ECO 2302 - Networks in Trade and Macroeconomics

Lecture 3 - Buyer-Seller Relationship Formation

Motivation

- So far, we have studied the effects of shocks in networks...
  - in environments where we take the network structure as given
- Today we will start thinking about what determines network formation
- As a starting point, consider a special class: bipartite networks
  - set of nodes can be partitioned into sets of "sellers" Ω_s and "buyers" Ω_b
  - then $ij \in E$ (i.e. $i \to j$) implies $i \in \Omega_s$ and $j \in \Omega_b$
- Key questions:
  - what are empirical patterns of matching between buyers and sellers?
  - what determines which sellers match with which buyers?
  - what are the effects of relationship formation on firm outcomes?

Outline

- Bernard, Moxnes, and Ulltveit-Moe (2018, ReStat)
  - study buyer-seller matches in Norwegian export transactions data
  - document some stylized facts about patterns of buyer-seller matching
  - develop a structural trade model with two-sided heterogeneity
- Bernard, Moxnes, and Saito (2017, JPE forthcoming)
  - study buyer-seller relationships between Japanese firms
  - focus on geography of buyer-seller relationships
  - develop a structural trade model with costly search for suppliers
  - study expansion of Japanese bullet train (*Shinkansen*) as natural experiment that lowers search costs

Overview

- Bernard, Moxnes, and Ulltveit-Moe (2018, ReStat), "Two-sided Heterogeneity and Trade"
- Study international trade transactions data (Norway)
  - in which both exporters and importers can be identified
- Document some basic facts about patterns of buyer-seller matching
  - how important is the buyer margin in explaining trade variation
  - how do in- and out-degrees vary across firms
  - how do trade volumes vary across relationships
  - which exporters match with which importers
- Develop a structural model of trade to explain basic facts
  - basic framework is similar to Melitz (2003)
  - but now exporters have to pay cost to match with each importer

Data

- Norwegian transactions-level customs data, 2004–2012:
  - universe of Norwegian non-oil merchandise exports
  - annual flows of exports by exporter, product, destination, and year
  - observe both export value and quantity
- In addition, observe identities of both exporter and importer
  - each firm's exports can be linked to specific buyers in every destination
  - each firm's imports can be linked to specific suppliers from every source

Basic Facts: Buyer Margin

Fact 1: The buyer margin explains a large fraction of variation in aggregate trade.

- Decomposition of total exports to country j:

$$x_j \equiv \underbrace{f_j}_{\substack{\text{no. of}\\ \text{exporters}}} \times \underbrace{p_j}_{\substack{\text{no. of}\\ \text{products}}} \times \underbrace{b_j}_{\substack{\text{no. of}\\ \text{importers}}} \times \underbrace{d_j}_{\substack{\text{density of}\\ \text{trade}}} \times \underbrace{\bar{x}_j}_{\substack{\text{avg. value}\\ \text{of trade}}}$$

- Density of trade is:

$$d_j \equiv o_j / \left(f_j p_j b_j\right)$$

where o_j is no. of exporter-product-importer triplets with positive trade

- Average value of trade is:

$$\bar{x}_j = x_j / o_j$$

Basic Facts: Buyer Margin

Fact 1: The buyer margin explains a large fraction of variation in aggregate trade.

- Regress log of each RHS component on log total exports in 2006

TABLE 1.—THE MARGINS OF TRADE, 2006

	Sellers	Products	Buyers	Density	Intensive
Exports (log)	0.57***	0.53***	0.61***	−1.05***	0.32***
	(0.02)	(0.02)	(0.02)	(0.04)	(0.02)
N	205	205	205	205	205
R^2	0.86	0.85	0.81	0.81	0.50

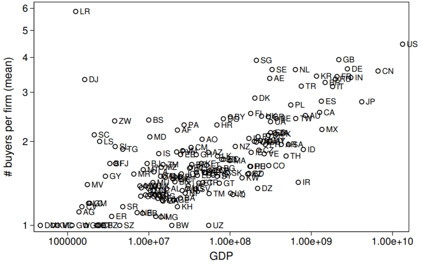
Given that OLS is a linear estimator and its residuals have an expected value of 0, the coefficients for each set of regressions sum to unity, with each coefficient representing the share of overall variation in trade explained by the respective margin. Significance of the robust standard error in parentheses: $^{***}p < 0.01$.

Source: Bernard et al (2018).

- No. of exporters and no. of products are important margins, as usual
  - but importer margin is shown to be equally as important

Basic Facts: Buyer Margin

Fact 1: The buyer margin explains a large fraction of variation in aggregate trade.



Source: Bernard et al (2018).

- No. of customers per exporter varies systematically with export market GDP
  - larger markets associated with more customers per exporter

Basic Facts: Buyer Margin

Fact 1: The buyer margin explains a large fraction of variation in aggregate trade.

Table 6: Within-Firm Gravity (2006).

	Exports (log)	# Buyers (log)	Exports/Buyer (log)
Distance	-0.48[a]	-0.31[a]	-0.17[a]
GDP	0.23[a]	0.13[a]	0.10[a]
Firm FE	Yes	Yes	Yes
N	53,269	53,269	53,269
R^2	0.06	0.15	0.01

Note: Robust standard errors clustered by firm. GDP data from Penn World Table 7.1 (cgdp x pop). [a] p< 0.01, [b] p< 0.05, [c] p< 0.1.

Source: Bernard et al (2018).

- No. of customers per exporter also declining with distance

Basic Facts: Many-to-many Matches

Fact 2: Many-to-many matches account for the majority of aggregate trade.

