Production Networks, Geography and Firm Performance

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2016 RIETI WS

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)
  - Kyushu Shinkansen (2004).
  - 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

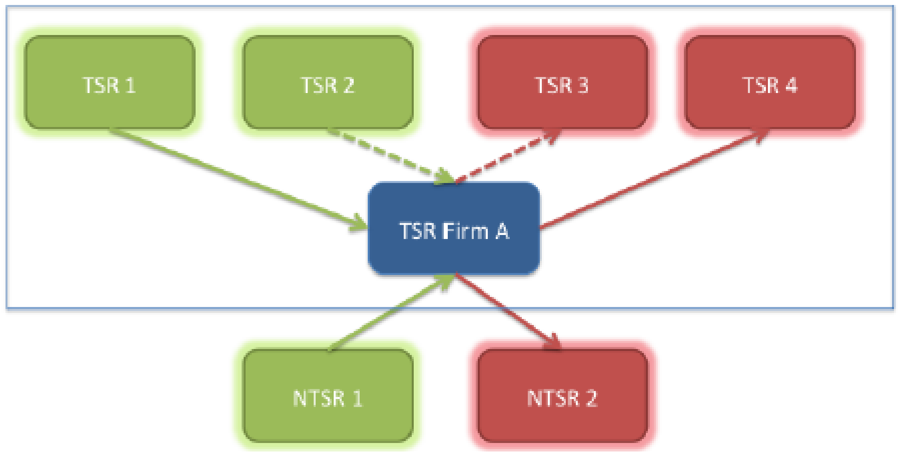
- Tokyo Shoko Research (TSR):
  - Credit reporting agency (1 of 2 in Japan)
  - 950,000+ firms in the private sector.
    - Close to complete coverage of firms with 5+ employees.
      - Not limited to a particular sector.
      - More than 50% of all firms in Japan (relative to census).
  - Buyer-supplier 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*:
  - 1998-2008 data (balance sheet plus much more) from the results of the "Basic Survey of Japanese Business Structure and Activities" by METI (*Kigyo Katsudo Kihon Chosa, in Japanese*)
  - 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.

