Production Networks, Geography and Firm Performance

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Motivation and Questions

• “Power of Network”
  by Ministry of Economy, Trade and Industry (METI)
  – Competitiveness of Japanese firms depends on strong connections with their suppliers.

• What determines buyer-supplier (firm-to-firm) connections?
• What are the consequences for firm performance?

• We’ll develop a model in which:
  – Firms have a comparative advantage (CA) in producing a given task.
  – Searching for suppliers (observing price/quality) is costly.
  – Trade-off between benefits from exploiting CA and cost of search.

• We’ll examine the quantitative importance of this mechanism.
Implications

- Variation in firm output and productivity across space (Sveikauskas 1975, Glaeser and Mare 2001, Combes et al 2012).
  - Using and searching for good suppliers which are less costly in central locations → Outsourcing & productivity ↑

- Substantial heterogeneity in firm sales (w/in localities and industries).
  - High productivity firms have an incentive to search harder for good suppliers.

- Effect of infrastructure on firm performance.
  - Lowers the cost of using & searching for suppliers.
Three Components of the Paper

• Facts about (Japanese) production networks
  – Comprehensive data on (nearly) complete production networks

• Model of producers and domestic sourcing.
  – Building on Antras, Fort and Tintelnot (2014).

• ‘Natural’ experiment testing predictions of model (effects of infrastructure)
  – Up to 75% fall in travel time for persons, 0% for goods.

Disclaimer: This paper is not about the relocation of inputs or firms. It applies only to within-firm identification.
Data Sources

• Tokyo Shoko Research (TSR):
  – Credit reporting agency (1 of 2 in Japan)
  – 950,000+ firms in the private sector.
    • Close to complete coverage of firms with 5+ employees.
      – Not limited to a particular sector.
      – More than 50% of all firms in Japan (relative to census).
  – Buyer-supplier linkages in 2005 & 2010 + firm sales & geolocation.
    • Firm address is geocoded to longitude and latitude data, using the system provided by the Center for Spatial Information Science (CSIS), University of Tokyo

• Kikatsu:
  – All firms with 50+ employees & capital of more than 30 million yen (US $300,000).
TSR Data - Network

• Each firm provides a rank ordered list of suppliers & customers (max 24).

• We use a combination of own-reported and other-reported information.
  – A supplies B if both firms are in the TSR data and
    • A reports B as a customer or
    • B reports A as a supplier.
• In-degree (# of suppliers) = 2 (1 own-reported + 1 other-reported)
• Out-degree (# of customers) = 2 (1 own-reported + 1 other-reported)
Network Structure:

Degree Distributions

• 3,783,711 supplier-customer connections.

• Among firms with positive degree:
  – Mean (median) # customers is 5.6 (1).
  – Mean (median) # suppliers is 4.9 (2).

• 1/slope is -1.32 (in-degree) and -1.50 (out-degree).
The Production Network: Facts

• Key relationships that inform the model:
  – Larger firms have more suppliers.
  – The majority of connections is formed locally.
  – Larger firms have suppliers in more locations and their distance to suppliers is longer.
  – Negative degree assortativity among sellers and buyers.
Fact I: Larger firms have more suppliers
Fact II: The majority of connections is formed locally.

Median (mean) distance to connections: 30 (172) km.
Fact III: Larger firms have suppliers in more locations

Slope = 0.27
Fact III: Larger firms have suppliers located farther away.

![Graph showing median distance to suppliers vs. sales in mill yen](image)

Slope = 0.04

(kernel = epanechnikov, degree = 0, bandwidth = .41, pwidth = .81)
Fact IV: Negative degree assortativity

A firm with more suppliers - those suppliers have fewer customers.
A firm with fewer suppliers - those suppliers have more customers.
The Model

• We build on the international sourcing model of Antras et al (2014) and introduce:
  – In-house production or outsourcing
  – Continuum of locations ↔ domestic sourcing
The Model: Upstream

Upstream stage:

• Unit continuum of tasks $\omega$ produced in location $i$.
• PF $y_U(\omega) = zU(\omega)l_U(\omega)$.
• Task productivity $z_U(\omega)$ from $Frechet(T, q)$.
• Iceberg trade costs: $\tau(i, j) \geq 1$.
• Perfect competition.
The Model: Downstream

Downstream stage:

- PF $y(z, j) = z l^\alpha v(z, j)^{1-\alpha}$
  
  $v(z, j)$ is CES task composite, $z$ is efficiency.