- Imports and exports are both characterized by extreme concentration
  - top 10% of exporters account for $\geq$ 90% of exports to typical market
  - top 10% of buyers from typical market account for $\geq$ 90% of exports
- But these large firms are matching with many partners

Table 8: Types of Matches between Exporters and Importers.

	One-to-one	Many-to-one	One-to-many	Many-to-many
Share of total trade value, %	4.6	26.9	4.9	63.6
Share of total number of matches, %	9.5	40.1	11.0	39.4

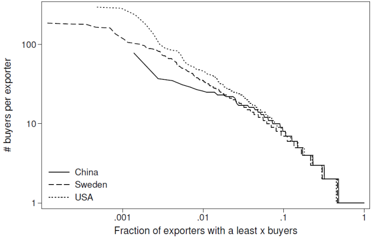
Source: Bernard et al (2018).

  - one-to-one: both exporter and importer have one link in a market
  - many-to-one: exporter has many links; importer has one link
  - one-to-many: exporter has one link; importer has many links
  - many-to-many: both exporter and importer have many links

Basic Facts: Degree Distributions

Fact 3: There are many firms with few links and few firms with many links.

Figure 4: Distribution of the number of buyers per exporter (2006).



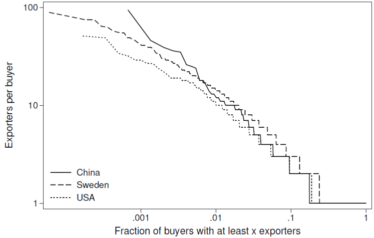
Source: Bernard et al (2018).

- Distributions are well-approximated by Pareto distribution
- Very similar distributions across markets
- Estimated slope coefficients: China (-1.02), Sweden (-1.02), USA (-1.13)

Basic Facts: Degree Distributions

Fact 3: There are many firms with few links and few firms with many links.

Figure 5: Distribution of the number of exporters per buyer (2006).



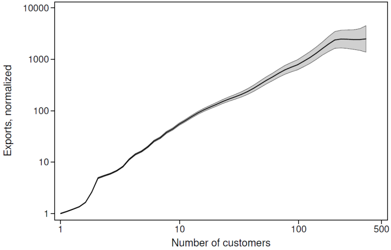
Source: Bernard et al (2018).

- Distributions are well-approximated by Pareto distribution
- Very similar distributions across markets
- Estimated slope coefficients: China ($-.92$), Sweden ($-.88$), USA ($-.80$)

Basic Facts: Intensive Margin

Fact 4: The distribution of exports across customers does not vary systematically with the number of customers.

Figure 6: Number of Buyers & Firm-level Exports (2006).



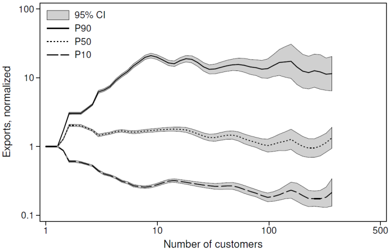
Source: Bernard et al (2018).

- Within a market, exporters with more customers have higher total sales

Basic Facts: Intensive Margin

Fact 4: The distribution of exports across customers does not vary systematically with the number of customers.

Figure 7: Number of Buyers & Within-firm Dispersion in Exports (2006).

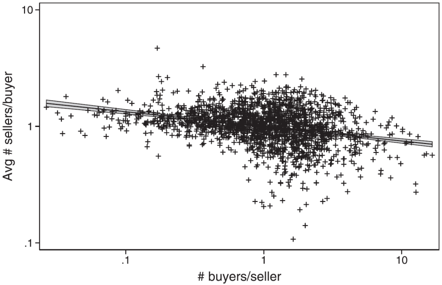


Source: Bernard et al (2018).

- However, better-connected sellers are not selling more to their median buyer

Basic Facts: Degree Assortativity

Fact 5: There is negative degree assortativity among sellers and buyers.



Source: Bernard et al (2018).

- The more buyers a seller has, the fewer sellers its average buyer tends to have
- Slope of fitted regression line $= -.13$
  - 10% increase in out-degree $\Leftrightarrow$ 1.3% decline in avg. customer in-degree

Basic Facts: Degree Assortativity

Fact 5: There is negative degree assortativity among sellers and buyers.

- Negative degree assortativity does not mean...
  - that well-connected exporters sell *only* to less-connected buyers:
- Well-connected exporters typically sell...
  - to *both* well-connected buyers and less-connected buyers
- However, less-connected exporters typically sell...
  - only to well-connected buyers
- Negative degree assortativity also documented in other data:
  - Japan: Bernard, Moxnes, and Saito (2017)
  - Chilean-Argentinean trade: Blum et al. (2010)

Basic Facts: Connection Hierarchies

Fact 6: Firms tend to follow a hierarchy in their choice of connections.

- Investigate pervasiveness of *buyer hierarchies*
  - e.g. if I sell to 10^{th}-most connected buyer...
  - do I also sell to k^{th}-most connected buyers for $k \in \{1, \cdots, 9\}$?
  - similar to analysis in Eaton, Kortum, and Kramarz (2011)
- For buyer b in a given export market with B buyers:
  - denote no. of links to Norwegian exporters by d_b
  - denote rank in terms of d_b by r_b (e.g. $r_b = 1 \Leftrightarrow b = \arg\max_{b'} d_{b'}$)
- Probability of connecting to buyer b:

$$\rho_{r_b} = \frac{d_b}{\sum_{b'=1}^{B} d_{b'}}$$

Basic Facts: Connection Hierarchies

Fact 6: Firms tend to follow a hierarchy in their choice of connections.

