The Network Structure of International Trade

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April 30, 2013

AER revised and resubmitted
Introduction (I)

- Individual firms differ in the exposure to International Trade
  - Most firms do not export
  - High degree of heterogeneity in the export intensity
  - Only a few firms export to a large number of countries
- Explain the extensive margin of trade, that is the patterns of entry of individual exporters into different foreign markets.
 introducción (II)

- Desarrollar una teoría de fricciones comerciales basada en la noción de fricciones informacionales.

- Las empresas individuales entran en el mercado extranjero si y solo si han adquirido un contacto en ese mercado.

- Los exportadores potenciales encuentran socios comerciales extranjeros de dos maneras distintas:
  - Búsqueda directa → búsquedas al azar geográficamente sesgadas
  - Búsqueda remota → Utilizar contactos existentes para encontrar nuevos.
Introduction (III)

- Characterizes the dynamic formation of an international network of exporters and importers
- Using data on French exporters between 1986 and 1992 explains
  - Cross-sectional distribution of the number of foreign markets accessed by individual exporters
  - Cross-sectional geographic distribution of exports
  - Dynamics of firm level exports
Set Up

- Discrete set of locations $x \in \mathbb{Z}$
- Discrete set of firms
  - Number of firms grows at constant rate $\gamma$
  - In every location there are $N$ firms at age $t$
    - $N_t = N(1 + \gamma)^t$
- $m_{i,t}$: total number of consumers of firm $i$
- $f_{i,t}(x)$: total number of consumers firm $i$ has in location $x$.

\[ f_{i,t} : \mathbb{Z} \to \mathbb{N} \text{ with } \sum_{x \in \mathbb{Z}} f_{i,t}(x) \equiv m_{i,t} \]
Matching Frictions

Firms can acquire new consumers in two distinct ways:

- Search for new consumers locally
  - $\gamma \mu$ new consumers each period
  - Geographic location $x \in \mathbb{R}$ of each consumer is random, drawn from $g(x)$
  - $g(x)$ measures the geographical bias of this search technology

- Use its existing network of consumers to search remotely
  - $\gamma \mu \pi$ new consumers each period, with $\pi \geq 0$
  - Geographic location $y \in \mathbb{R}$ of each remote consumer is drawn from $g(x - y)$

- Remote search works exactly as local search
Dynamic evolution of the network of consumers is

\[
f_{i,t+1}(x) - f_{i,t}(x) = \sum_{k=1}^{\gamma \mu} \mathbb{I}[\tilde{x}_{i,k} = x] + \sum_{y \in \mathbb{Z}} f_{i,t}(y) \mathbb{I} \sum_{k_y=1}^{\gamma \mu \pi} [\tilde{x}_{i,k_y} = y - x]
\]

- \( f_{i,0}(x) = 0, \ \forall x \in \mathbb{Z} \)
- \( \tilde{x} \) are independent realizations of \( g(\cdot) \)
Evolution

- Dynamic evolution of the network of consumers is

\[ f_{i,t+1}(x) - f_{i,t}(x) = \sum_{k=1}^{\gamma \mu} \mathbb{I}[\tilde{x}_{i,k} = x] + \sum_{y \in \mathbb{Z}} f_{i,t}(y) \mathbb{I} \sum_{k_y=1}^{\gamma \mu \pi} [\tilde{x}_{i,k_y} = y - x] \]

- \( f_{i,0}(x) = 0, \forall x \in \mathbb{Z} \)
- \( \tilde{x} \) are independent realizations of \( g(\cdot) \)

- If the population is large, the randomness disappears:

\[ f_{t+1}(x) - f_t(x) = \gamma \mu g(x) + \gamma \mu \pi \sum_{y \in \mathbb{Z}} f_t(y) g(x - y) \]

- Firms within a cohort are not identical
- Differences are summarized by a stable function, despite
  - The inherent randomness of the small sample
  - The network of consumers diverging as times goes on
Predictions and Estimation Strategies

- The evolution of the dynamics of $f_t$

\[ f_{t+1}(x) - f_t(x) = \gamma \mu g(x) + \gamma \mu \pi \sum_{y \in \mathbb{Z}} f_t(y) g(x - y) \]