TSR Data - Network

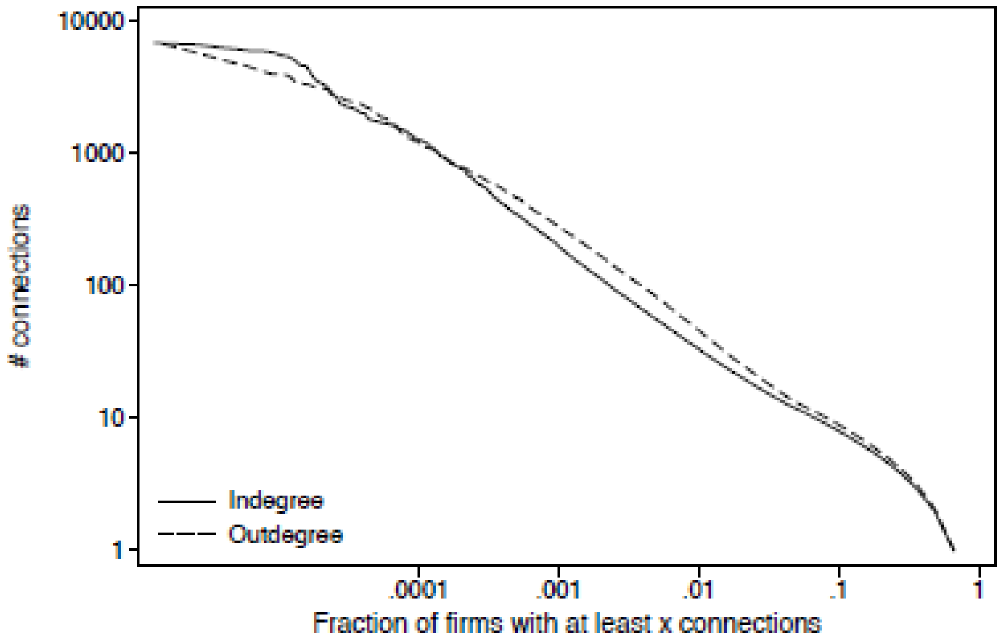


Solid lines – own-reported links
Dashed lines – other-reported links

- 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

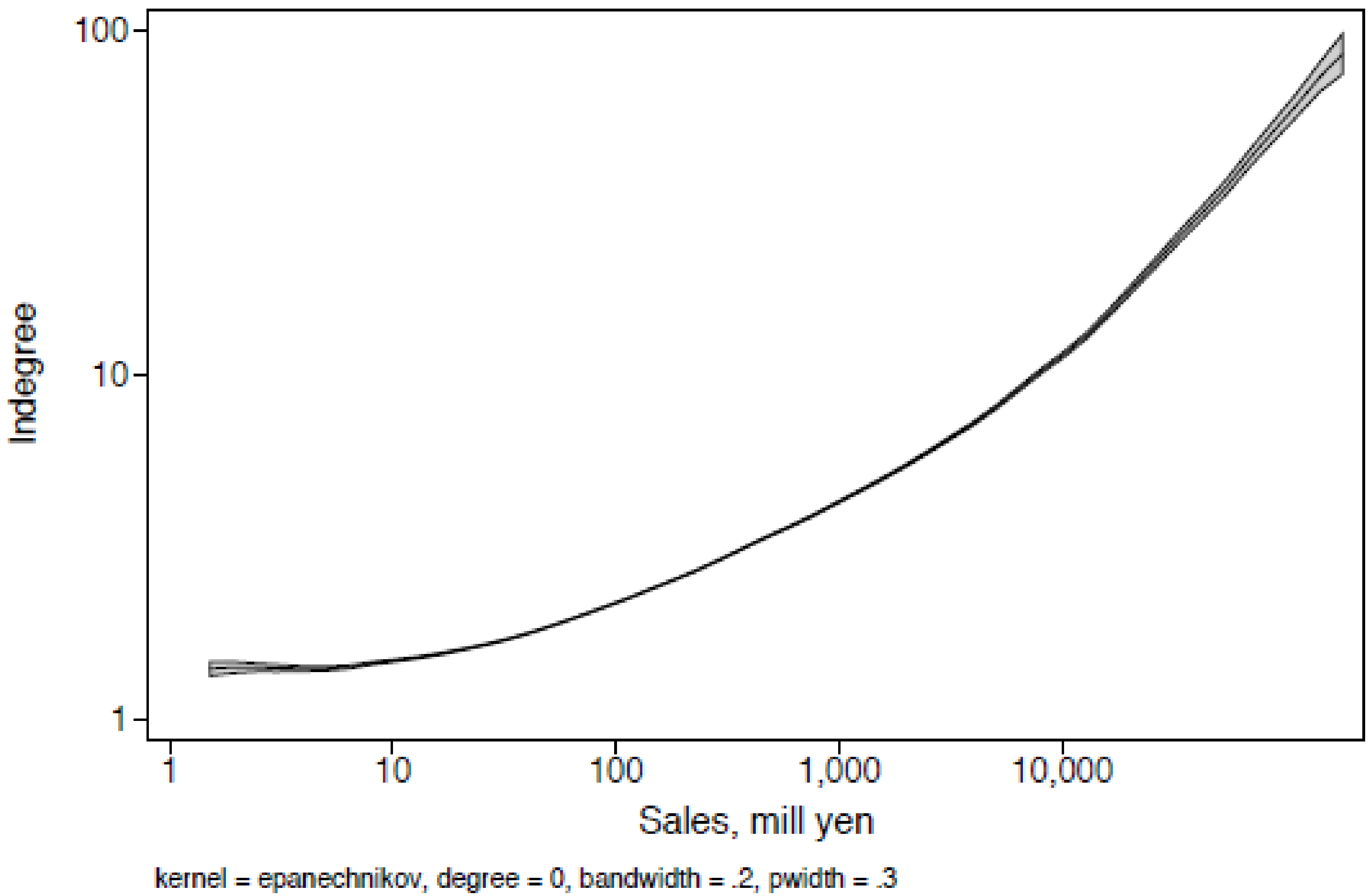


- 3,783,711 supplier-customer connections.
- Among firms with positive degree:
  - Mean (median) # customers is 5.6 (1).
  - Mean (median) # suppliers is 4.9 (2).
- 1/slope is -1.32 (in-degree) and -1.50 (out-degree).