- Under independence, probability of connecting only to rank $\{1, \cdots, r\}$ buyers:

$$p_r = \prod_{r'=1}^{r} \rho_{r'} \prod_{r''=r+1}^{B} (1 - \rho_{r''})$$

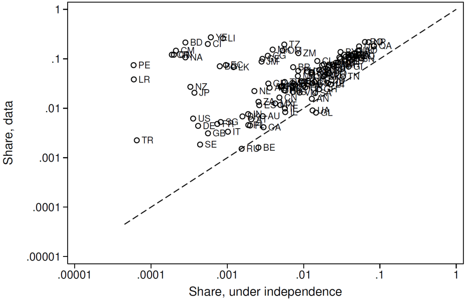
- Under independence, likelihood of following buyer hierarchy is:

$$\sum_{r=1}^{B} p_r$$

- Now compare this to observed fraction of exporters following the hierarchy

Basic Facts: Connection Hierarchies

Fact 6: Firms tend to follow a hierarchy in their choice of connections.



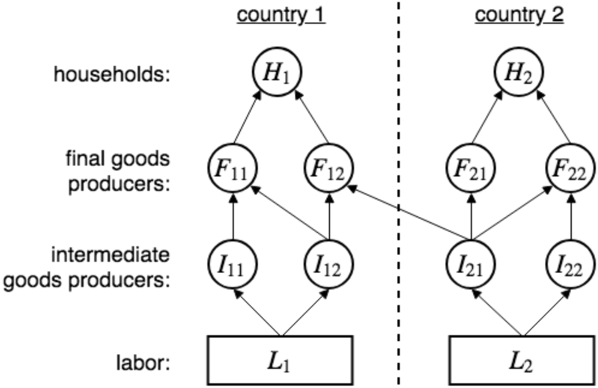
Source: Bernard et al (2018).

- In most export markets, fraction of firms adhering to hierarchy is higher than independent benchmark

Basic Environment

- K countries producing and consuming differentiated goods
- Intermediate goods sector
  - tradable (at trade cost $\tau_{ij} \geq 1$ for $i \to j$)
  - production uses only labor
  - firms are heterogeneous in productivity
  - firms pay relationship-specific cost to sell to final goods producers
  - operates under monopolistic competition
- Final goods sector
  - non-tradable
  - production combines differentiated intermediate goods
  - firms are heterogeneous in productivity
  - operates under monopolistic competition

Basic Environment



Production

- Final goods producers are heterogeneous in productivity Z
  - drawn from Pareto distribution with CDF:

$$G(Z) = 1 - Z^{-\Gamma}$$

- Intermediate goods producers are heterogeneous in productivity z
  - drawn from Pareto distribution with CDF:

$$F(z) = 1 - (z_L/z)^{-\gamma}$$

- To match with a buyer in j, seller in i must pay fixed cost f_{ij} (in units of labor)
- Given fixed cost, buyer-seller matches can be characterized as follows:
  - seller z in i will sell only to buyers in j with productivity $\geq \underline{Z}_{ij}(z)$
  - buyer Z in j will buy only from sellers in i with productivity $\geq \underline{z}_{ij}(Z)$
- $\underline{Z}_{ij}(\cdot)$ and $\underline{z}_{ij}(\cdot)$ are the (endogenous) **sorting functions** of the economy
  - $\underline{Z}_{ij}$ and $\underline{z}_{ij}$ are inverses of each other

Production

- Intermediate goods production for z-firms in country i:

$$x_i(z) = z l_i(z)$$

  - $x_i(z)$: output
  - $l_i(z)$: quantity of labor hired

- Final goods production for Z-firms in country i:

$$X_i(Z) = Z\left[\sum_{j=1}^{K} n_j \int_{\underline{z}_{ji}(Z)} m_{ji}(z, Z)^{\frac{\sigma-1}{\sigma}} dF(z)\right]^{\frac{\sigma}{\sigma-1}}$$

  - $X_i(Z)$: output
  - $m_{ji}(z, Z)$: quantity of inputs purchased from z-suppliers from j
  - n_j: measure of suppliers from j
  - σ: elasticity of substitution across intermediate inputs

Pricing

- Given monopolistic competition market structure:
  - all firms charge CES markup $\mu \equiv \frac{\sigma}{\sigma-1}$ over marginal costs
- Intermediate goods producers:

$$p_{ij}(z) = \mu \frac{w_i \tau_{ij}}{z}$$

- Final goods producers:

$$P_j(Z) = \mu \frac{q_j(Z)}{Z}$$

- Final goods input price index inherits CES structure:

$$q_j(Z)^{1-\sigma} = \sum_{k=1}^{K} n_k \int_{\underline{z}_{kj}(Z)} p_{kj}(z)^{1-\sigma} \, dF(z)$$

Profits and sorting

- Profits for a z-firm in i selling to a Z-firm in j:

$$\pi_{ij}(z, Z) = \frac{1}{\sigma} E_j(Z) \left[\frac{p_{ij}(z)}{q_j(Z)}\right]^{1-\sigma} - w_i f_{ij}$$

  - $E_j(Z)$: total spending on intermediates by Z-firms in j (endogenous)

- Equilibrium sorting function defined implicitly by:

$$\pi_{ij}\left(z, \underline{Z}_{ij}(z)\right) = 0$$

- Model closed by assuming:
  - household CES preferences over final goods
  - outside homogeneous sector to pin down wages
  - studying limiting economy where $z_L \to 0$ and $n_k = \bar{n}_k z_L^{-\gamma}$
  - measures of firms $\{N_i, n_i\}$ proportional to country size Y_i (≈GDP)

