Firms and Global Production

Costas Arkolakis, Natalia Ramondo, Andres Rodriguez-Clare, Stephen Yeaple

December 2010
The world is a cube, not a square

Trade economists need to think more “inside the box”:

- The volume of trade by firms that originate in country $i$, are produced in country $l$, for destination $n$ is $X_{iln}$

- Trade models generally ignore $i$ and focus instead on

  $$X_{ln} = \sum_i X_{iln}$$

This approach misses much.
Inconvenient Facts from the US

Consider the case for $i = \text{United States (2004)}$

- Most US firm sales abroad are produced by their plants outside the US:
  \[
  \frac{\sum_{l \neq i, n \neq i} X_{iln}}{\sum_{l, n \neq i} X_{iln}} = 0.65
  \]

- Of this, one-third is exported to foreign countries other than the host:
  \[
  \frac{\sum_{l \neq i, n \neq i, l} X_{iln}}{\sum_{l \neq i, n \neq i} X_{iln}} = 0.37
  \]

Further, for $l = \text{US}$

- Foreign affiliates in US account for substantial fraction of US exports:
  \[
  \frac{\sum_{i \neq l, n \neq l} X_{iln}}{\sum_{i, n \neq l} X_{iln}} = 0.19
  \]
Our way of thinking inside the box

A tractable multicountry, monopolistic competition model of trade & MP

- Starting point: ingredients by Melitz/Chaney; Eaton, Kortum, Kramarz
  - Monopolistically competitive firms
  - Fixed marketing & variable trade costs— not all firms serve all markets.
  - Pareto parameterization of heterogeneous firm productivity

- To look inside the box, we add
  - Extend probabilistic productivity draws by firm to all countries
  - Add variable MP costs (friction to moving ideas)
  - Firms compare costs of exporting, MP and BMP

- New theory of trade and MP: Proximity vs Comparative Advantage
  - No fixed costs of production: avoid very difficult discrete choice problem
Quantitative Models in trade and MP

Existing literature

- Trade Only models: Melitz; Chaney; EKK
- MP Only models: Burstein, Monge-Naranjo; Ramondo; McGrattan, Prescott
- Models with both trade and MP
  - NO BMP: Variants of Helpman et al, e.g. Moxnes et al
  - With BMP, Ramondo and Rodríguez-Clare
Quantitative Models in trade and MP

This paper

- Use more data in calibration
  - Deepen insight into gravity relationships
  - Jointly estimate trade and MP frictions
- Role of profits in welfare results
  - 20% of Irish GDP shipped abroad as payments to foreign ideas
- Allow for free entry → specialization in innovation vs production
- Effect of trade & MP liberalization on firm decisions & key aggregates?
  - U.S.-Canadian FTA – substitution away from local MP for exports
  - Example: increase in Greek openness to MP: trade & MP flows, welfare
    - Increase Greek openness to match Irish episode
    - By some estimates, foreign firms in Ireland account for 75% ind. output
Model
Notation

- $N$ countries. $i$: origin, $l$: location, $n$: destination

- $X_{iln}$: sales of firms from $i$, producing in $l$, selling to $n$

- $Y_l$: GDP, total production by all firms in location $l$
  - $\sum_{i,n} X_{iln} = Y_l$

- $X_n$: GNI, total income (and spending) of country $n$
  - $\sum_{i,l} X_{iln} = X_n$
Setup

- Measure of $L_i$ consumers/workers, and measure $M_i$ of firms (exogenous if no free entry)

Consumers

- Dixit-Stiglitz preferences over varieties, elasticity of substitution $\sigma$
- Income from labor & profits from national firms (profits zero if free entry)
Setup

- **Firms**
  - Monopolists over their variety. Enter in $i$ with fixed cost $w_i f_i^e$
  - Can serve $n$ from any location $l$ at "marketing" cost $w_n F_n$
  - Linear production technology. Productivity in location $l$ is $z_l$, use $z = (z_1, ..., z_N)$
  - $\tau_{ln}$ iceberg trade costs, $\gamma_{il}$ iceberg MP costs
  - Marginal production and shipping cost from $l$ to $n$

$$C_{iln} = \frac{w_l \tau_{ln} \gamma_{il}}{z_l} \equiv \frac{\zeta_{iln}}{z_l}$$
Firm Productivities

