The Gains from Openness:
Trade, Multinational Production, and Diffusion

Natalia Ramondo  
UT-Austin

Andrés Rodríguez-Clare  
PSU and NBER

June 2008
Motivation

How big are the Gains from Openness (GO)?

- Trade, Multinational Production (MP), and Diffusion of ideas
  - Interaction among them determines their contribution to GO
    - Substitutes? Complements?
This Paper

- Unified framework for Trade, MP and Diffusion: Ricardian, multi-country, GE model (EK, 02)
This Paper

- Unified framework for Trade, MP and Diffusion: Ricardian, multi-country, GE model (EK, 02)
  - Trade and MP are alternative ways to serve a market (substitution)
This Paper

- Unified framework for Trade, MP and Diffusion: Ricardian, multi-country, GE model (EK, 02)
  - Trade and MP are alternative ways to serve a market (substitution)
  - Affiliates can import intermediates from Home - “intra-firm” trade (complementarity)
This Paper

- Unified framework for Trade, MP and Diffusion: Ricardian, multi-country, GE model (EK, 02)
  - Trade and MP are alternative ways to serve a market (substitution)
  - Affiliates can import intermediates from Home - “intra-firm” trade (complementarity)
  - “Bridge” MP (complementarity)

- Trade/MP are substitutes for diffusion

- The model is calibrated using trade and MP data for OECD (19)

- Evaluate Gains: GO, GT, GMP, and GD
This Paper

- Unified framework for Trade, MP and Diffusion: Ricardian, multi-country, GE model (EK, 02)
  - Trade and MP are alternative ways to serve a market (substitution)
  - Affiliates can import intermediates from Home - “intra-firm” trade (complementarity)
  - “Bridge” MP (complementarity)
    - A does MP in B and exports to C

- Trade/MP are substitutes for diffusion

- The model is calibrated using trade and MP data for OECD (19)

- Evaluate Gains: GO, GT, GMP, and GD
This Paper

- Unified framework for Trade, MP and Diffusion: Ricardian, multi-country, GE model (EK, 02)
  - Trade and MP are alternative ways to serve a market (substitution)
  - Affiliates can import intermediates from Home - “intra-firm” trade (complementarity)
  - “Bridge” MP (complementarity)
    - A does MP in B and exports to C
  - Trade/MP are substitutes for diffusion

- Evaluate Gains: GO, GT, GMP, and GD
This Paper

- Unified framework for Trade, MP and Diffusion: Ricardian, multi-country, GE model (EK, 02)
  - Trade and MP are alternative ways to serve a market (substitution)
  - Affiliates can import intermediates from Home - “intra-firm” trade (complementarity)
  - “Bridge” MP (complementarity)
    - A does MP in B and exports to C
  - Trade/MP are substitutes for diffusion

- The model is calibrated using trade and MP data for OECD (19)
This Paper

- Unified framework for Trade, MP and Diffusion: Ricardian, multi-country, GE model (EK, 02)
  - Trade and MP are alternative ways to serve a market (substitution)
  - Affiliates can import intermediates from Home - “intra-firm” trade (complementarity)
  - “Bridge” MP (complementarity)
    - A does MP in B and exports to C
  - Trade/MP are substitutes for diffusion

- The model is calibrated using trade and MP data for OECD (19)

- Evaluate Gains: \( GO, \ GT, \ GMP, \) and \( GD \)
Simple(r) Model

- $I$ countries: $i = 1, \ldots, I$
- Labor is the only factor of production: $L_i$
- Tradable intermediate goods $u \in [0, 1]$

$$Q = \left[ \int_0^1 q(u) \frac{\sigma-1}{\sigma} du \right]^{\frac{\sigma}{\sigma-1}}$$
Technologies

- Random CRS technologies (EK 02, AL 07): $x(u)$
Technologies

- Random CRS technologies (EK 02, AL 07): $x(u)$
- Unit input cost: $c = w$
Technologies