Profits and sorting

- With these assumptions, solution for the sorting function is:

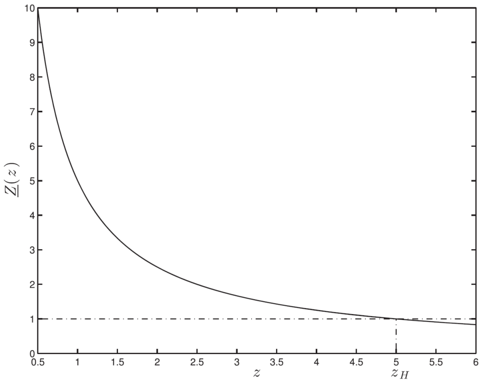
$$\underline{Z}_{ij}(z) = \Omega_j \left(w_i f_{ij}\right)^{\frac{1}{\sigma-1}} w_i \tau_{ij}/z$$

where:

$$\Omega_j \propto \left[\sum_{k=1}^{K} Y_k \left(w_k \tau_{kj}\right)^{-\gamma} \left(w_k f_{kj}\right)^{-\frac{\gamma-(\sigma-1)}{\sigma-1}}\right]^{\frac{1}{\gamma}}$$

- z-seller from i matches with more buyers in j when:
  - wage w_i is lower
  - relationship cost f_{ij} is lower
  - trade cost τ_{ij} is lower
  - "multilateral resistance" Ω_j is lower
- Ω_j is "multilateral resistance" in market j (c.f. Anderson-van Wincoop (2004))
  - country j's "access" to inputs from k is inversely related to...
  - nominal variable trade costs $w_k \tau_{kj}$ and fixed costs $w_k f_{kj}$
  - so Ω_j is large if j has greater access to inputs from high Y_k sources
  - Ω_j hence captures "competition" effects across source markets

Profits and sorting



Source: Bernard et al (2018).

Linking Facts and Theory

- Measure of buyers in j for z-firm from i:

$$
\begin{aligned}
b_{ij}(z) &= N_j \int_{\underline{Z}_{ij}(z)}^{\infty} dG(Z) \\
&= Y_j \underline{Z}_{ij}(z)^{-\Gamma} \\
&= Y_j \Omega_j^{-\Gamma} \left(w_i f_{ij}\right)^{-\Gamma/(\sigma-1)} \left(w_i \tau_{ij}\right)^{-\Gamma} z^{\Gamma}
\end{aligned}
$$

- Hence, number of buyers per exporter is:
  - increasing in destination market size Y_j (fact 1)
  - decreasing with trade costs τ_{ij} (with elasticity $-\Gamma$) (fact 1)
  - distributed Pareto (with shape parameter γ/Γ) (fact 3)
- Model naturally generates many-to-many matching (fact 2)

Linking Facts and Theory

- Can show that within-firm sales distribution is:

$$\Pr\left[r_{ij}\left(Z\right) < r | z\right] = 1 - \left(\frac{\sigma w_i f_{ij}}{r}\right)^{\frac{\Gamma}{\sigma-1}}$$

  which is independent of z (fact 4)
- Consider firms from i with b_{ij} customers in j
  - amongst these firms' customers in j, average measure of suppliers is:

$$\bar{S}_{ij}\left(b_{ij}\right) \propto b_{ij}^{-\gamma/\Gamma}$$

    which is decreasing with b_{ij} (fact 5)
- However, model predicts that all sellers follow strict buyer hierarchy
  - if a firm sells to Z'-buyer, it must sell to all buyers with $Z \geq Z'$
  - hence the model cannot match fact 6
  - need additional source of randomness (e.g. stochastic relationship costs)

Overview

- Bernard, Moxnes, and Saito (2017), "Production Networks, Geography, and Firm Performance"
- Study buyer-seller relationships between Japanese firms
  - focus on geography of buyer-seller relationships
- Document some basic facts about patterns of buyer-seller matching
  - which firms source from where
- Develop a structural model of trade to explain basic facts
  - framework is similar to Bernard et al (2018)
  - but now searching locations for suppliers is costly for buyers
- Also investigate:
  - effects of lower search costs on relationship formation
  - effects of relationship formation on firm performance
- Identification strategy: expansion of Shinkansen (bullet train) in Tokyo in 2004
  - reduces travel/communication costs but not shipping costs

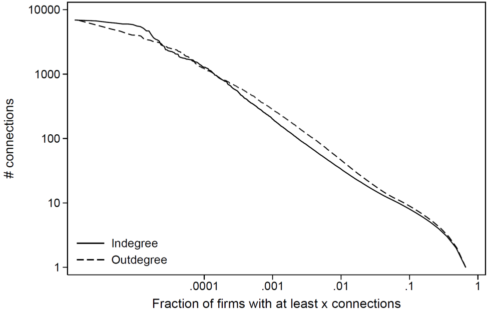
Firm-level Data

- Firm-level balance sheet data from “Kikatsu” database, 1998-2008
  - annual survey of Japanese firms
  - covers all firms with $\geq$50 employees, $\geq$ 30m yen capital
- Provides information on:
  - sales
  - employment
  - capital stock
  - intermediate purchases
  - industry affiliation