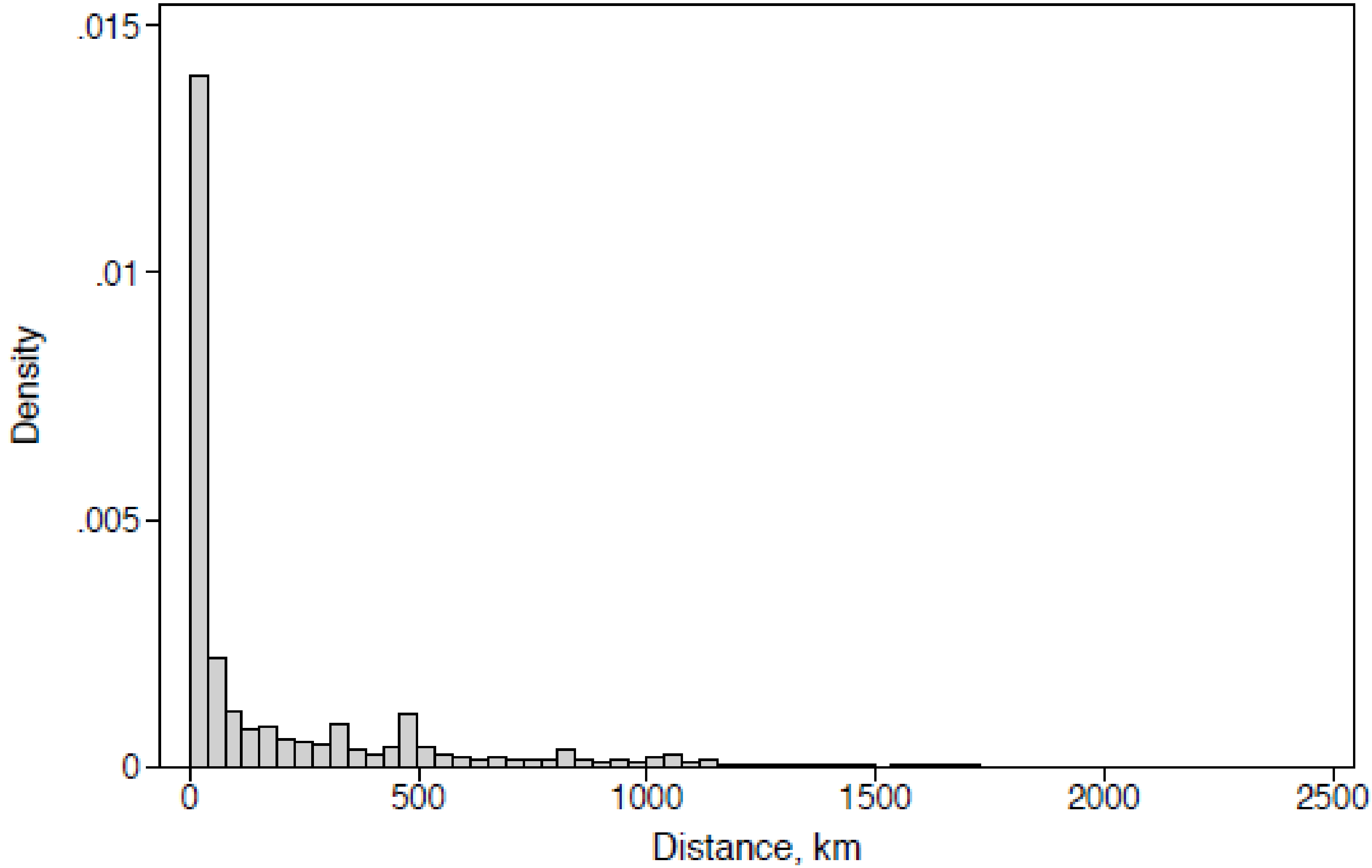
The Production Network : Facts

- 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

