Endogenous Production Networks

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Motivation

Questions:

(a) What explains the different structures of firm input usage over time?

(b) Do these differences contribute to productivity and growth differences?

What this paper does:

(a) Build an endogenous production networks model focusing on firms using new inputs, cheaper inputs, or new technologies.

(b) Extend the model to a dynamic version to study TFP growth implications of endogenous production network formations.

(c) Applied exercise on industry TFP growth due to new input combinations.

Key takeaway : Changes to the input-output structure of the economy might have economic growth implications.

Static Model: Setup

Production technology: $Y_i = F_i(S_i, A_i(S_i), L_i, X_i)$

i: industry, S_i: endogenous supplier set, X_i:intermediate inputs

A1: F has CRS in (L, X), increasing in A. Labor is essential $F(..L = 0..) = 0$

Cost minimization problem:

$K_i(S_i, A(S_i), P) = \underset{X_i, L_i}{Min} L_i + \sum_j P_j X_{ij}$ s.t. $F_i(S_i, A_i(S_i), L_i, X_i) = 1$

μ: distortion: markup, taxes, regulations, finance market imperfections

$P_i^* = (1 + \mu_i) K_i^*(S_i^*, A(S_i^*), P^*)$

Household preferences: $u(C_1, .., C_n)$

A2: continuous, differentiable, increasing, quasiconcave, all goods normal

Equilibrium:

(1) Contestability. (2) Consumer Max. (3) Cost Min (4) Market clearing.

Static Model: CD production function

$$F_i = \frac{1}{\left(1 - \sum_{j \in S_i} \alpha_{ij}\right)^{1-\sum_{j \in S_i} \alpha_{ij}} \prod_{j \in S_i} \alpha_{ij}^{\alpha_{ij}}} A_i\left(S_i\right) L_i^{1-\sum_{j \in S_i} \alpha_{ij}} \prod_{j \in S_i} X_{ij}^{\alpha_{ij}}$$

$$K_i = \frac{1}{A_i\left(S_i\right)} \prod_{j \in S_i} P_j^{\alpha_{ij}}$$

Firms choose a set of suppliers by balancing the tradeoff between high productivity and low prices.

Static Model: Equilibrium charecterization

- Existence
- Uniqueness
- Efficiency: 4 possible cases, including a realistic one with heterogenous distortions ($\mu_i \neq \mu_j$) where Pareto efficiency is not achieved.

Other key assumptions

(a) Each industry is contestable (i.e., all firms have access to the same production technology and can enter without barriers)

(b) The production function does not depend on specific intermediate inputs (X_i); combining a richer set of inputs, an industry can reach higher productivity.

(c) Adopting/dropping new suppliers is costless.

Static Model: Comparative Statics

Three main results:

(a) $\Delta^+ A_i(S_i)$ or $\Delta^- \mu \implies \Delta^- P$.

(b) $\Delta^+ A_i(S_i) \implies$ Network expansion.

(c) Discontinuous effects; small changes in parameters $\implies$ large GDP effects.

Two complementary channels:

- Direct effect: $A_i(S_i)$ increases $\implies$ industry i reduce its unit costs (K).
- Indirect effect: $\Delta^+ A_i(S_i) \implies \Delta^- P_j \implies \Delta^- K_j$
  $\implies$ buyers of industry j will face lower prices too, and so on.

Static Model: Comparative Statics key assumption

Technology-Price Single-Crossing Condition

$$K_i\left(S_i', A_i\left(S_i'\right), P\right) - K_i\left(S_i, A_i\left(S_i\right), P\right) \leq 0$$
$$\implies \quad K_i\left(S_i', A_i\left(S_i'\right), P'\right) - K_i\left(S_i, A_i\left(S_i\right), P'\right) \leq 0$$

Facing lower prices, other industries will also be induced to (weakly) expand their sets of suppliers.