- Productivity vector $\mathbf{z}$ is drawn from a multivariate Pareto distribution

$$\Pr(Z_1 \leq z_1, \ldots, Z_N \leq z_N) = H(z_1, \ldots, z_N) = 1 - \left( \frac{1}{N} \sum_{v=1}^{N} z_v^{-\theta/\rho} \right)^{\rho}$$

for $z_v \geq 1$, $\theta > \sigma - 1$, $\rho \in ]0, 1]$.

- Properties of the distributions
  - Marginals are not Pareto, but do have Pareto tails – for $z_l \geq a > 1$,
    $$\Pr(Z_l \geq z_l \mid Z_l \geq a) = (z_l/a)^{-\theta}$$
  - As $\rho \to 0$ then perfect correlation among $z_v$.
  - With no free entry and $\gamma_{il} \to \infty \ \forall i \neq l$ then this is the Chaney-EKK version of Melitz
Firm Problem: Entry

- Firm $i$ chooses to sell to $n$ from $l$ if

$$\arg \min_v C_{ivn} = l \cap C_{ivn} \leq c_n^*$$

where

$$c_n^* = \left( \frac{\sigma w_n F_n}{\tilde{\sigma} X_n} \right)^{1/(1-\sigma)} P_n$$

and where $P_n$ is the Dixit-Stiglitz price index.
Firms

Lemma
The probability that a firm from $i$ will serve market $n$ from $l$ is

$$ \int_0^{c^*_n} \theta \Psi_{in}^{\rho-1} \zeta_{iln}^{\theta/\rho} c^{\theta-1} dc = N^{-\rho} \Psi_{in}^{\rho-1} \zeta_{iln}^{\theta/\rho} (c^*_n)^\theta. $$

(1)

where $\Psi_{in} \equiv \sum_v \zeta_{ivn}^{-\theta/\rho}$ and the measure of firms from $i$ that serve market $n$ from $l$ at cost $c < \zeta_{ivn}$ is $\theta M_i N^{-\rho} \Psi_{in}^{\rho-1} \zeta_{iln}^{-\theta/\rho} c^{\theta-1}$.

- Conditional on selling to $n$ from $l$, distribution of $c \leq c^*_n$ is $(c/c^*_n)^\theta$
Trade Flows

Since the sales of a firm with cost $c$ in a market $n$ are $\bar{\sigma} X_n P_n^{\sigma-1} c^{1-\sigma}$, the previous results imply that

$$X_{iln} = \psi_{iln} \pi_{in} X_n,$$

where

$$\pi_{in} = \frac{\sum_l X_{iln}}{\sum_{j,l} X_{jln}} = \frac{M_i \Psi_i^\rho}{\sum_j M_j \Psi_j^\rho},$$

and

$$\psi_{iln} \equiv \frac{\bar{\xi}_{iln}^{-\theta/\rho}}{\sum_v \bar{\xi}_{ivn}^{-\theta/\rho}}.$$
Trade and MP shares

- Expenditure shares of consumers in $n$ on goods produced in $l$ (trade shares)
  \[
  \lambda_{ln} = \frac{\sum_i X_{iln}}{\sum_{j,l} X_{jln}} = \sum_i \psi_{iln} \pi_{in}
  \]

- Production shares of firms from $i$ in $l$ (MP shares)
  \[
  \mu_{il} = \frac{\sum_n X_{iln}}{\sum_{j,n} X_{jln}} = \frac{\sum_n \psi_{iln} \pi_{in} X_n}{Y_l}
  \]
Equilibrium

- **Lemma:** Profits are a constant fraction \( \eta \equiv \frac{(\sigma - 1)}{(\sigma \theta)} \) of aggregate sales.

