Firm-to-Firm Trade

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NYU Atlanta Fed Conference

December 13, 2014
• The Ultimate Goal: Understanding the impact of interfirm trade, particularly outsourcing, on labor market outcomes

• Achieving it requires coming to grips with enormous heterogeneity in how firms produce and who they sell to
• Previous work this decade: accommodating producer heterogeneity into general equilibrium analysis
• But producers’ demand and their technologies continue to be treated as monolithic
Observation 1

- Huge heterogeneity in firm input and purchasing decisions

- Example: French manufacturing firms’ labor shares and unskilled labor shares in gross production
• But standard models have a common production function with common shares across firms, at least within a sector
Observation 2

- Huge heterogeneity in the number of buyers a firm has and in their sales to a given buyer

- But as with exporters, there are clear patterns

- Some EU evidence
French Exporters and Market Size

- Number of French exporters vs. market size ($ billions)

Countries: BE, DE, ES, GT, NL, LU, PT, DK, GR, AU, PL, SE, CY, CZ, FI, HU, MT, LV, EE, SI, SK.
French exporters, adjusted for market share

French Exporters and Market Size

French exporters, adjusted for market share

French Exporters and Market Size

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Buyers per French Exporter, by Destination

- Y-axis: Buyers per exporter
- X-axis: Market size ($ billions)

Countries represented include:
- AT (Austria)
- BE (Belgium)
- CY (Cyprus)
- CZ (Czechia)
- DE (Germany)
- DK (Denmark)
- EE (Estonia)
- ES (Spain)
- FI (Finland)
- GB (United Kingdom)
- GR (Greece)
- HU (Hungary)
- IE (Ireland)
- IT (Italy)
- LT (Lithuania)
- LU (Luxembourg)
- LV (Latvia)
- MT (Malta)
- NL (Netherlands)
- PL (Poland)
- PT (Portugal)
- SE (Sweden)
- SI (Slovenia)
- SK (Slovakia)
- FI (Finland)
## Customers per French Exporter

<table>
<thead>
<tr>
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<th>Lithuania</th>
<th>Denmark</th>
<th>UK</th>
<th>Germany</th>
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<td>Market Size ($billions)</td>
<td>18</td>
<td>94</td>
<td>882</td>
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<td>Customers per Exporter:</td>
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<tr>
<td>Mean</td>
<td>4.2</td>
<td>7.1</td>
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<tr>
<td>Percentiles:</td>
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<td>25th</td>
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<td>50th</td>
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<td>75th</td>
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<td>90th</td>
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<td>99th</td>
<td>40</td>
<td>77</td>
<td>224</td>
<td>329</td>
</tr>
</tbody>
</table>

Data are for 2005.
But standard models have a representative buyer
Can we also incorporate the heterogeneity and granularity we observe in the customs and firm-level production data into a GE framework?
Progress so Far

- Continuum at the aggregate. Otherwise general equilibrium analysis is problematic

- But outcomes for individual firms and households are granular
Related Literature

- Much

- But particularly Oberfield (2013) on upstream and downstream linkages

- Garetto (2013) with head-to-head competition between workers and intermediates

- Relates to buyer-seller networks as in Chaney (2013) and in Eaton, Eslava, Krizan, Jinkins, and Tybout (2014) but we are static and GE
Model Basics

Standard Ricardian Assumptions

• $N$ countries which we index by $i$ (when selling) or $n$ (when buying)

• Country $i$ has an endowment of $L_{i}^{l}$ workers of type $l$

• Workers are the final buyers
Buyers (Households or Firms)

- $k = 1, \ldots, K$ purposes (a household’s needs or a firm’s tasks)

- Cobb-Douglas share $\alpha_k$ for households or $\beta_k$ for firms

- Purpose $k$ can be fulfilled with a good from a particular firm or with a type of labor
Production Function

Output of firm $j$ in country $i$:

$$Q_i(j) = z_i(j) \prod_{k=1}^{K} b_k^{-1} \left( \frac{m_{k,i}(j)}{\beta_k} \right)^{\beta_k}$$

$z_i(j)$ efficiency, $k = 1, 2, \ldots, K$, tasks, $b_k$ a constant (to go away later), $\beta_k$ share
- Type of labor appropriate for task $k$, $l(k)$

- Wage for task $k$, $w_{k,i} = w_{l(k),i}$

- Firm labor productivity at task $k$, $q_{i,k}(j)$

- Nash bargaining with an all-powerful buyer → unit cost pricing

- Hence no profits or fixed costs
• Unit cost to perform task $k$:

$$c_{k,i}(j) = \min \left\{ \frac{w_{k,i}}{q_{k,i}(j)}, c_{k,i}^{\text{min}}(j) \right\}$$