Buyer-seller Linkages

- Firm network data from Tokyo Shoko Research (TSR)
  - major Japanese credit reporting agency
  - firms engage TSR to obtain credit reports on customers/suppliers
  - provide list of up to 24 most important customers/suppliers
  - 950,000 firms, close to full population of firms with > 4 employees
  - data available for 2005 and 2010 (although TSR has data for more years)
- Other variables collected:
  - employment, number of establishments, number of factories, up to three (4-digit) industries, sales, profits, physical address, credit score
- Addresses are geocoded to obtain location of firm HQ
- Advantages of dataset:
  - includes firms of all sizes and industries
  - includes both public and private firms
- Main drawbacks:
  - no information on product or value traded
  - truncation in no. of customers/suppliers...
  - although most important links are reported

Japanese Production Network

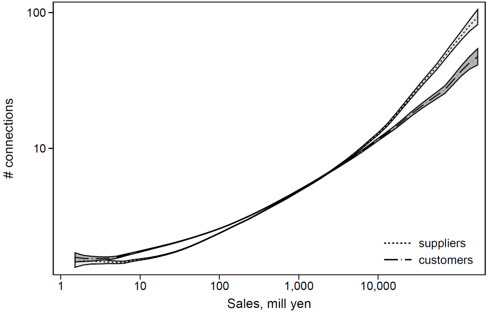


Source: Bernard et al (2017).

- In 2005, network has $\sim$ 800k firms with $\sim$3.4m supplier-customer relationships
  - $\sim$ 650k firms have positive in-degree (mean$=$ 5.1, median $=$ 3)
  - $\sim$ 570k firms have positive out-degree (mean$=$ 5.9, median $=$ 3)
- Degree distributions are well-approximated by Pareto distributions
  - estimated shape parameters: -1.37 (in-degree), -1.46 (out-degree)

Basic Facts: Size vs. Degree

Fact 1: Larger firms have more suppliers.

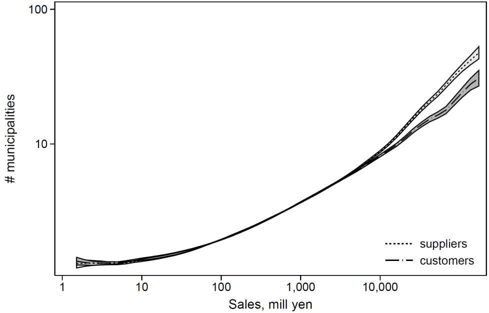


Source: Bernard et al (2017).

- Linear regression slopes ≈ .33
  - e.g. 10% increase in sales associated with 3.3% increase in no. of suppliers

Basic Facts: Size vs. Distance

Fact 2: Larger firms source from more locations and from further away.

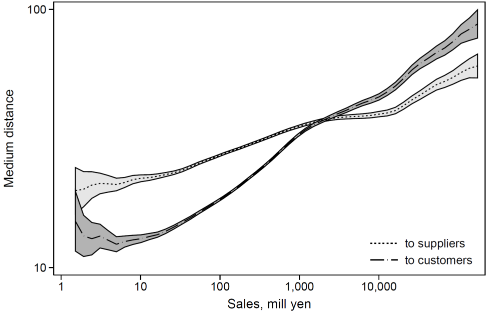


Source: Bernard et al (2017).

- Average number of supplier locations:
  - for firms in 1^{st} sales decile = 1.7 municipalities
  - for firms in 9^{th} sales decile = 3.9 municipalities

Basic Facts: Size vs. Distance

Fact 2: Larger firms source from more locations and from further away.



Source: Bernard et al (2017).

- Median distance to suppliers:
  - for firms in 1^{st} sales decile = 23.7 km
  - for firms in 9^{th} sales decile = 30.1 km

Basic Facts: Size vs. Distance

Fact 2: Larger firms source from more locations and from further away.

	In-degree	Sales	Employment	Labor prod.
All firms:				
Distance	0.16***	0.19***	0.16***	0.03***
	(320.50)	(261.40)	(264.80)	(99.48)
R-sq	0.58	0.62	0.60	0.46
N	3,302,104	3,298,607	3,297,191	3,294,028
Single-plant firms:				
Distance	0.01***	0.02***	0.01***	0.01***
	(7.59)	(8.64)	(5.79)	(7.59)
R-sq	0.64	0.68	0.69	0.62
N	269,761	269,373	269,342	268,975
Buyer prefecture FE	Yes	Yes	Yes	Yes
Supplier FE	Yes	Yes	Yes	Yes

Source: Bernard et al (2017).

- Among customers of the same supplier....
  - "better-performing" customers also tend to be further away
- e.g. 10% higher distance to supplier $\Leftrightarrow$ 1.9% higher sales for customer

Basic Facts: Size vs. Distance

Fact 2: Larger firms source from more locations and from further away.

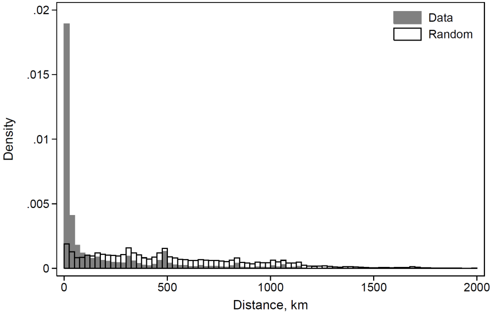
Dep. variable:	# sourcing cities	# customer cities	Median distance to suppliers	Median distance to customers	In-degree	Out-degree
Firm sales	0.31***	0.29***	0.02**	0.18***	0.36***	0.31***
	(402.9)	(326.6)	(11.51)	(99.15)	(421.1)	(317.9)
..×Single plant	-0.00***	-0.00***	-0.01***	-0.01***	0.00	-0.00***
	(3.00)	(17.85)	(15.28)	(20.52)	(0.37)	(16.80)
..×Single industry	-0.01***	-0.01***	-0.01***	0.00***	-0.02***	-0.01***
	(72.46)	(35.36)	(19.45)	(5.08)	(79.18)	(44.67)
# industries	401	401	401	401	401	403
# obs	435,479	435,479	426,305	426,305	435,479	435,479
R-sq	0.40	0.36	0.16	0.13	0.41	0.34

Source: Bernard et al (2017).