- $\omega$ produced in-house or outsourced:

  - In-house: PF $y_l(\omega) = zl(\omega)ll(\omega)$.
    
    - Task productivity $z_l(\omega)$ from Frechet($T_0, q$).
    
    - No trade costs.

  - Outsourced:
    
    - Firm sees price distribution in $i$ but not individual prices $p(\omega, i)$.
    
    - Firm in $j$ must pay $f(j)$ to observe individual $p(\omega, i)$.

- Monopolistic competition & CES final demand.
The Model: Assumptions

For tractability:

- \( T_0 \) and \( T \) the same everywhere.
- Perfect labor mobility \( \rightarrow \) wages same everywhere.
- No trade costs on final good.
- Positive measure of downstream firms in each location \( j \).
- Restrict to interior solution.
The firm’s problem

Solve by backwards induction:

- Conditional on locations searched, firm chooses in-house / outsourcing in searched location for each task $\omega$.
- Firm chooses locations to search, characterized by cutoff $\tau(z, j)$: highest trade cost of location.
  - $\tau(z, j)$ chosen to balance the benefit of lower MC against the cost of search.
Model and Data

- More productive firms outsource more tasks and therefore have more suppliers:
  \[ \frac{\partial \ln o(z,j)}{\partial \ln z} > 0, \]

- Locality of connection: Iceberg Trade cost
- More productive firms search more and costlier locations:
  \[ \frac{\partial \ln \bar{x}}{\partial \ln z} > 0 \]

- Negative degree assortivity:
  Higher \( z \) (higher indegree) \( \rightarrow \) firm reaches costlier locations \( \rightarrow \) suppliers there are on average not very competitive in \( z \)’s home market (low avg. outdegree).
A Distributional Assumption

• Every location faces a density of trade costs $g(t, j)$.
• Assume $g()$ inverse Pareto with shape $g > q$ and support $[1, \tau_H]$.
  – A location has few nearby markets and many remote ones.
• Density fits empirical distance cdf well.
Two Propositions

• Proposition 1
  – Lower search costs $f(j)$ lead to growth in sales among downstream firms in $j$.
  – Sales growth is stronger in input-intensive (low $\alpha$) industries relative to labor intensive (high $\alpha$) industries.

\[
\frac{\partial \ln r(z,j)}{\partial \ln f(j)} < 0 \quad \text{and} \quad \frac{\partial^2 \ln r(z,j)}{\partial \ln f(j) \partial \alpha} > 0
\]

• Two channels:
  – Direct: low $\alpha$ firms grow more because of large input share.
  – Indirect: low $\alpha$ firms search more markets when $f(j)$ ↓ (\( |\partial \bar{\tau}/\partial f| \) decreasing in $\alpha$).
Two Propositions

• Proposition 2
  – Lower search costs $f(j)$ lead to more outsourcing and suppliers from new locations (higher $\tau$) among downstream firms in $j$.

\[
\frac{\partial o(z,j)}{\partial f(j)} < 0 \quad \text{and} \quad \frac{\partial \tau(z,j)}{\partial f(j)} < 0.
\]
Shinkansen - A Natural Experiment

• High-speed train network (Shinkansen) opened in 2004.
• Operating speed: 260 km/h.
• 2-3 departures / hour; Capacity: 392 passengers per train.
Shinkansen - Geography

- Rail line connecting two prefectures (Kagoshima + Kumamoto) with a total population of 3.5 million.
- Travel time
  - Kagoshima – Shin-Yatsushiro: 130 → 35 min.
  - Kagoshima – Hakata: 4 → 2 hours.
Shinkansen - A Natural Experiment

• Do lower search costs improve firm performance by facilitating (better) linkages in the production network?