- Random CRS technologies (EK 02, AL 07): $x(u)$
- Unit input cost: $c = w$
- Unit cost of good $u$: $x(u)^\theta c$
Technologies

- Random CRS technologies (EK 02, AL 07): $x(u)$
- Unit input cost: $c = w$
- Unit cost of good $u$: $x(u)^\theta c$

- National and Multinational technologies
Technologies

- Random CRS technologies (EK 02, AL 07): $x(u)$
- Unit input cost: $c = w$
- Unit cost of good $u$: $x(u)^\theta c$

- **National and Multinational technologies**
  - Independently drawn from exponentials
    - $x_i^N \sim \exp(\lambda_i^N)$
    - $x_i^M \sim \exp(\lambda_i^M)$
Technologies

- Random CRS technologies (EK 02, AL 07): $x(u)$
- Unit input cost: $c = w$
- Unit cost of good $u$: $x(u)^\theta c$

- National and Multinational technologies
  - Independently drawn from exponentials
    
    $x_i^N \sim \exp(\lambda_i^N)$
    $x_i^M \sim \exp(\lambda_i^M)$

- Label goods by $x = (x_1^N, x_1^M, \ldots, x_I^N, x_I^M)$
Technologies

- Indexes:

National technologies (N):
- Production with a national technology from \( i \) entails \( c_i \)

Multinational technologies (M):
- Production with a multinational technology from \( i \) in \( l \) entails a unit cost \( c_i l \)
Technologies

- Indexes:
  - $i =$ country of origin
Technologies

- Indexes:
  - $i =$ country of origin
  - $l =$ country of production

- National technologies (N):
  - Production with a national technology from $i$ entails $c_i$

- Multinational technologies (M):
  - Production with a multinational technology from $i$ in $l$ entails a unit cost $c_{li}$
Technologies

- Indexes:
  - $i =$ country of origin
  - $l =$ country of production
  - $n =$ country of destination
Technologies

- Indexes:
  - $i =$ country of origin
  - $l =$ country of production
  - $n =$ country of destination

- National technologies (N):

- Multinational technologies (M):
Technologies

▶ Indexes:
  ▶ $i =$ country of origin
  ▶ $l =$ country of production
  ▶ $n =$ country of destination

▶ National technologies (N):
  ▶ $i = l$
Technologies

- **Indexes:**
  - $i =$ country of origin
  - $l =$ country of production
  - $n =$ country of destination

- **National technologies (N):**
  - $i = l$
  - Production with a national technology from $i$ entails $c_i$
Technologies

- Indexes:
  - $i =$ country of origin
  - $l =$ country of production
  - $n =$ country of destination

- National technologies (N):
  - $i = l$
  - Production with a national technology from $i$ entails $c_i$

- Multinational technologies (M):
Technologies

▶ Indexes:
  ▶ \( i \) = country of origin
  ▶ \( l \) = country of production
  ▶ \( n \) = country of destination

▶ National technologies (N):
  ▶ \( i = l \)
    ▶ Production with a national technology from \( i \) entails \( c_i \)

▶ Multinational technologies (M):
  ▶ \( i = l \neq n \) (exports) or \( i \neq l = n \) (MP) or \( i \neq l \neq n \) (BMP)
Technologies

- Indexes:
  - $i =$ country of origin
  - $l =$ country of production
  - $n =$ country of destination

- National technologies (N):
  - $i = l$
  - Production with a national technology from $i$ entails $c_i$

- Multinational technologies (M):
  - $i = l \neq n$ (exports) or $i \neq l = n$ (MP) or $i \neq l \neq n$ (BMP)
  - Production with a multinational technology from $i$ in $l$ entails a unit cost $c_{li}$
Trade and MP Costs

- “Iceberg” trade costs from $l$ to $n$ is $k_{nl} \leq 1$, $k_{nn} = 1$
Trade and MP Costs

- “Iceberg” trade costs from \( l \) to \( n \) is \( k_{nl} \leq 1, \ k_{nn} = 1 \)
- MP by \( i \) in \( l \) entails efficiency losses of \( h_{li} \leq 1, \ h_{ll} = 1 \).
Trade and MP Costs

