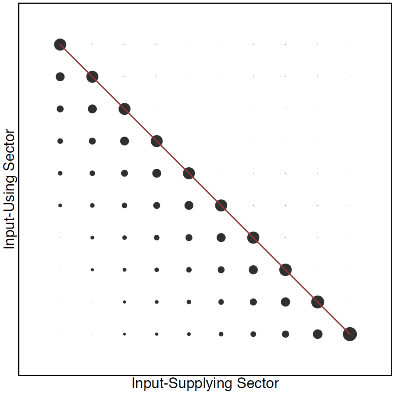
- **Upstreamness**: It captures the notion that sectors selling a disproportionate share of their output to relatively upstream sectors should themselves be relatively upstream.
- **Hierarchical**: A network has the hierarchical property if sectors can be ordered as $1, 2, ..., S$ such that it has non-increasing partial column sums.

Hierarchical networks (2)

A. vertical chain

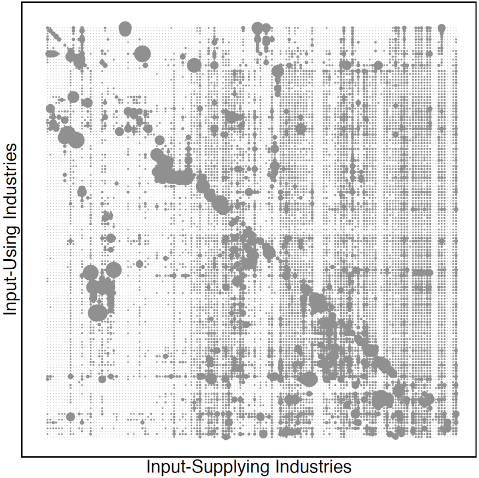


B. hierarchical network

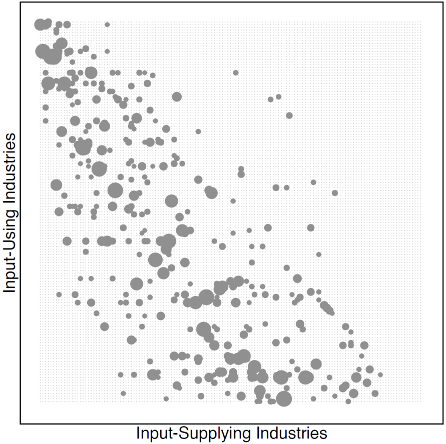


- Below the diagonal, the IO structure is dense, with upstream sectors selling to other upstream sectors.
- Above the diagonal, the area is sparse; downstream sectors do not sell to upstream sectors.

Application: Korea's input-output table in 1970

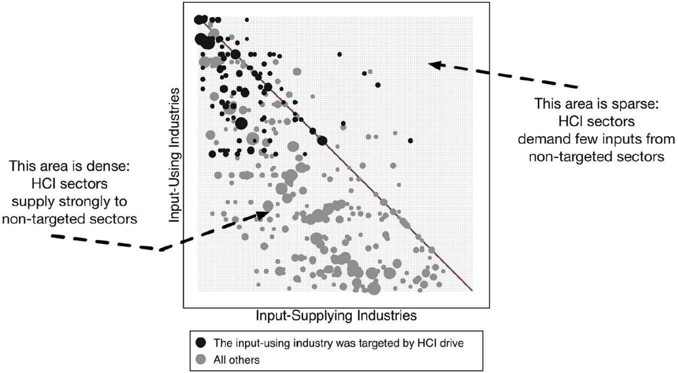


Application: Korea's input-output table in 1970 ordered by ξ



Testing for hierarchical property: among ¿1 million unique inequalities: 84% holds true (90% if small violations ¡0.01 are tolerated)

Application: 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

Application: Korea's HCI industries ξ

	ξ Specification	$sd(\xi)$	Average ξ_i of HCI sectors	% sectors with $\xi_i > 1$	
				HCI	non-HCI
	Benchmark	0.09	1.16	100%	47.8%
B3	Rajan and Zingales	0.06	1.12	100%	47.0%
B5	Sectoral profit share	0.16	1.28	100%	45.1%
A3	$N(0.1, 0.1)$	0.09	1.17	100%	47.7%
A7	$U[0, 0.2]$	0.09	1.16	100%	47.7%
A8	$Exp(0.1)$	0.10	1.17	100%	47.7%

HCI industries have higher simulated distortion centralities.

Application: Policy Evaluation in China, Aggregate Gains ($\Delta Y/Y$)

		$\Delta Y/Y$ in percentage points			
Distortion centrality specification	*sd* (ξ)	Credit	Taxes	SOEs	Total
Benchmark ($\xi^{10\%}$)	0.22	1.69	0.64	1.27	3.60
De Loecker and Warzynski	0.42	3.07	1.19	2.39	6.65
Foreign firms as controls	0.25	1.69	0.67	1.16	3.51
Rajan and Zingales	0.11	1.01	0.36	0.65	2.02
Sectoral profit share	0.17	1.20	0.47	0.95	2.62

Subsidized credit, Tax incentives, State-owned enterprises.

Conclusion

Distortion centrality: the ratio between sectoral influence and sales share:

- a sufficient statistic for the social value of sectoral spending.
- can be used to assess the welfare impact of the sectoral intervention.

Distortions accumulate upstream through backward demand linkages

- distortion centrality is stable in hierarchical networks

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.