- Equilibrium can be determined by \( 3 \times N \) equations on \( X_i, w_i, M_i \)
  - Current Account balance
    \[
    X_i = w_i L_i^p + \eta \sum_n \pi_{in} X_n
    \]
  - Labor market equilibrium
    \[
    w_i L_i = w_i L_i^p + w_i L_i^e
    \]
    \[
    w_i L_i^p = (1 - \eta) \sum_n \lambda_{in} X_n
    \]
    \[
    w_i L_i^e = w_i M_i f_i^e
    \]
  - Free entry condition
    \[
    M_i w_i f_i^e = \eta \sum_l \mu_{il} Y_l
    \]
MP and Entry: An Illustration

Let $L^e_i$ be labor devoted to entry and $L^p_i = L_i - L^e_i$ be labor devoted to production. From equilibrium conditions, we have

$$\frac{L^e_i}{L^p_i} = \frac{\eta X_i}{1 - \eta Y_i}.$$  

- With no MP ($\gamma_{il} = \infty$ for $i \neq l$) then $X_i = Y_i$, so $L^e_i / L^p_i = \eta / (1 - \eta)$
  - Standard feature of Melitz/Chaney
- With MP a country facing lower entry costs now has
  $$\frac{L^e_i}{L^p_i} > \frac{\eta}{1 - \eta}$$
  - Countries with lower entry cost specialize in entry
  - Countries with high entry cost specialize in production.
Welfare Measurement

- The gains from openness can be written

\[ GO_n = \lambda_{nn}^{-\rho/\theta} \pi_{nn}^{-(1-\rho)/\theta} \varepsilon_{nnn}^{-\rho/\theta} \left( \frac{X_n}{Y_n} \right)^{1+\frac{\theta-(\sigma-1)}{\theta(\sigma-1)}} \]

where \( \varepsilon_{nnn} \equiv X_{nnn} / \sum_i X_{inn} \)

- In the special case with \( \rho = 1 \) and we have that \( \varepsilon_{nnn} = \mu_{nn} \), so

\[ GO_n = \lambda_{nn}^{-1/\theta} \times \varepsilon_{nnn}^{-1/\theta} \left( \frac{X_n}{Y_n} \right)^{1+\frac{\theta-(\sigma-1)}{\theta(\sigma-1)}} \]

- Inward versus Outward MP gains
Taking the Model to Data (Preliminary)
Calibrating the Model

- Parameters to obtain $M_i$, $\sigma$, $\theta/\rho$, $\tau_{ln}$, $\gamma_{il}$, and $\rho$

- Main Idea
  - Step 1: calibrate $M_i$ and $\sigma$
  - Step 2: use structural relationship to estimate $\theta/\rho$; pick a value for $\rho$
  - Step 3: given $\rho$ & $\theta$, get $\tau_{ln}$ & $\gamma_{il}$ by fitting model to trade and MP data
  - Step 4: loop until calibrated model is consistent with the trade elasticity in the data
Calibration: Step 1

- Calibrate $M_i$ and $\sigma$
  - $M_i$ proportional to equipped labor
  - $\sigma = 6$ to match a 20% markup (Martines et. al.)
    - $\sigma$ does not affect rest of estimation (minor effects on gains)
Calibration: Step 2

- We get $\theta/\rho$ as the trade elasticity in a *restricted* gravity equation.
- Recall that

\[
X_{iln} = \psi_{iln} \pi_{in} X_n
\]

\[
= (\tau_{ln})^{-\theta/\rho} \left( \frac{M_i \Psi_{in}^\rho - 1 X_n}{\sum_j M_j \Psi_{jn}^\rho} \right) (w_i \gamma_{il})^{-\theta/\rho}
\]

- Within network of $i$ firms gravity holds and coefficient on log$(\tau_{ln})$ is $-\theta/\rho$ (trade elasticity).
Calibration: Step 3