- “Iceberg” trade costs from $l$ to $n$ is $k_{nl} \leq 1$, $k_{nn} = 1$
- MP by $i$ in $l$ entails efficiency losses of $h_{li} \leq 1$, $h_{ll} = 1$.
- Unit input cost of MP by $i$ in $l$

\[
c_{li} = \left[ (1 - a) \left( \frac{c_i}{h_{li}} \right)^{1-\rho} + a \left( \frac{c_i}{k_{li}} \right)^{1-\rho} \right]^\frac{1}{1-\rho},
\]

(with $c_{ll} = c_l$)
Trade and MP Costs

- “Iceberg” trade costs from $l$ to $n$ is $k_{nl} \leq 1$, $k_{nn} = 1$
- MP by $i$ in $l$ entails efficiency losses of $h_{li} \leq 1$, $h_{ll} = 1$.
- Unit input cost of MP by $i$ in $l$

\[ c_{li} = \left(\left[(1-a) \left(\frac{c_l}{h_{li}}\right)^{1-\rho} + a \left(\frac{c_i}{k_{li}}\right)^{1-\rho}\right]\right)^{\frac{1}{1-\rho}}, \]

(with $c_{ll} = c_l$)
- MP by $i$ in $l$ entails an “intra-firm” trade flow from $i$ to $l$
Trade vs MP

- With technology $x_i^M$, market $n$ can be served by
Trade vs MP

- With technology $x_i^M$, market $n$ can be served by
  - exporting at cost $(x_i^M)^\theta c_i/k_{ni}$
Trade vs MP

- With technology $x_i^M$, market $n$ can be served by
  - exporting at cost $\left(x_i^M\right)^{\theta} c_i / k_{ni}$
  - doing MP at cost $\left(x_i^M\right)^{\theta} c_{ni}$
Trade vs MP

- With technology $x_i^M$, market $n$ can be served by
  - exporting at cost $\left(x_i^M\right)^\theta c_i / k_{ni}$
  - doing MP at cost $\left(x_i^M\right)^\theta c_{ni}$
  - doing BMP through bridge country $l$ at cost $\left(x_i^M\right)^\theta c_{li} / k_{nl}$
Trade vs MP

- With technology $x_i^M$, market $n$ can be served by
  - exporting at cost $\left( x_i^M \right)^\theta c_i / k_{ni}$
  - doing MP at cost $\left( x_i^M \right)^\theta c_{ni}$
  - doing BMP through bridge country $l$ at cost $\left( x_i^M \right)^\theta c_{li} / k_{nl}$

- With technology $x_i^N$, market $n$ can be served only by
Trade vs MP

- With technology $x_i^M$, market $n$ can be served by
  - exporting at cost $\left(x_i^M\right)^\theta c_i / k_{ni}$
  - doing MP at cost $\left(x_i^M\right)^\theta c_{ni}$
  - doing BMP through bridge country $l$ at cost $\left(x_i^M\right)^\theta c_{li} / k_{nl}$

- With technology $x_i^N$, market $n$ can be served only by
  - exporting at cost $\left(x_i^N\right)^\theta c_i / k_{ni}$
Trade vs MP

- With technology $x_i^M$, market $n$ can be served by
  - exporting at cost $\left(x_i^M\right)^\theta c_i / k_{ni}$
  - doing MP at cost $\left(x_i^M\right)^\theta c_{ni}$
  - doing BMP through bridge country $l$ at cost $\left(x_i^M\right)^\theta c_{li} / k_{nl}$

- With technology $x_i^N$, market $n$ can be served only by
  - exporting at cost $\left(x_i^N\right)^\theta c_i / k_{ni}$

- Price of good $x$ in country $n$:

$$p_n(x) = \min_i \left[ \left(x_i^N\right)^\theta \frac{c_i}{k_{ni}}, \left(x_i^M\right)^\theta \min_l \frac{c_{li}}{k_{nl}} \right]$$
Symmetry Example