$\Delta^+ A_i(S_i) \implies$

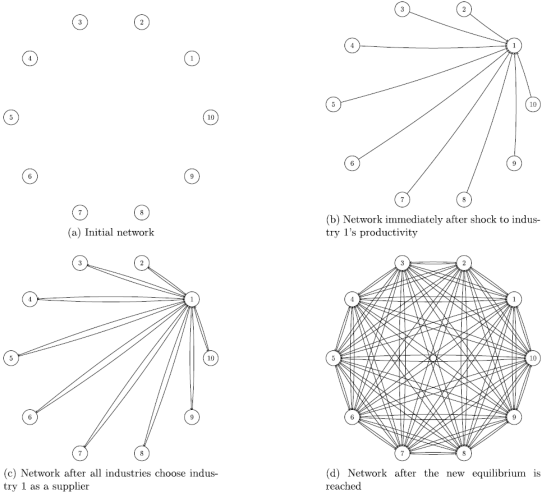
(a) Δ^+ Productivity level of different input combinations.

(b) Increase in the marginal return from adopting additional input combinations.

(c) Additional inputs do not directly reduce the productivity from adopting yet further inputs.

Static Model: Discontinuous effect example

Figure: $\Delta^{+}A_1$; 1 use all industries as inputs; $\Delta^{-}P_1$; all industries buy from 1



(a) Initial network

(b) Network immediately after shock to industry 1's productivity

(c) Network after all industries choose industry 1 as a supplier

(d) Network after the new equilibrium is reached

Dynamic Model

Goal: Show how a new economic force productivity growth (from new input combinations) to generate sustained economic growth

Technology set: t products in the economy, then each industry i has access to $t-1$ possible suppliers and 2^{t-1} ways of combining these suppliers.

Dynamics: One new industry arrives in each period, and all firms can update their technology by combining the new industry's product with any other subset of products.

Dynamic Model: New features

- Household preferences:

$$u\left(C_1(t),\ldots,C_t(t),\beta\right)=\left[\prod_{i=1}^{t}\left(\frac{\beta_i}{\sum_{i=1}^{t}\beta_i}\right)^{-\beta_i}\prod_{i=1}^{t}C_i(t)^{\beta_i}\right]^{\frac{1}{\sum_{i=1}^{t}\beta_i}}$$

- Real GDP: $Y(t)=\dfrac{Y^N(t)}{\prod_{i=1}^{t}P_i(t)^{\frac{\beta_i}{\sum_{i=1}^{t}\beta_j}}}$

- Price index: $\pi(t)=-\beta(t)'\mathcal{L}(t)a(S(t)-m(t))$
  β consumption shares vector, a log productivity vector, $\mathcal{L}$ Leontief Inverse, m distortions vector.
  A4: log productivity distributions cannot have either too thin or too thick tails. (ie. Gumbel or exponential distributions)

  Implicit A.: All new inputs can be used on industry i technology. New inputs may not just reduce costs but also transform a product's use in consumption or as an input significantly, transforming it into a new good.

Dynamic Model: Sustained growth

Key Result When firms can select their set of suppliers from all available combinations, the economy will achieve sustained economic growth. Each industry chooses the cost-minimizing combination.

Two channels:

- Direct effect: Each industry i faces an expanded set of possible input combinations, its cost, and thus equilibrium price declines.
- Indirect effect: $\Delta^{-} P_i$, industries that use industry i output as input will also benefit because their costs will decrease.

Dynamic Model: Dealing with unrealistic assumptions

With small changes to assumptions, the model can deal with two caveats.

- Certain input classes may be essential for the production of some types of goods (i.e., copper for cables)
- It does not allow for new inputs or new input combinations, to replace old ones. Not creative destruction.

Cross-sectional implications: Static economy with large n

Productivity: $a_i(S_i) = \sum j \in S_i b_j + \epsilon(S_i)$.
The productivity of a set of inputs depends on the average productivity of the inputs as well as a random term drawn from a Gumbel distribution.