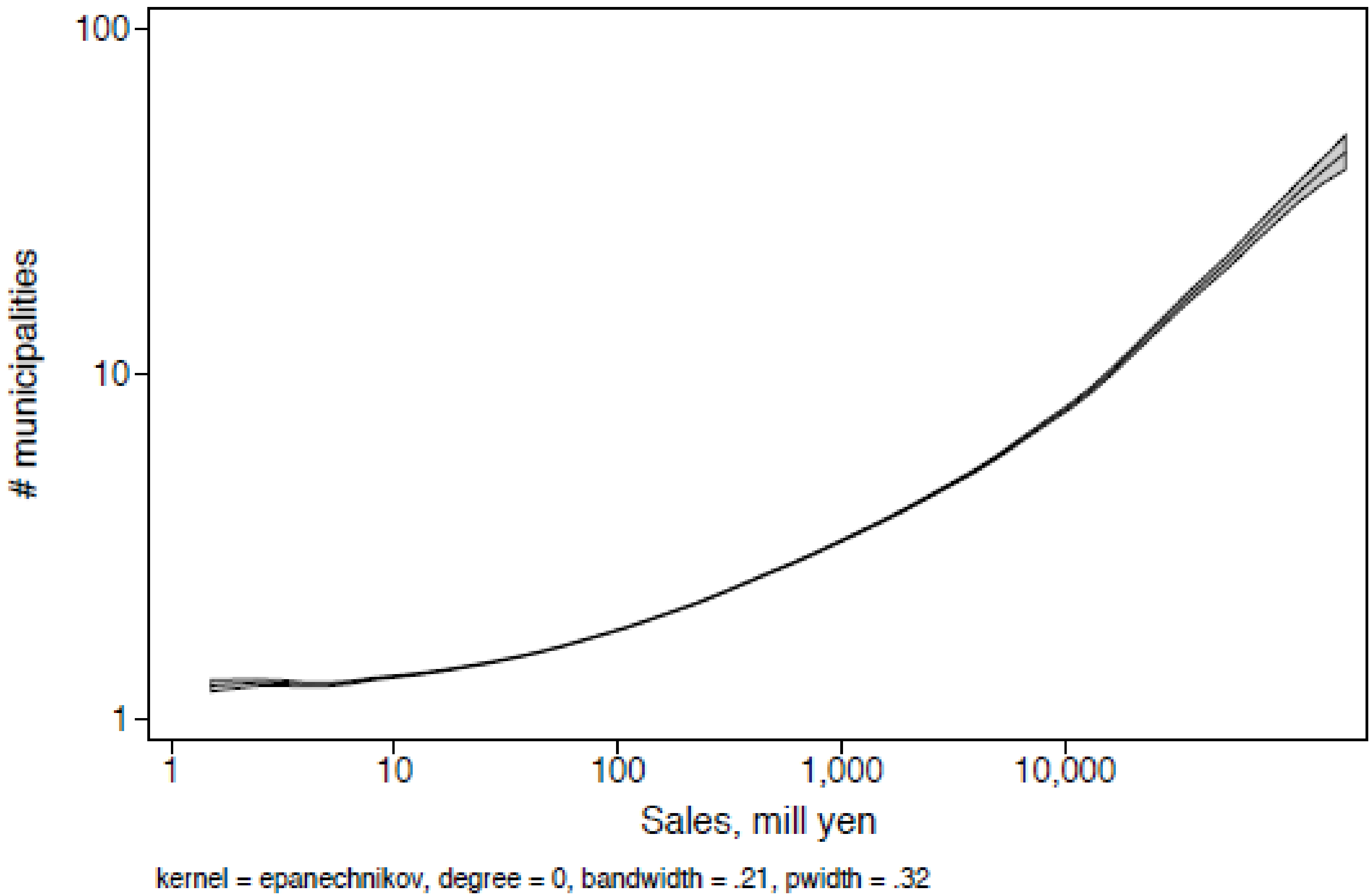


Fact II : The majority of connections is formed locally