- Countries are identical
  - \( c_n = w_n = 1, \ p_n = p \)
  - MP (inverse of) unit cost is
    \[
    m = \left[ (1 - a) h^{\rho - 1} + a k^{\rho - 1} \right]^{\frac{1}{\rho - 1}}
    \]
    \[
    \hat{m} \equiv m|_{k=0} = (1 - a)^{\frac{1}{\rho - 1}} h
    \]
  - \( \hat{m} \to 0 \) as \( \rho \to 1 \)

- Assume \( h > k \)
  - as \( \rho \to \infty, \hat{m} = m = h \)
Symmetry: Gains (from isolation)

\[
\tilde{GO} = \left(1 + (l - 1)k^{1/\theta}(1 - \delta_M) + (l - 1)m^{1/\theta}\delta_M\right)^\theta
\]

\[
\tilde{GMP} = \left(1 + (l - 1)\hat{m}^{1/\theta}\delta_M\right)^\theta
\]

\[
\tilde{GT} = \left(1 + (l - 1)k^{1/\theta}\right)^\theta
\]

\[
m = \left[(1 - a)h^{\rho - 1} + ak^{\rho - 1}\right]^{\frac{1}{\rho - 1}}
\]

\[
\hat{m} = (1 - a)^{\frac{1}{\rho - 1}} h
\]
Substitution vs. Complementarity: Gains

Role of $\rho$

- If $\rho \to 1$

- If $\rho \to \infty$

More generally: if $\rho > 1 + \frac{1}{\theta}$,
Substitution vs. Complementarity: Gains

Role of $\rho$

- If $\rho \rightarrow 1$
  - $\hat{m} = 0 \rightarrow \text{GMP} = 0$

- If $\rho \rightarrow \infty$
  - $\text{GO} < \text{GMP} + \text{GT}$ - trade and MP are substitutes

More generally: if $\rho > 1 + 1/\theta$,
- $\text{GO} < \text{GMP} + \text{GT}$ - trade and MP are substitutes
Role of $\rho$

- If $\rho \to 1$
  - $\hat{m} = 0 \to \text{GMP} = 0$
  - $GO > GMP + GT$ - trade and MP are complements
Substitution vs. Complementarity: Gains

Role of $\rho$

- If $\rho \to 1$
  - $\hat{m} = 0 \to \text{GMP} = 0$
  - $GO > \text{GMP} + GT$ - trade and MP are complements

- If $\rho \to \infty$

---

$$\hat{m} = 0 \to \text{GMP} = 0$$

$$GO > \text{GMP} + GT$$ - trade and MP are complements
Role of $\rho$

- If $\rho \to 1$
  - $\hat{m} = 0 \to GMP = 0$
  - $GO > GMP + GT$ - trade and MP are complements

- If $\rho \to \infty$
  - $GO < GMP + GT$ - trade and MP are substitutes
Role of $\rho$

- If $\rho \to 1$
  - $\hat{m} = 0 \to \text{GMP} = 0$
  - $GO > GMP + GT$ - trade and MP are complements

- If $\rho \to \infty$
  - $GO < GMP + GT$ - trade and MP are substitutes

- More generally: if $\rho > 1 + 1/\theta$, 
Substitution vs. Complementarity: Gains

Role of $\rho$

- **If $\rho \to 1$**
  - $\hat{m} = 0 \to \text{GMP} = 0$
  - $GO > GMP + GT$ - trade and MP are complements

- **If $\rho \to \infty$**
  - $GO < GMP + GT$ - trade and MP are substitutes

- **More generally: if $\rho > 1 + 1/\theta$,**
  - $GO < GMP + GT$ - trade and MP are substitutes
Substitution vs. Complementarity: Flows

How trade shares change with $h$?