• Firm $j$’s cost to deliver in $n$:

$$c_{ni}(j) = \frac{d_{ni}}{z_i(j)} \prod_{k=1}^{K} \left( \frac{c_{k,i}(j)^{\beta_k}}{b_k} \right)$$
Distributional Assumptions

1. Measure of potential producers in country $i$ with efficiency $Z \geq z$:
   \[
   \mu_i^Z(z) = T_iz^{-\theta}
   \]

2. Worker productivity performing a task for a given producer $Q$ distributed:
   \[
   F(q) = \Pr[Q \leq q] = e^{-q^{-\phi}}
   \]

3. Measure of producers who can supply country $i$ at a unit cost below $c$ is:
   \[
   \mu_i(c) = \gamma_i c^\theta
   \]
   where $\theta > 0$ and $\gamma_i \geq 0$.

1,2 are exogenous. We will derive 3
Matching Buyers and Sellers

- Match intensity between a seller with cost $c$ and a buyer for task $k$ in $n$ is:

$$e_{k,i}(c) = \lambda_{k,i} c^{-\varphi}$$

- $\lambda_{k,i}$ is a parameter governing how easy it is for sellers and buyers to find each other for task $k$ in market $i$

- $0 \leq \varphi < \theta$ gives an advantage to low cost sellers
A buyer in $i$ for task $k$ encounters a number of suppliers with unit cost below $c$ that is distributed Poisson with parameter

$$\rho_{k,i}(c) = \int_0^c e_{k,i}(x)d\mu_i(x)$$

$$= \int_0^c \lambda_{k,i} x^{-\varphi} \theta \Gamma_i x^{\theta-1} dx$$

$$= \frac{\theta}{\theta - \varphi} \lambda_{k,i} \Gamma_i c^{\theta-\varphi}$$
Distribution of Lowest Cost

- From Poisson, probability of no input with unit cost $C \leq c_k$:
  \[ \exp \left[ -\rho_{k,i}(c_k) \right] \]

- Probability no worker can perform the task at cost $C \leq c_k$ is $F(w_{k,i}/c_k)$.

- Distribution of the lowest cost to fulfill task $k$:
  \[ G_{k,i}(c_k) = 1 - F(w_{k,i}/c_k)e^{-\rho_{k,i}(c_k)} \]
• Assume:

\[ \theta - \varphi = \phi \]

to give us:

\[ G_{k,i}(c_k) = 1 - e^{-\Xi_{k,i}c_k^\phi} \]

where

\[ \Xi_{k,i} = \nu_{k,i} + w_{k,i} \]

\[ \nu_{k,i} = \frac{\theta}{\phi} \lambda_{k,i} \tau_i \]
• Hire workers with probability \( v_{k,i} = w_{k,i}^{-\phi} / \Xi_{k,i} \)

• Purchase intermediate with probability \( 1 - v_{k,i} = \nu_{k,i} / \Xi_{k,i} \)
Labor Shares

- With a continuum of producers $v_{k,i}$ is the aggregate share of labor in performing task $k$ in country $i$.

- Aggregate share of labor of type $l$ in total production costs:
  \[ \beta_i^l = \sum_{k \in \Omega_l} \beta_k v_{k,i} \]

- Overall labor share in production costs:
  \[ \beta_i^L = \sum_l \beta_i^l. \]

- Labor share depends on wages and other factors through $v_{k,i}$. 

The Aggregate Cost Distribution

- Measure of suppliers from $n$ who can deliver to $i$ at a unit cost below $c$:

$$\mu_{ni}(c) = T_i d_{ni}^{-\theta} c^\theta \prod_k \int_0^\infty b_k^{\theta \phi} c_k^{-\theta \beta_k} dG_{k,i}(c_k)$$

$$= T_i d_{ni}^{-\theta} c^\theta \prod_k \int_0^\infty b_k^{\theta \phi} c_k^{-\theta \beta_k} \phi \Xi_{k,i} c_k^{\phi-1} \exp \left(-\Xi_{k,i} c_k^\phi\right) dc_k$$

$$= T_i d_{ni}^{-\theta} c^\theta \prod_k \Xi_{k,i}$$

$$= T_i \Xi_i d_{ni}^{-\theta} c^\theta$$
where:

\[ \tilde{\beta}_k = \frac{\theta}{\phi} \beta_k \]

\[ \Xi_i = \prod_{k=1}^{K} (\Xi_{k,i})^{\tilde{\beta}_k} \]