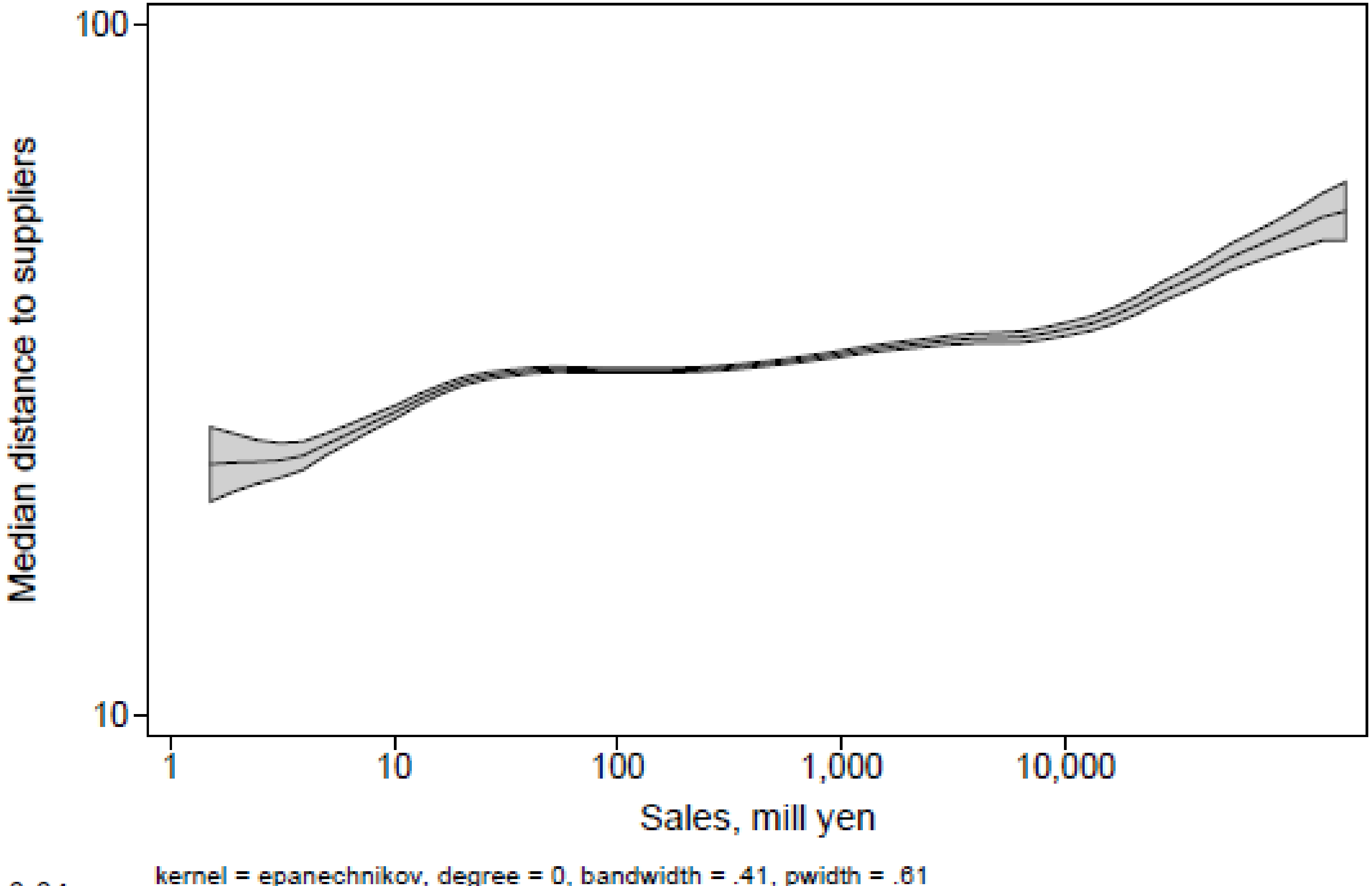
Median (mean) distance to connections: 30 (172) km.