- Backing out trade and MP costs
- From the model, we have

\[ \lambda_{ln} = \sum_{i} \psi_{iln} \pi_{in} \]

\[ \mu_{il} = \frac{\sum_{n} \psi_{iln} \pi_{in} X_n}{Y_l} \]

where

\[ \pi_{in} = \frac{M_i \Psi_{in}^{\rho}}{\sum_{j} M_j \Psi_{jn}^{\rho}} \]

while \( \Psi_{in} = \sum_{v} \zeta_{ivn}^{-\theta/\rho} \), \( \zeta_{iln} \equiv w_l \gamma_{il} \tau_{ln} \), and \( \psi_{iln} \equiv \zeta_{iln}^{-\theta/\rho} / \Psi_{in} \).
Calibration: Step 3

- Given
  - $w_l$ (GDP per equipped labor),
  - $M_i$ (proportional to equipped labor),
  - aggregate bilateral trade and MP shares, $\lambda_{ln}$ and $\mu_{il}$,
  - an estimate of $\theta/\rho$ and a guess of $\rho$

Then all $\tau_{ln}$ and $\gamma_{il}$ are exactly identified.
Calibration: Step 4

- Simulate the model and run a standard (unrestricted) gravity regression to get the trade elasticity implied by the calibrated model.
- Compare this trade elasticity with the one in the data.
- Loop on $\rho$ until these elasticities match.

**Note:** we do not directly use info on $X_{iln}$ to estimate $\tau_{ln}$, $\gamma_{il}$ only $X_{ln}$, $Y_{il}$!
Calibration: Step 4

- The unrestricted gravity equation is associated with following equation

\[ X_{ln} = \sum_{i} X_{iln} \]

\[ = (\tau_{ln})^{-\theta/\rho} \left( \frac{X_{n}}{\sum_{j} M_{j} \Psi_{jn}^{\rho}} \right) (w_{l})^{-\theta/\rho} \left[ \sum_{i} M_{i} \Psi_{in}^{\rho-1} (\gamma_{il})^{-\theta/\rho} \right] \]

Note that last term in brackets cannot be decomposed.

- **Key Implication**: restr. gravity trade elasticity > unrestr. gravity trade elasticity
  - Only when \( \rho = 1 \) or when \( \gamma_{il} = \infty \) for all \( i \neq l \) restricted and unrestricted trade elasticities are the same (and equal to \(-\theta\)
Gravity Equations: Specification

For restricted and unrestricted sample, we estimate the following equation:

$$\log X_{iln} = \alpha_l + \eta_n + \beta \log(1 + T_{ln}) + \sum \delta_j[1|d_{ln} \in d_j] + \Theta Z_{ln},$$

where

- $T_{ln}$: simple average tariff applied by $n$ on goods from $l$ (WTO tariffs)
  - Estimate of $\beta = -\theta / \rho$
- $\delta_j$: indicator variables for a given distance between $n$ and $l$ (CEPIII)
- $Z_{ln}$: standard gravity controls such as language (also dummy for “self”)
Gravity Equations: Data

For restricted and unrestricted sample, we estimate the following equation:

$$\log X_{iln} = \alpha_l + \eta_n + \beta \log(1 + T_{ln}) + \sum_j \delta_j [1|d_{ln} \in d_j] + \Theta Z_{ln},$$

- **Data sources** $X_{iln}$: BEA. $X_{ln}$: Feenstra et al, UNIDO, and STAN, '99
  - BMP data for Canada, EU (minus UK), Japan, UK, and US as destinations for everywhere
  - 55 countries local sales versus imports from the United States
Gravity Regression Results

<table>
<thead>
<tr>
<th></th>
<th>Restricted</th>
<th>Unrestricted</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{ln}$</td>
<td>-7.0</td>
<td>-4.8</td>
</tr>
<tr>
<td>$\delta_1$</td>
<td>-0.9</td>
<td>-0.4</td>
</tr>
<tr>
<td>$\delta_2$</td>
<td>-2.3</td>
<td>-1.6</td>
</tr>
<tr>
<td>$\delta_3$</td>
<td>-2.7</td>
<td>-2.4</td>
</tr>
<tr>
<td>$\delta_4$</td>
<td>-1.9</td>
<td>-1.5</td>
</tr>
<tr>
<td>$\delta_5$</td>
<td>-2.0</td>
<td>-1.6</td>
</tr>
<tr>
<td>Self</td>
<td>1.0</td>
<td>2.4</td>
</tr>
</tbody>
</table>

n=255

Bold indicates standard statistical significance.