\[ b_k = \left[ \Gamma(1 - \tilde{\beta}_k) \right]^{-1/\theta} \]
• Summing across sources $i$:

$$\mu_n(c) = \sum_{i=1}^{N} \mu_{ni}(c) = \gamma_n c^\theta$$

the cost distribution of suppliers posited above, where we now have:

$$\gamma_n = \sum_{i} T_i \Xi_i d_{ni}^{-\theta},$$
• The \( \gamma_n \)'s solve the system of equations:

\[
\gamma_n = \sum_i T_i d_{ni}^{\theta} \prod_k \left( \frac{\theta}{\phi} \lambda_{k,i} \gamma_i + w_{k,i}^{-\phi} \right) \beta_k
\]

for \( n = 1, 2, ..., N \) (given wages)

• Blackwell’s sufficient conditions for solution

• Homogeneity of \( \gamma_n \)'s in all \( T_i \)'s and all \( 1/\lambda_{k,i} \)'s
• Trade shares:

\[ \pi_{ni} = \frac{T_i \Xi_i d_{ni}^{-\theta}}{\sum_{i'} T_{i'} \Xi_{i'} d_{ni'}^{-\theta}} \]
The Aggregate Production Function

\[ Q_i = \prod_{k=1}^{K} \left[ \tilde{\gamma} \left( L_{k,i} \right)^{\phi/(\phi+1)} + (1 - \tilde{\gamma}) \left( I_{k,i} \right)^{\phi/(\phi+1)} \right]^{\beta_k(\phi+1)/\phi} \]

\[ \tilde{\gamma} = \frac{1}{1 + \Gamma(1 + 1/\phi)^{\phi/(1+\phi)}} \]

where \( L_{k,i} \) is the labor used in task \( k \) in country \( i \) and \( I_{k,i} \) are intermediates used for task \( k \) in country \( i \).
Consumer side

- analogous to firms

- shares $\alpha_k$ instead of $\beta_k$.

- Expected expenditure function for utility $V$

\[ Y(V, P^C_n) = VP^C_n. \]

- Price index

\[ P^C_n = \prod_{k=1}^{K} (\Xi_{k,n})^{-\bar{\alpha}_k} \]
Aggregate Equilibrium I: Production

• With balanced trade final spending $X^C_n$ is labor income:

$$X^C_n = \sum_{l=1}^{L} w^n_l L^n_l = \sum_{k=1}^{K} w_{k,n} L_{k,n}.$$
• Total production:

\[ Y_i = \sum_{n=1}^{N} \pi_{ni} \left[ \Phi_n^C X_n^C + \Phi_n^I Y_n \right] \]

\[ \Phi_n^C = 1 - \alpha_n^L, \quad \Phi_n^I = 1 - \beta_n^L \]
Leontief Algebra

\[ \mathbf{Y} = \Pi \left( \Phi^C \mathbf{X}^C + \Phi^I \mathbf{Y} \right) \]
\[ Y = \begin{bmatrix}
  Y_1 \\
  Y_2 \\
  \vdots \\
  Y_N
\end{bmatrix}, \quad X^C = \begin{bmatrix}
  X_1^C \\
  X_2^C \\
  \vdots \\
  X_N^C
\end{bmatrix} \]
\[ \Phi^j = \begin{bmatrix}
\Phi_1^j & 0 & \ldots & 0 & 0 \\
0 & \Phi_2^j & \ldots & 0 & 0 \\
\vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & \ldots & \Phi_{N-1}^j & 0 \\
0 & 0 & \ldots & 0 & \Phi_N^j
\end{bmatrix} \quad j = C, I \]
\[ \Pi = \begin{bmatrix}
\pi_{11} & \pi_{21} & \ldots & \pi_{N-1,1} & \pi_{N1} \\
\pi_{12} & \pi_{22} & \ldots & \pi_{N-1,2} & \pi_{N2} \\
\vdots & \vdots & \ddots & \vdots & \vdots \\
\pi_{1,N-1} & \pi_{2,N-1} & \ldots & \pi_{N-1,N-1} & \pi_{NN} \\
\pi_{1N} & \pi_{2N} & \ldots & \pi_{N-1,N} & \pi_{NN}
\end{bmatrix} \]
Solving for $\mathbf{Y}$:

$$\mathbf{Y} = (\mathbf{I}_{\mathcal{N}} - \Pi \Phi^I)^{-1} \Pi \Phi^C \mathbf{X}^C$$

where $\mathbf{I}_{\mathcal{N}}$ is the $\mathcal{N} \times \mathcal{N}$ identity matrix.
Aggregate Outcomes II: The Labor Market

\[ w_i^l L_i^l = \alpha_i^l X_i^C + \beta_i^l Y_i. \]
Simulating Aggregate Outcomes
Table 1: Baseline Parameter Settings for Simulation