Fact III : Larger firms have suppliers in more locations



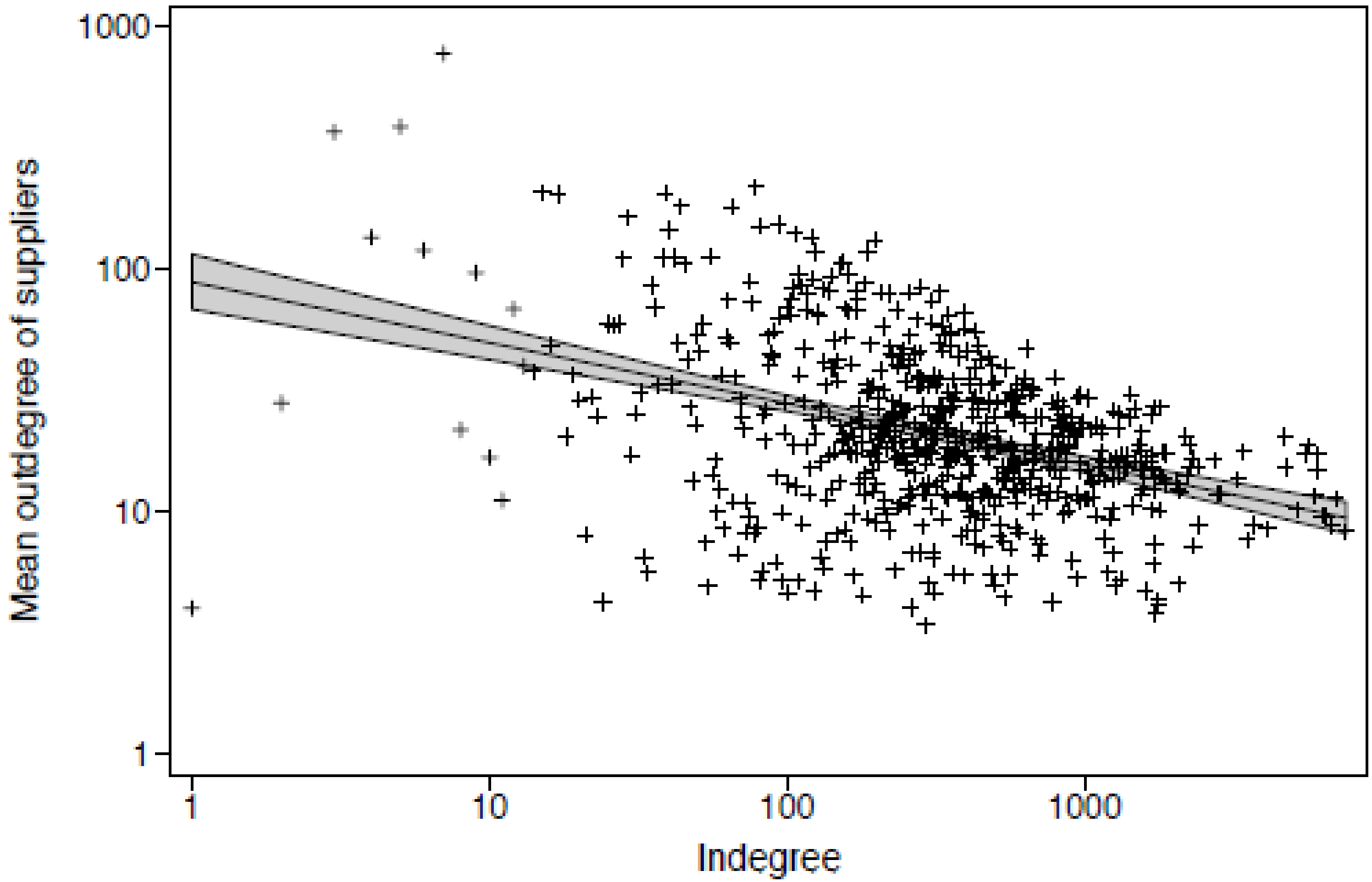
Slope=0.27

Fact III : Larger firms have suppliers located farther away



Slope=0.04

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 ω 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 $y(z,j) = zl^{\alpha}v(z,j)^{1-\alpha}$