- Three effects of $\uparrow h$:
  - Less “arms-length” trade
  - More MP → More “intra-firm” trade
    (use more of all inputs)
  - Lower “intra-firm” trade share
    (use proportionally less home inputs)
    - higher $\rho$ implies stronger shifts toward host country inputs

- For $\rho > 1 + 1/\theta$: $\uparrow h$, $\downarrow$ trade shares
  - Trade and MP are substitutes
The Full Model

- Simple model plus the following features
  - Diffusion: each good can be also produced with a global technology $x^G_i \sim \exp(\lambda^G_i)$
    - available for production everywhere: $x^G = \max_i x^G_i$
  - (Continuum of) Non-tradable final goods
    - MP is feasible (at a cost $h_{ni}$, but not Home inputs used)
  - Input-output loop: intermediate CES aggregate good used in production of each intermediate and final goods
    (EK ’02, AL ’07)
Quantitative Analysis: Parameters to Estimate

- We estimate $h_{ni}$ assuming

$$h_{ni} = k_{ni} + \gamma \varepsilon_{ni}(1 - k_{ni}) \text{ where } \varepsilon_{ni} \sim U[0, 1]$$
Quantitative Analysis: Parameters to Estimate

We estimate $h_{ni}$ assuming

$$h_{ni} = k_{ni} + \gamma \varepsilon_{ni} (1 - k_{ni}) \text{ where } \varepsilon_{ni} \sim U[0, 1]$$

- lower $\gamma$, stronger correlation between $h_{ni}$ and $k_{ni}$
Quantitative Analysis: Parameters to Estimate

- We estimate $h_{ni}$ assuming

$$h_{ni} = k_{ni} + \gamma \epsilon_{ni}(1 - k_{ni}) \text{ where } \epsilon_{ni} \sim U[0, 1]$$

- lower $\gamma$, stronger correlation between $h_{ni}$ and $k_{ni}$

- Technologies: $\lambda_i^M = \delta_M \bar{\lambda}_i$, $\lambda_i^G = \delta_G \bar{\lambda}_i$, $\bar{\lambda}_i \sim L_i$
Quantitative Analysis: Parameters to Estimate

- We estimate $h_{ni}$ assuming

  \[ h_{ni} = k_{ni} + \gamma \varepsilon_{ni}(1 - k_{ni}) \text{ where } \varepsilon_{ni} \sim U[0, 1] \]

  - lower $\gamma$, stronger correlation between $h_{ni}$ and $k_{ni}$

- Technologies:
  \[ \lambda^M_i = \delta_M \tilde{\lambda}_i, \quad \lambda^G_i = \delta_G \tilde{\lambda}_i, \quad \tilde{\lambda}_i \sim L_i \]

- Labor shares:
  \[ \alpha = 0.75 \text{ (NT)} \] and \[ \beta = 0.5 \text{ (T)} \] - from AL (07)
We estimate $h_{ni}$ assuming

$$h_{ni} = k_{ni} + \gamma \epsilon_{ni} (1 - k_{ni}) \text{ where } \epsilon_{ni} \sim U[0, 1]$$

- lower $\gamma$, stronger correlation between $h_{ni}$ and $k_{ni}$
- Technologies: $\lambda_i^M = \delta_M \tilde{\lambda}_i$, $\lambda_i^G = \delta_G \tilde{\lambda}_i$, $\tilde{\lambda}_i \sim L_i$
- Labor shares: $\alpha = 0.75$ (NT) and $\beta = 0.5$ (T) -from AL (07)
- For $\rho = 2, 5, 8$, **FIVE** model’s parameters to estimate

$$\Delta \equiv [\delta_M, \delta_G, \theta, \gamma, a]$$
# Quantitative Analysis: Moments to Match