• Key advantages of the Shinkansen experiment:
  – Dramatic reduction in travel time between stations.
    • 75% reduction for many city pairs.
  – Goods do not travel by Shinkansen, just people.
    • No contemporaneous reduction in travel time for goods along this southern route.
  – Likely exogenous.
    • Planned decades in advance (1973). Timing of completion was subject to substantial uncertainty.
Shinkansen Factsheet

• Total length of 2,388 km and connects the majority of the JP population.

• Share of train passenger traffic larger than in any other country.
  – Rail has 28% of total passenger km in JP, 1% in US, and 8% in France
  – Car has 50% in JP, 85% in US, and France (Clever et al 2008).

• The modal shares of railways and airlines changed from 41% to 71% and 42% to 12% respectively between Fukuoka and Kagoshima prefectures (2000 to 2005). (Tokyo Institute of Technology, 2008).
Shinkansen Factsheet

- Shinkansen dominates medium distance travel:

Share of the Shinkansen in various long-distance transport modes

“Features and economic and social effects of the Shinkansen”,
Japan Railway and Transport Review (1994)
Empirical Methodology

• Lower travel time should benefit input-intensive firms more than labor intensive firms (Proposition 1).
  – Lower \( f(j) \) has no impact on MC of firms belonging to \( \alpha = 1 \) industries.

• Classify industry \( k \) according to their 2003 intermediate input use:
  \( H_k = 1 - \text{labor share of industry } k \)

• Define \( Treat_f = 1 \) if firm \( f \) is < 30 km from new Shinkansen station (stations between Kagoshima and Shin-Yatsushiro).

• Dependent variables:
  InSales, In(sales/employee), TFP (Olley-Pakes); relative to industry-year means.
Empirical Methodology

• Estimate for 2000-2008 period

\[ \ln y_{fkr} = \alpha_1^f + \alpha_2^{rt} + \beta_1 \text{\textit{Treat}}_f \times H_k \times \text{\textit{Post2004}}_t + \gamma X_{fkr} + \varepsilon_{fkr}, \]

• where \( \alpha_1^f \) and \( \alpha_2^{rt} \) are firm and prefecture-year fixed effects.

• Triple differences:
  – Pre to post shock (1st diff)
  – Firms near stations relative to those not near stations (2nd diff).
  – High \( H_k \) relative low \( H_k \) firms (3rd diff).

• Positive \( \beta_1 \) if high \( H_k \) firms are growing faster relative to low-\( H_k \) firms near new stations relative to elsewhere.

• More controls:
  – Time-varying geographic controls by using average performance in f’s municipality (\( \approx 1,400 \) municipalities).
  – Remaining interactions (\( \text{\textit{Treat}}_f \times H_k \), etc.).
Potential Concerns

• Market access (demand side) effects:
  – No, because demand should affect both input- and labor-intensive firms.

• Different trends for input- and labor-intensive firms:
  – No, industry trends are differenced out.

• Location of the stations are endogenous:
  – Not a problem as long as locations are not determined based on differential growth for input/labor intensive industries.

• Pre-trends; input-intensive firms near new stations always grow faster relative to labor-intensive firms:
  – No evidence of this in placebo test.
Results

<table>
<thead>
<tr>
<th></th>
<th>Sales</th>
<th>Sales/employee</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Treat_f \times H_j \times Post2004_t$</td>
<td>0.47**</td>
<td>0.42*</td>
<td>0.29**</td>
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<tr>
<td></td>
<td>(2.12)</td>
<td>(1.76)</td>
<td>(2.44)</td>
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<tr>
<td>Firm and city controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Prefecture-year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Firm FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>N</td>
<td>148,264</td>
<td>146,466</td>
<td>145,058</td>
</tr>
<tr>
<td>R-sq</td>
<td>0.97</td>
<td>0.92</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Note: Robust t-statistics in parentheses. Dependent variables in logs.