- It allows to derive closed-form solutions for
  - The distribution of the total number of consumers ($m_t$) within the population
  - The geographic distributions of these consumers

- Estimation
  - SMM approach is based on the distribution of the number of foreign markets firms export to
  - Reduced form approach is based on the geography of the exports
Data

- Firm level export data for French exporters, 1986 - 1992 (French Customs)
  - Value of exports to a given country
  - Between 119,000 exporters (in 1988) to 126,594 (in 1992)
  - 210 different export destinations
  - French exporters export on average to 4 foreign markets
- Size of a country: nominal GDP (Penn World Tables)
- Distance between countries: population weighted geodesic distances between main cities in both countries (CEPII)
- Aggregate bilateral trade flows (NBER)
Simulated Method of Moments Estimation

- **Parametrization** — Laplace distribution: \( g(x) = \frac{1}{2\lambda} e^{-|x|/\lambda} \)

- **Simulation Algorithm** — Let \( \gamma = 0.02 \), for a given set of parameters \( \Theta = \{\mu, \pi, \lambda\} \) simulate artificial cohorts of French firms that sells to consumers in various countries.

1. **Firms** - The oldest generation has 20 firms: \( N_t = 20(1 + 0.02)^t \)
   Simulate 360 successive cohorts.

2. **Potential Consumers** - Choose “large” values for \( \mu \) and \( \mu\pi \).
   For each firm of age \( t \), keep all consumers it had in \( t - 1 \)
   Add a directly searched consumer (\( \gamma\mu = 0.02 \)) and a remotely searched consumer (\( \gamma\mu\pi = 0.027 \)).

3. **Stored Information** - For each link \( l \) between a French firm and a consumer store: \( l', u_1, u_2 \text{ and } u_3 \).
   \( l' \) is the name of link if \( l \) is the outcome of remote search
   If \( l' = 0 \), \( u_1 \sim U[0, 1] \text{ and } u_2 = 0 \)
   If \( l' \neq 0 \), \( u_1 = 0 \text{ and } u_2 = \min\{U[0, 1], u_2'\} \)
   \( u_3 \sim U[0, 1] \) that determines the destination
Simulation Algorithm

4. Actual Consumers - For given $\mu$ and $\pi$ different from Step 2, a particular link exist if both $\gamma \mu > u_1$ and $\gamma \mu \pi > u_2$

5. Geographic Location - $Pr_{\text{link}_{c,c'}} = \alpha \lambda \cdot GDP_c \cdot g_\lambda (Dist_{c,c'})$
   A link from country $c$ will fall in country $c'$ if
   \[
   \sum_{n=1}^{c'} \alpha \lambda GDP_n g_\lambda (Dist_c,n) \leq u_3 < \sum_{n=1}^{c'+1} \alpha \lambda GDP_n g_\lambda (Dist_c,n)
   \]

Moments - Match 120 moments.
   70 moments: fraction of firms exporting to 1, 2, ... and $\geq 70$
   50 moments: average (squared) distance of exports among firms that export to 1, 2, ... and 50 countries

Estimation Procedure - $\tilde{\Theta} = \arg\min_{\Theta} \{ y (\Theta)' Wy (\Theta) \}$
## Results SMM

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>1991</th>
<th>1992</th>
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<tr>
<td>( \pi )</td>
<td>2.543</td>
<td>2.324</td>
<td>2.401</td>
</tr>
<tr>
<td></td>
<td>(.129)</td>
<td>(.305)</td>
<td>(.171)</td>
</tr>
<tr>
<td>( \mu )</td>
<td>0.357</td>
<td>0.372</td>
<td>0.384</td>
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<td></td>
<td>(.014)</td>
<td>(.035)</td>
<td>(.034)</td>
</tr>
<tr>
<td>( \lambda )</td>
<td>3.339</td>
<td>3.287</td>
<td>3.513</td>
</tr>
<tr>
<td></td>
<td>(.109)</td>
<td>(.110)</td>
<td>(.220)</td>
</tr>
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**Table 1:** Remote Search, Direct Search and Geography
Predictions