<table>
<thead>
<tr>
<th>Moments</th>
<th>Data</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. normalized bilateral trade share</td>
<td>0.033</td>
<td>$\delta_G$</td>
</tr>
<tr>
<td>Avg. normalized bilateral MP share</td>
<td>0.025</td>
<td>$\delta_M$</td>
</tr>
<tr>
<td>Correlation trade and MP shares</td>
<td>0.7</td>
<td>$\gamma$</td>
</tr>
<tr>
<td>OLS trade “gravity” coefficient</td>
<td>4.69</td>
<td>$\theta$</td>
</tr>
<tr>
<td>$\log \tau_{ni} = b_g \log k_{ni} + S_i + H_n + \nu_{ni}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. bilateral intra-firm trade as share of MP sales (US)</td>
<td>0.074</td>
<td>$a$</td>
</tr>
</tbody>
</table>
Results: Parameters’ Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\rho = 2$</th>
<th>$\rho = 5$</th>
<th>$\rho = 8$</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta_G$</td>
<td>0.031</td>
<td>0.025</td>
<td>0.033</td>
<td>share of G-technologies</td>
</tr>
<tr>
<td>$\delta_M$</td>
<td>0.11</td>
<td>0.12</td>
<td>0.15</td>
<td>share of M-technologies</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.21</td>
<td>0.21</td>
<td>0.216</td>
<td>variability of cost draws $x(u)$</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.79</td>
<td>0.66</td>
<td>0.65</td>
<td>$h_{ni} = k_{ni} + \gamma \varepsilon_{ni}(1 - k_{ni})$</td>
</tr>
<tr>
<td>$a$</td>
<td>0.55</td>
<td>0.76</td>
<td>0.84</td>
<td>$c_{li}^{1-\rho} = (1 - a) \left( \frac{c_l}{h_{li}} \right)^{1-\rho} + a \left( \frac{c_i}{k_{li}} \right)^{1-\rho}$</td>
</tr>
<tr>
<td>$COR_{kh}$</td>
<td>0.70</td>
<td>0.79</td>
<td>0.80</td>
<td>correlation trade and MP costs</td>
</tr>
</tbody>
</table>
### Goodness of Fit: Model and Data

<table>
<thead>
<tr>
<th></th>
<th>Levels</th>
<th>GDP shares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exports</td>
<td>0.92</td>
<td>0.62</td>
</tr>
<tr>
<td>Imports</td>
<td>0.92</td>
<td>0.64</td>
</tr>
<tr>
<td>Outward MP</td>
<td>0.81</td>
<td>0.27</td>
</tr>
<tr>
<td>Inward MP</td>
<td>0.96</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Estimates with $\rho = 8$. 
## Results: Gains \( \log \frac{w}{p} - \log \frac{w^{iso}}{p^{iso}} \)

<table>
<thead>
<tr>
<th></th>
<th>( \rho = 2 )</th>
<th>( \rho = 5 )</th>
<th>( \rho = 8 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>trade, MP, and diffusion (GO)</td>
<td>0.52</td>
<td>0.49</td>
<td>0.55</td>
</tr>
<tr>
<td>only trade (GT)</td>
<td>0.14</td>
<td>0.14</td>
<td>0.15</td>
</tr>
<tr>
<td>only MP (GMP)</td>
<td>0.27</td>
<td>0.28</td>
<td>0.33</td>
</tr>
<tr>
<td>only diffusion (GD)</td>
<td>0.36</td>
<td>0.32</td>
<td>0.38</td>
</tr>
<tr>
<td>only trade and MP (GTMP)</td>
<td>0.42</td>
<td>0.38</td>
<td>0.43</td>
</tr>
<tr>
<td>only trade with ( \theta = 0.12 ) (( GT_{EK} ))</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>trade given MP and diffusion (GT')</td>
<td>0.07</td>
<td>0.06</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Conclusion

▶ Unified and flexible model to evaluate Gains from Trade, MP and Diffusion and their interactions
Conclusion

- Unified and flexible model to evaluate Gains from Trade, MP and Diffusion and their interactions
  - Diffusion and Trade/MP are substitutes
Conclusion

- Unified and flexible model to evaluate Gains from Trade, MP and Diffusion and their interactions
  - Diffusion and Trade/MP are substitutes
  - At most, there is a weak complementarity between Trade and MP