  $v(z,j)$ is CES task composite, z is efficiency.
- ω produced in-house or outsourced:
- **In-house:** PF $\mathrm{y}_l(\omega) = zl(\omega)ll(\omega)$.
  - 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 → 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 ω.
- 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:

$$\frac{\partial \ln \bar{\tau}}{\partial \ln z} > 0$$

- Negative degree assortivity:

  Higher z (higher indegree) → firm reaches costlier locations → 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 α) industries relative to labor intensive (high α) 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 α firms grow more because of large input share.
  - Indirect: low α firms search more markets when $f(j) \downarrow$ ($|\partial \bar{\tau} / \partial f|$ decreasing in α).

Two Propositions

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

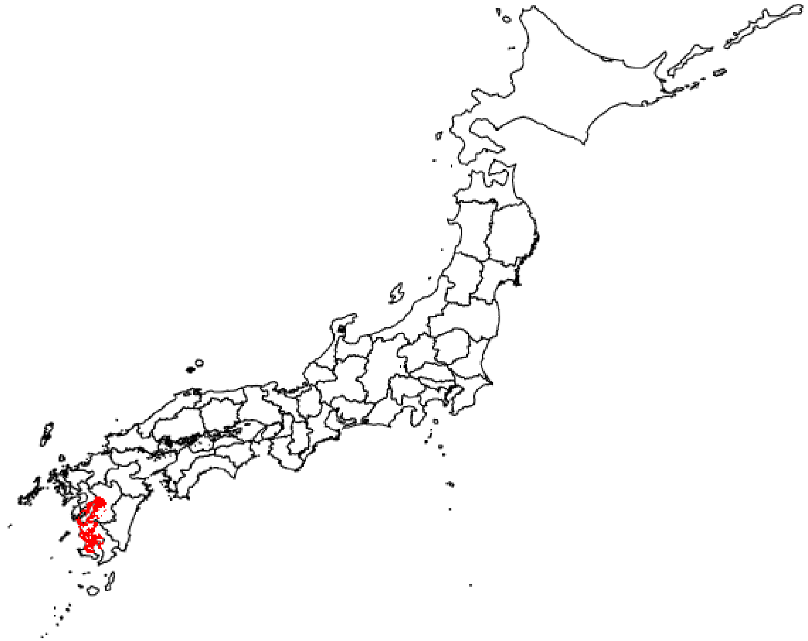
$$\frac{\partial o(z,j)}{\partial f(j)} < 0 \quad \text{and} \quad \frac{\partial \bar{\tau}(z,j)}{\partial f(j)} < 0.$$