- Results are robust to controlling for industry fixed effects
  - i.e. patterns hold within industries as well
- Results also robust to controlling for firms with multiple plants

Basic Facts: Distance Distribution

Fact 3: Most relationships are formed locally.

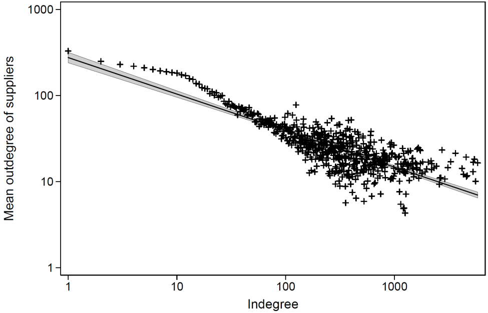


Source: Bernard et al (2017).

- In actual production network:
  - relationship distance median= 30 km, mean = 172 km
- In random network benchmark (i.e. firm with *n* edges forms these at random)
  - relationship distance median = 472 km, mean = 555 km

Basic Facts: Degree Assortativity

Fact 4: There is negative degree assortativity among sellers and buyers.



Source: Bernard et al (2017).

- Slope of fitted regression line $= -.42$
  - 10% increase in in-degree $\Leftrightarrow$ 4.2% decline in avg. supplier out-degree
- Same pattern as seen in Norwegian export transactions data

Model

- Model shares many basic features with Bernard, Moxnes, Ulltveit-Moe (2018)
  - CES preferences and production
  - two tiers of production: upstream inputs and downstream final outputs
  - fixed costs of forming buyer-seller relationships
  - iceberg trade costs across locations
- Key differences:
  - introduce multiple locations of production
  - buying firm pays relationship cost (instead of selling firm)
  - buying firm has option to produce input in-house or outsource
  - upstream input sector is perfectly competitive

Final Goods Production

- Consider final goods production in some location
- To produce output, firms must combine labor with *tasks* $\omega \in [0,1]$:

$$X = ZL^{1-\alpha}M^{\alpha}$$

$$M = \left[\int_0^1 x(\omega)^{\frac{\rho-1}{\rho}}\, d\omega\right]^{\frac{\rho}{\rho-1}}$$

  - X: output of downstream firm
  - Z: TFP of downstream firm
  - L: quantity of labor hired
  - M: aggregate task input
  - $x(\omega)$: production of task ω
  - α: intermediate input share
  - ρ: elasticity of substitution across tasks

Final Goods Production

- Each task ω can be produced either by:
  - performing it in-house
  - or outsourcing it to upstream firms (in any location)
- All production of tasks uses CRS technology with labor as sole input
  - but labor productivities are heterogeneous
  - and outsourcing from another location incurs trade costs
- Assume labor is freely mobile across locations
  - so that wages are equalized
  - take common wage as numeraire

In-house Production of Tasks

- Cost of producing a task in-house:

$$p_0 = 1/\phi_0$$

- In-house productivity ϕ_0 is drawn from Fréchet distribution:

$$\Pr\left[\phi_0 \leq \phi\right] = F_0\left(\phi\right) = e^{-T_0 \phi^{-\theta}}$$

  - T_0: scale parameter (controls average productivity)
  - θ: shape parameter (controls productivity dispersion)
  - ϕ_0 is *iid* across all downstream firms and tasks

Outsourcing of Tasks

- For a given task, all upstream firms in a location have same productivity
- Cost of outsourcing a task to upstream firms in location j:

$$p_j^u = \tau_j / \phi_j^u$$

  - τ_j: iceberg trade cost of buying from location j
- Upstream productivity ϕ_j^u is also drawn from Fréchet distribution:

$$\Pr\left[\phi_j^u \leq \phi\right] = F_u(\phi) = e^{-T\phi^{-\theta}}$$

  - T: scale parameter (common across source locations)
  - θ: shape parameter (same as in-house productivity distribution)
  - ϕ_j^u is *iid* across all locations and tasks

Optimal Sourcing

- Suppose that downstream firm sees upstream prices from locations $\{1, \cdots, K\}$
- For each task, firm will seek to minimize cost of production $p(\omega)$
- Since all $\phi's$ are Fréchet RVs, can show that:

$$p(\omega)^{-1} \sim \text{Frechet}(\Phi, \theta)$$

where Φ is total "market access" for the downstream firm:

$$\Phi \equiv T_0 + \sum_{k=1}^{K} T \tau_k^{-\theta}$$

- Since final goods production is CES in tasks, marginal cost of output is:

$$\begin{aligned} c &= Z^{-1} \left[\int_0^1 p(\omega)^{1-\rho} \, d\omega \right]^{\frac{\alpha}{1-\rho}} \\ &= \gamma Z^{-1} \Phi^{-\frac{\alpha}{\theta}} \end{aligned}$$

where γ is a constant

- Note that marginal cost depends on θ but is independent of ρ
- Exactly the same derivation as in Eaton-Kortum (2002)