Main result:
The distribution of outdegrees (industry i sales to other industries, $O(n)$) will be much more unequal than the distribution of indegrees (industry i purchases to other sectors, $I(n)$). Wich matches the US (and Chilean) data
.

New input combinations boost productivity growth (1)

Data: TFP and input-output tables for 452 manufacturing industries and 36 nonmanufacturing industry for the years 1987, 1992, 1997, 2002, and 2007, from NBER-CES and BEA.

Jaccard distance of sets of suppliers between t and $t-1$:

$J_i(t) = \frac{|S_i(t) \cup S_i(t-1)| - |S_i(t) \cap S_i(t-1)|}{|S_i(t) \cup S_i(t-1)|}$

$J_{i,20}(t)$: Dummy for this measure being above the 20th percentile of its distributionis; proxy for significant change in input structure

Reduced form model:

$\Delta a_i(t) = \gamma \Delta J_{i,20}(t) + \nu_i + \eta(t) + \epsilon_i(t)$

$\Delta a_i(t)$: five-year change in (log) TFP; $\eta(t)$ denotes a full set of time effects, $\epsilon_i(t)$ denotes a full set of industry dummies

New input combinations boost productivity growth (2)

	(1)	(2)	(3)
Panel A: All Industries (1987–2007)			
$J_{i,20}$	0.018	0.020	0.047
	(0.007)	(0.010)	(0.014)
Counterfactual TFP change	0.42%	0.48%	1.12%
Panel B: Manufacturing (1987–2007)			
$J_{i,20}$	0.018	0.021	0.047
	(0.008)	(0.011)	(0.016)
Counterfactual TFP change	0.42%	0.49%	1.14%
Panel C: All Industries Excluding Computers (1987–2007)			
$J_{i,20}$	0.011	0.011	0.033
	(0.006)	(0.009)	(0.014)
Counterfactual TFP change	0.25%	0.25%	0.78%
Linear industry trends	No	Yes	Yes
Control for lagged change in TFP	No	No	Yes

$\Longrightarrow$ Without the productivity gains from new input combinations, average productivity growth would have been lower by 0.42 percentage points (40%) relative to the annualized average industry TFP growth of 1.05%

New input combinations boost productivity growth (3)

Productivity gains from new input combinations could be quite large!
But the results are just illustrative:

(a) Results rely on the structure of the model, which is simplified in many dimensions.
(b) Estimates may be upwardly biased and thus exaggerate the contribution of new input combinations to productivity because of omitted variables. (e.g., exogenous innovations may encourage the use of new inputs)

Wrapping up: Static model

(a) When a product adopts new inputs to minimize its costs, this not only reduces its price but (weakly) reduces all prices in the economy.

(b) A change in technology that makes the adoption of additional inputs more productive for one industry—or a reduction in distortions in one industry—expands technology sets for all industries.

(c) Technology changes are potentially discontinuous; a small change in one industry can cause large changes in GDP or trigger a chain reaction, leading to major shifts in the production structure of many industries.

Wrapping up: Dynamic model

(a) When a new product arrives, it becomes a potential input for all existing products and significantly expands the number of input combinations (production techniques) available to other industries.

(b) With n products, the arrival of one more new product increases the combinations of inputs that each existing product can use from 2^{n-1} to 2^{n}, thus enabling nontrivial cost reductions from the choice of optimal technology combinations.

(c) A new production technique reduces the price of the relevant product, encouraging other industries to adopt this product as an additional input and change their production techniques.

Personal comments

The paper proposes a brilliant structure to analyze how the change in production networks can shape economic growth.

Room for future research:

- The model allows for makups, but assumes $\pi = 0$, and does not allow for buyer market power (markdows).
- No bargaining process modeling and no bargaining power at all.
- The model is built at the industry level; not that difficult to extend it to the firm level and exploit within industry variation.
- Industry-level data might hide lots of heterogeneity and extensive/intensive margin of inputs. Firm-level data might shed light on the performance of the model.