Shinkansen - A Natural Experiment

800 series Shinkansen

- 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

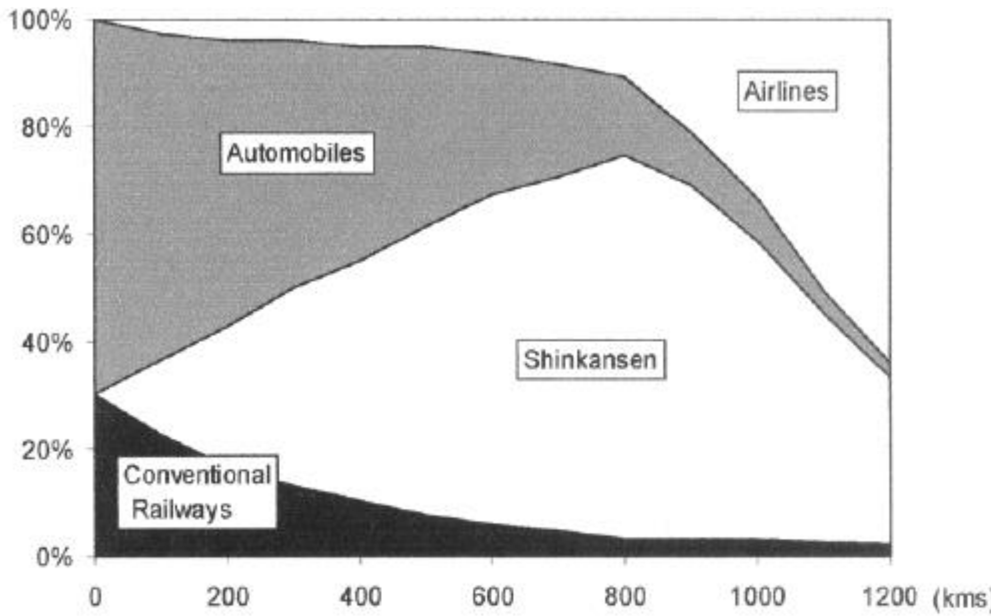
- Do lower search costs improve firm performance by facilitating (better) linkages in the production network?
- Key advantages of the Shinkansen experiment:
  - Dramatic reduction in travel time between stations.
    - 75% reduction for many city pairs.
  - Goods do not travel by Shinkansen, just people.
    - 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 - $ 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:
  lnSales, ln(sales/employee), TFP (Olley-Pakes);
  relative to industry-year means.

Empirical Methodology

- Estimate for 2000-2008 period

$$\ln y_{fkrt} = \alpha_f^1 + \alpha_{rt}^2 + \beta_1 \, Treat_f \times H_k \times Post2004_t + \gamma X_{fkrt} + \varepsilon_{fkrt} \,,$$

- 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 β_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 (≈ 1,400 municipalities).
  – Remaining interactions ($Treat_f \times H_k$, 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

	Sales	Sales/employee	TFP
$Treat_f \times H_j \times Post2004_t$	0.47^{**}	0.42^{*}	0.29^{**}
	(2.12)	(1.76)	(2.44)
Firm and city controls	Yes	Yes	Yes
Prefecture-year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
N	148,264	146,466	145,058
R-sq	0.97	0.92	0.94

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

- Use 1998-2002 data and Post2000 dummy.

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

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 × 500 locations (5.62 km^2).
- Number of connections from *i* to *j* at time *t* is C_{ijt} , *t* = (2005;2010).
- Regress

$$\Delta \ln C_{ij} = \xi_i^1 + \xi_j^2 + \beta_1 Both_{ij} + \beta_2 One_{ij} + \gamma X_{ij} + \varepsilon_{ij},$$

where ξ_i^1 and ξ_j^2 are source and destination FE,

$Both_{ij}$ = 1 if both locations *i* and *j* get a new station,

One_{ij} = 1 if one of them gets a new station.

Shinkansen - New Connections

	(1)	(2)	(3)	(4)
$Both_{ij}$	0.07***	0.12***	0.39***	0.42***
	(5.91)	(7.91)	(20.12)	(7.93)
One_{ij}	-0.02***	-0.01	0.19***	0.15***
	(3.56)	(0.74)	(19.87)	(6.42)
$\ln Dist_{ij}$			-0.06***	-0.06***
			(71.32)	(81.98)
$Both_{ij} \times \ln Dist_{ij}$				-0.01
				(0.86)
$One_{ij} \times \ln Dist_{ij}$				0.01*
				(1.87)
Destination FE	No	Yes	Yes	Yes
Source FE	No	Yes	Yes	Yes
# obs	386,294	386,294	386,294	386,294
# sources		7,613	7,613	7,613
# destinations		8,054	8,054	8,054
R-sq	0.00	0.17	0.18	0.18

Note: Bootstrapped t-statistics in parentheses with 200 replications. Dependent variable is $\Delta \ln C_{ij} = \ln C_{ij2010} - \ln C_{ij2006}$. *** 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.