Search Technology

- Now to capture fact that firms do not source from all locations...
  - assume that searching for inputs is costly
- Specifically, to observe prices in any location...
  - downstream firm must pay labor cost f (per location)
- Note that:
  - search cost f does not vary by source location
  - source locations differ only in terms of trade costs τ_j
- Hence, optimal search solution must be characterized by...
  - searching all locations up to some maximum trade cost $\bar{\tau}$

Search Technology

- For simplicity, assume that there is a *continuum* of locations
  - density of locations with trade cost τ is $g(\tau)$, on continuous support
- Then conditional on searching up to $\bar{\tau}$, marginal cost is:

$$c = \gamma Z^{-1} \Phi^{-\frac{\alpha}{\theta}}$$

$$\Phi = T_0 + \int_1^{\bar{\tau}} T \tau^{-\theta} g(\tau)\, d\tau$$

- Total measure of locations searched is:

$$n = \int_1^{\bar{\tau}} g(\tau)\, d\tau$$

and hence total cost of search is fn

Optimal Search

- Now suppose that final goods producers face constant elasticity demand:

$$X = Ap_F^{-\sigma}$$

  - A: demand shifter (determined in GE)
  - σ: price elasticity of final demand
  - p_F: final goods price charged to households

- Then variable profit for a final goods producer with marginal cost c is:

$$\pi = \frac{1}{\sigma} Ac^{1-\sigma}$$

- Hence, the **optimal search** problem for a final goods producer is:

$$\max_{\bar{\tau}} \left\{ \frac{1}{\sigma} \gamma^{1-\sigma} AZ^{\sigma-1} \Phi^{\frac{\alpha(\sigma-1)}{\theta}} - fn \right\}$$

$$\text{s.t. } \Phi = T_0 + \int_1^{\bar{\tau}} T\tau^{-\theta} g(\tau)\, d\tau$$

$$n = \int_1^{\bar{\tau}} g(\tau)\, d\tau$$

Optimal Search

- Easy to show that the solution is:

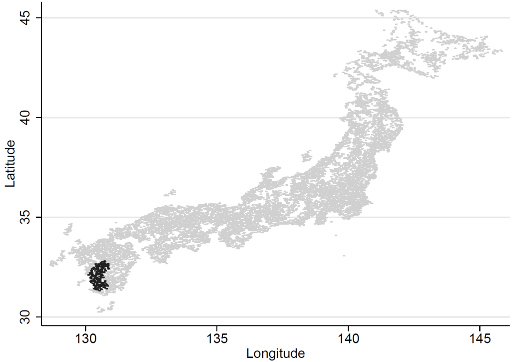
$$\bar{\tau} = \text{const.} \times \left[\frac{AZ^{\sigma-1}T}{f\Phi^{\frac{\theta-\alpha(\sigma-1)}{\theta}}} \right]^{\frac{1}{\theta}}$$

- Since Φ is a function of $\bar{\tau}$, this defines an implicit solution for $\bar{\tau}$
  - typically, need to solve this numerically
- Model predicts that it is optimal to search further ($\bar{\tau} \uparrow$) if...
  - demand is higher ($A \uparrow$)
  - source locations have better technology ($T \uparrow$)
  - downstream firm has higher TFP ($Z \uparrow$)
  - search costs are low ($f \downarrow$)
- In particular, model predicts that more productive (high Z) firms ...
  - are larger
  - have more suppliers
  - source from more locations
  - source from locations that are further away on average

Japanese *Shinkansen* Expansion

- Two key predictions of the model: lower search costs should lead to...
  - formation of more buyer-seller relationships
  - increase in sales of downstream firms (esp. for input-intensive firms)
- To test these predictions, study expansion of Japanese bullet train (*Shinkansen*)
  - southern portion of bullet train network expanded in March 2004
  - extended service to two prefectures with a total population of 3.5 million
  - resulted in dramatic reduction in travel time between major cities
- Planning of expansion started in 1973:
  - hence unlikely that firms influence timing and location of stations
- Timing of completion was subject to substantial uncertainty:
  - hence scope for anticipation effects is limited
- Goods do not travel on Shinkansen and no reduction in travel time for goods:
  - hence can separate search costs from trade costs

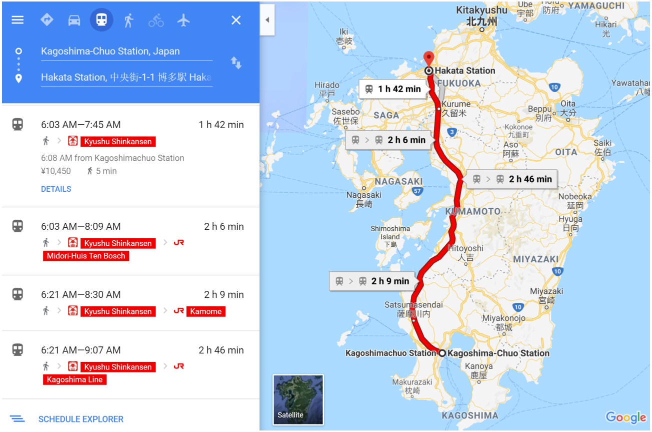
Japanese *Shinkansen* Expansion



Source: Bernard et al (2017).