- The evolution of the dynamics of $f_t$

$$f_{t+1}(x) - f_t(x) = \gamma \mu g(x) + \gamma \mu \pi \sum_{y \in \mathbb{Z}} f_t(y) g(x - y)$$

- It allows to derive closed-form solutions for
  - The distribution of the total number of consumers ($m_t$) within the population
  - The geographic distributions of these consumers
Distribution of the Total Number of Consumers

Proposition

For short time intervals, the fraction of firms with fewer than $m$ consumers is,

$$F(m) = 1 - \left(\frac{1}{1 + \pi m}\right)^{\frac{1}{\mu \pi}}$$  \hspace{1cm} (1)$$

- Geography plays no role in this distribution
- Mix of Pareto and Exponential distributions.
- For $m$ large, the local search component becomes negligible $m_t \approx e^{\gamma \mu \pi t} \implies$ Pareto distribution with exponent $-1/\mu \pi$
- For $m$ small, the remote search component becomes negligible $m_t \approx \gamma \mu t \implies$ Exponential distribution with parameter $-1/\mu$
Distribution of the Total Number of Consumers

Figure 1: Fraction of Exporters

Notes: Left panel: fraction of firms that export to $M$ different countries. Right panel: average squared distance to a firm's export destinations, among firms exporting to $M$ destinations, as defined in Equation (10); distances are calculated in 1,000's of kms.

Blue dots: data, all French exporters in 1992. Red plus signs: simulated data; $\pi = 2.401 (0.171)$, $\mu = 0.384 (0.034)$ and $\lambda = 3.513 (0.220)$ are estimated by Simulated Method of Moments.

Bridging the gap between micro and macro: a reduced form approach

A very simple reduced approach to bring the model to the data is to assume that one country is equivalent to one consumer, and to assume that the actual world's geography is well approximated by the simplified one-dimensional infinite world of the theory. Following this reduced form approach, I can easily estimate the parameters $\pi_{\text{macro}}$, $\mu_{\text{macro}}$, and $\Delta_{\text{macro}}$. First, I estimate by non-linear least squares the following discrete analog of Proposition 1, which governs the distribution of the number of export countries between firms:

$$ f(M) = \left\{ F(M+1) - F(M) \right\} e^{\epsilon_M} $$

$$ \ln f(M) = \ln \frac{1}{1 + \pi_{\text{macro}} M} - \frac{1}{1 + \pi_{\text{macro}} (M+1)} + \epsilon_M $$

(11)
Geographic Distributions

Proposition

For short time intervals, the average (squared) distance from a firm's consumers, $\Delta(m)$, increases with the number of consumers $m$,

$$\Delta(m) = \left( \frac{1}{1 + \pi m} \right) \ln(1 + \pi m) \Delta_g$$

with $\Delta_g \equiv \sum_{x \in \mathbb{Z}} x^2 g(x)$ the variance of $g(\cdot)$.

- Absent remote search ($\pi = 0$), the average (squared) distance from consumers would be constant: $\Delta(m) \equiv \Delta_g$, $\forall m$

- If remote search is present ($\pi \neq 0$), the geographic distance from the consumers increases over time.

The average (squared) distance from consumers increases in a log-linear way: $\Delta(m) \approx constant + \Delta_g ln(m)$
Geographic Distributions

Figure 1: The number and geography of exports, SMM estimates.
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$$f(M) = \frac{F(M + 1) - F(M)}{e^{\epsilon_M \ln f(M)}} = \frac{1}{1 + \pi \frac{M}{\mu}} - \frac{1}{1 + \pi \frac{M + 1}{\mu}} + \epsilon_M$$

Figure 2: Geography of Exports
Extras

- Reduced form approach
  - Assume that one country is equivalent to one consumer
  - Needs a very large dispersion for the $g$ function, large $\lambda$.
  - Results in low $\pi$ and high $\mu$.
  - Observing only the coarse partition of the world into countries, everything looks as if remote search was much less important than it actually is.

- Both approaches are successful in the matching but connect to different empirical observations.

- Matches trade dynamics in a final section
  - Firms with more contacts have a larger probability of entering new markets
  - A firm follows a history dependent path when expanding into foreign markets