- A Shinkansen station increases sales by 0.47 log points more for a firm with $H_k = 1$ relative to a firm with $H_k = 0$.
- A firm in the 9th decile of the $H_k$ distribution (industrial plastic products) increased sales by 0.10 log points more than a firm in the 1st decile of the $H_k$ distribution (general goods rental and leasing).
Robustness: Placebo


<table>
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<th>Sales/employee</th>
<th>TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Treat_f \times H_j \times Post2000_t$</td>
<td>-0.30</td>
<td>-0.05</td>
<td>0.02</td>
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<tr>
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<td>(1.05)</td>
<td>(0.22)</td>
<td>(0.17)</td>
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<tr>
<td>Firm and city controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Prefecture-year FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Firm FE</td>
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<td>Yes</td>
<td>Yes</td>
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<td>N</td>
<td>66,756</td>
<td>66,756</td>
<td>66,487</td>
</tr>
<tr>
<td>R-sq</td>
<td>0.99</td>
<td>0.94</td>
<td>0.95</td>
</tr>
</tbody>
</table>

Note: Robust t-statistics in parentheses. Dependent variables in logs.
More robustness

- Labor supply - Recruiting now easier for knowledge intensive industries (which may happen to be input intensive).
  - Calculate R&D intensity of industries, add additional interactions → No change in results.
- The ‘straw effect’ - Less economic activity in nearby locations.
  - Add interactions for firms 30-60km from new station → Small negative effect for these firms & no change in main results.
- Demand side again - Input intensive industries may have more remote customers.
  - Should not see TFP effects.
  - corr (avg distance to customers, \( H_j \)) = -0.02.
- Drop the construction industry.
- Change 30 km threshold.
Shinkansen - New Connections

- Mechanism: Should see more supplier linkages in treated regions.
- Divide Japan into a grid consisting of $500 \times 500$ locations ($5.62 \text{ km}^2$).
- Number of connections from $i$ to $j$ at time $t$ is $C_{ijt}$, $t = (2005;2010)$.
- Regress

$$\Delta \ln C_{ij} = \xi_i^1 + \xi_j^2 + \beta_1 \text{Both}_{ij} + \beta_2 \text{One}_{ij} + \gamma X_{ij} + \varepsilon_{ij},$$

where $\xi_i^1$ and $\xi_j^2$ are source and destination FE,
$\text{Both}_{ij} = 1$ if both locations $i$ and $j$ get a new station,
$\text{One}_{ij} = 1$ if one of them gets a new station.
Shinkansen - New Connections

<table>
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<th>(3)</th>
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<tbody>
<tr>
<td>Both\textsubscript{ij}</td>
<td>0.07***</td>
<td>0.12***</td>
<td>0.39***</td>
<td>0.42***</td>
</tr>
<tr>
<td></td>
<td>(5.91)</td>
<td>(7.91)</td>
<td>(20.12)</td>
<td>(7.93)</td>
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<tr>
<td>One\textsubscript{ij}</td>
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<td>-0.01</td>
<td>0.19***</td>
<td>0.15***</td>
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<td>(3.56)</td>
<td>(0.74)</td>
<td>(19.87)</td>
<td>(6.42)</td>
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<td>ln Dist\textsubscript{ij}</td>
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<td>-0.06***</td>
<td>-0.06***</td>
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<td>(71.32)</td>
<td>(81.98)</td>
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<tr>
<td>Both\textsubscript{ij} × ln Dist\textsubscript{ij}</td>
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<td></td>
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<td>One\textsubscript{ij} × ln Dist\textsubscript{ij}</td>
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<tr>
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<td>(1.87)</td>
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<tr>
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<td>Yes</td>
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<td>R-sq</td>
<td>0.00</td>
<td>0.17</td>
<td>0.18</td>
<td>0.18</td>
</tr>
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</table>

Note: Bootstrapped t-statistics in parentheses with 200 replications. Dependent variable is $Δ \ln C_{ij} = \ln C_{ij2010} - \ln C_{ij2005}$. *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level.
Conclusions

- The supply network matters for firm performance:
  - Infrastructure shock generates significant performance gains.
  - Evidence that gains are related to new (or more efficient) buyer-seller linkages, as suggested by the model.