- Black dots show 5 km × 5 km cells within 30 km of new Shinkansen station

Japanese *Shinkansen* Expansion



- For example, before bullet train expansion...
  - travel time between Hakata and Kagoshima was approximately 4 hours

Search Costs and Firm Performance

- Now estimate regressions of the form:

$$\log y_{fjrt} = \alpha_f + \alpha_{rt} + \beta S_f \times H_j \times I_t^{2004} + \gamma_1 S_f \times I_t^{2004} + \gamma_2 H_j \times I_t^{2004} + \epsilon_{fjrt}$$

  - y_{fjrt}: measure of performance for firm f, industry j, prefecture r, year t
  - S_f: $= 1$ if firm within 30 km of Shinkansen station
  - H_J: input intensity of industry j in 2003
  - I_t^{2004}: $= 1$ if year ≥ 2004
  - α_f,α_{rt}: firm and prefecture-year fixed effects
- Coefficient of interest: β

Search Costs and Firm Performance

- Note that Shinkansen expansion is expected to improve performance...
  - for input-intensive firms close to new stations...
  - compared to labor-intensive firms located close to new stations
- Identification is based on *triple-differences:*
  1. compare performance of input-intensive firms before/after 2004...
  2. to performance of labor-intensive firms...
  3. and compare this in locations with new stations vs. without

Search Costs and Firm Performance

	(1) Sales	(2) Sales/employee	(3) TFPR
$Station_f \times H_j \times Post2004_t$	0.65***	0.68***	0.58***
	(3.08)	(3.06)	(2.87)
Firm and municipality controls	Yes	Yes	Yes
Prefecture-year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
# obs	142,989	141,346	138,150
R-sq	0.97	0.92	0.97

Source: Bernard et al (2017).

- Magnitudes give differential performance of treated firms with $H_j = 1$ vs. $H_j = 0$
- e.g. for firms in 9^{th} decile of H_j distribution (0.92) vs. 1^{st}decile (0.70)
  - sales increased by 0.14 log points
  - equivalent to 14% lower input prices in the model

Search Costs and Buyer-Seller Linkages

- Next, test the main economic mechanism
  - lower search costs improve firm performance...
  - through formation of new buyer-seller linkages
- Estimate same form of regressions as before:

$$\log y_{fjrt} = \alpha_f + \alpha_{rt} + \beta S_f \times H_j \times I_t^{2004} + \gamma_1 S_f \times I_t^{2004} + \gamma_2 H_j \times I_t^{2004} + \epsilon_{fjrt}$$

  - except that now y_{fjrt} is a measure of relationship formation
- Note that relationship data is only available for two years (2005 and 2010)
- Since Shinkansen expansion occurred in 2004...
  - need to assume some delay in effects on linkage formation

Search Costs and Buyer-Seller Linkages

	(1) # municipalities	(2) χ	(3) # suppliers
$Station_f \times H_j \times 2010_t$	1.16**	0.13**	0.97
	(2.25)	(2.00)	(1.17)
Firm and municipality controls	Yes	Yes	Yes
Prefecture-year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes
# obs	610,948	610,948	610,948
R-sq	0.97	0.97	0.98

Note: χ refers to the share of suppliers located in treated locations, where treatment is defined as being <30 kilometers from a new Shinkansen station. t-statistics clustered by firm in parentheses. Dependent variables are measured relative to industry-year means. *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level.

Source: Bernard et al (2017).

- Results suggest that vis-à-vis treated labor-intensive firms, treated input-intensive firms...
  - source from more locations
  - reallocate suppliers towards treated locations
  - form linkages with more suppliers (but not statistically significant)

Buyer-Seller Linkages and Firm Performance

- Finally, test whether treatment effects on firm performance...
  - are present only for firms that form new supplier linkages
- Estimate same regressions as before:

$$\log y_{fjrt} = \alpha_f + \alpha_{rt} + \beta S_f \times H_j \times I_t^{2004} + \gamma_1 S_f \times I_t^{2004} + \gamma_2 H_j \times I_t^{2004} + \epsilon_{fjrt}$$

  - where y_{fjrt} is a measure of firm performance
  - but estimate effects separately for firms that added new suppliers vs. those that did not

Buyer-Seller Linkages and Firm Performance

	(1) Sales	(2) Sales /empl	(3) TFPR	(4) Sales	(5) Sales /empl	(6) TFPR
$Station_f \times H_j \times Post2004_t$	-0.08	0.07	-0.06	0.60**	0.72***	0.54**
	(0.19)	(0.26)	(0.12)	(2.48)	(2.74)	(2.31)
Firm and municipality controls	Yes	Yes	Yes	Yes	Yes	Yes
Prefecture-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
# obs	4,392	4,303	4,109	107,825	106,540	104,149
R-sq	0.94	0.91	0.94	0.97	0.92	0.97

Note: Columns (1)-(3) use the sample of firms with no new suppliers from 2005 to 2010. Columns (4)-(6) use the sample of firms with new suppliers from 2005 to 2010. t-statistics clustered by firm in parentheses. Dependent variables are in logs and are measured relative to industry-year means. *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level.

Source: Bernard et al (2017).

- Results show that Shinkansen expansion treatment:
  - induced growth in sourcing locations...
  - induced reallocation of buyer-seller linkages towards treated locations...
  - and that these changes in sourcing led to improved firm performance

Summary and Related Papers

- Studied empirical patterns of buyer-seller matching in:
  - international trade transactions data (Norway)
  - domestic production network data (Japan)
- Developed models of endogenous relationship formation in bipartite networks:
  - extensive margin is generated by assumption of costly relationships
- Saw evidence from natural experiment that:
  - lower search costs lead to changes in relationship formation
  - changes in relationship formation lead to changes in firm performance
- Related papers:
  - Monarch (2018) - estimates supplier switching costs (US-China)
  - Benguria (2015) - studies exporter-importer matching (US-Colombia)
  - Sugita et al (2018) - studies exporter-importer matching (US-Mexico)
- Next week: firms and production networks