Other controls: Language, Shared Colonial History, Border
Benchmark Calibration

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Target</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_i$</td>
<td>Equipped labor</td>
<td>Klenow &amp; Rodríguez-Clare</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>6</td>
<td>20% markup</td>
</tr>
<tr>
<td>$\theta / \rho$</td>
<td>7</td>
<td>Restricted Trade Elast.</td>
</tr>
<tr>
<td>$\rho$</td>
<td>.6</td>
<td>Unrestricted Trade Elast.</td>
</tr>
<tr>
<td>$\gamma_{il}$</td>
<td>Fit bilateral trade ...</td>
<td>Feenstra et. al., and ...</td>
</tr>
<tr>
<td>$\tau_{ln}$</td>
<td>... and MP data</td>
<td>... STAN, UNCTAD</td>
</tr>
</tbody>
</table>
Fit Inside the Cube: U.S. BMP

The unrestricted gravity elasticity is reproduced for $\rho = 0.6$. For BMP data for $i = \text{U.S.}$, we obtain

$$
\begin{array}{|c|c|c|}
\hline
\text{Average} & \text{Correlation} \\
\text{Data} & \text{Model} & \text{Data & Model} \\
\hline
\bar{X}_{iln} & 0.91 & 0.76 & 0.63 \\
\bar{X}_{inn} & 0.14 & 0.02 & 0.76 \\
\bar{X}_{ili} & 0.38 & 0.16 & \\
\bar{X}_{ill} &  &  & \\
\text{BMP share} &  &  & \\
\hline
\end{array}
$$

Model does generate BMP of the right order of magnitude, except for United States as a destination.
BMP Fit: All Countries

Just to US
Implied Taus and Gammas
Fact from Inside the Box

For $i = \text{US}$, high Correlation between actual $X_{iin}$ and $X_{inn}$

Consistent with high correlation between $\gamma_{in}$ and $\tau_{in}$. 
A Counterfactual Experiment
Counterfactual Experiment

- We use the model as a device to evaluate the gains from a reform

- Irish episode in the 90s: dramatically decreased the barriers to US MP
  - Result: an unprecedented increase in investment of US firms
  - Can the same experiment work for other countries?

- Simulate a decrease in the Greek $\gamma$’s that simulates the Irish experience
  - Can Greece become Ireland (rather than the other way!)?
Benefits of Openess for a Small Country

- According to some estimates $\mu_{I,I} = .25$ (cite: Taylor)

- Counterfactual: Greece opens to US Multinationals
  - $\mu_{G,G} = .575 \rightarrow \mu_{G,G} = .242$
  - Requires an across the board reduction of Greek (inward) $\gamma$’s by 30%

- Policies reducing MP costs (e.g. Irish Industrial Development Agency)
  - New “Fast-Track” Greek law for FDI (lets not be so optimistic!)
Counterfactual Results

- Gains from openness can be decomposed

\[ GO_n = \lambda_{nn}^{-\rho/\theta} \times \pi_{nn}^{-\rho/(1-\rho)/\theta} \epsilon_{nnn}^{\rho/\theta} \times \left( \frac{X_n}{Y_n} \right)^{1+\frac{\theta-(\sigma-1)}{\theta(\sigma-1)}} \]

- Greece a small-low tech country
Counterfactual Results

- Gains from openness can be decomposed

\[ 17.8\% \approx (-1.4\%) + 28.3\% + (-6.9\%) \]

- Greece a small-low tech country
  - Large drop in imports (Greek demand served by foreign firms)
  - Foreign firms take over, crowd out inefficient Greek firms
  - Large decrease in Greek firm’s profits
Extensions/Future Work

- (Very Soon) Allow for free entry in calibration/counterfactual exercises

- (Soon-ish) Model multi-product firms in order to make direct contact with firm-level data

- (A different paper, but we know how) Fixed Production costs