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<td>total share</td>
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## Table 2: Aggregate Results of Simulation

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<tr>
<td>Share of gross production</td>
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<td>0.27</td>
<td>0.26</td>
<td>0.24</td>
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<td>Fraction of production tasks outsourced:</td>
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<td>0.93</td>
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<td>0.91</td>
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<td>1.54</td>
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<td>1.67</td>
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<tr>
<td>production</td>
<td>1.42</td>
<td>1.42</td>
<td>1.41</td>
<td>1.39</td>
<td>1.37</td>
<td>1.36</td>
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<tr>
<td>Welfare (real per capita consumption)</td>
<td>1.40</td>
<td>1.41</td>
<td>1.44</td>
<td>1.48</td>
<td>1.51</td>
<td>1.54</td>
</tr>
</tbody>
</table>

1. Production value added does not include service tasks (i.e. purchased services)
2. Wage is normalized so that labor income of the World is 1
<table>
<thead>
<tr>
<th></th>
<th>Trade Cost (small country, L=0.009)</th>
<th>Trade Cost (large country, L=0.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.00</td>
<td>1.80</td>
</tr>
<tr>
<td><strong>Production value added:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share of GDP</td>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>Share of gross production</td>
<td>0.59</td>
<td>0.50</td>
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<tr>
<td>Fraction of prod. tasks outsourced</td>
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<td>Import share of production</td>
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<td>0.83</td>
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<td><strong>Wage:</strong></td>
<td></td>
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<tr>
<td>service</td>
<td>0.67</td>
<td>0.62</td>
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<td>production</td>
<td>1.48</td>
<td>1.17</td>
</tr>
<tr>
<td><strong>Skill premium (service/production):</strong></td>
<td>0.46</td>
<td>0.53</td>
</tr>
<tr>
<td><strong>Real wage:</strong></td>
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<tr>
<td>service</td>
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<td>0.85</td>
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<td>production</td>
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<td>1.61</td>
</tr>
<tr>
<td><strong>Welfare (real per capita cons.):</strong></td>
<td>1.12</td>
<td>1.16</td>
</tr>
</tbody>
</table>

1. Production value added does not include service tasks (i.e. purchased services)
2. Wage is normalized so that labor income of the World is 1
Implications for Individual Producers
I. The Distribution of Final Buyers

- Seller with cost $c$ in market $n$ encounters a number of final customers for need $k$ that is Poisson with parameter:

$$e_{k,n}(c)L_n = \lambda_{k,n} c^{-\varphi} L_n.$$ 

- Makes a sale with probability $e^{-\Xi_{k,n}c^{\phi}}$

- So the number of final sales for need $k$ is Poisson with parameter:

$$\eta^C_{k,n}(c) = \lambda_{k,n} L_n c^{-\varphi} e^{-\Xi_{k,n}c^{\phi}},$$
• Total final sales is Poisson with parameter:

$$\eta_n^C(c) = \sum_{k=1}^{K} \eta_{k,n}^C(c).$$
II. The Distribution of Intermediate Buyers

- $M_n$ denotes the measure of active producers in country $n$ (determined below)

- Seller with cost $c$ in market $n$ encounters a number of intermediate customers for task $k$ that is Poisson with parameter:
  
  $$e_{k,n}(c)M_n = \lambda_{k,n}c^{-\varphi}M_n.$$ 

- Makes a sale with probability $e^{-\Xi_{k,n}c^\phi}$

- So the number of intermediate sales for need $k$ is Poisson with parameter:
  
  $$\eta_{k,n}^I(c) = \lambda_{k,n}Mnc^{-\varphi}e^{-\Xi_{k,n}c^\phi},$$
• Total intermediate sales is Poisson with parameter:

\[ \eta^I_n(c) = \sum_{k=1}^{K} \eta^I_{k,n}(c). \]
III. The Distribution of Total Buyers

- Number of buyers for a firm selling in \( n \) at cost \( c \) is distributed Poisson with parameter:

\[
\eta_n(c) = \eta_n^C(c) + \eta_n^I(c) = (L_n + M_n) c^{-\varphi} \sum_{k=1}^{K} \lambda_{k,n} e^{-\Xi_{k,n,c^\varphi}}.
\]

- Worldwide number of buyers for a producer in \( i \) is distributed Poisson with parameter:

\[
\eta_i^W(c) = \sum_{n=1}^{N} \eta_n(cd_{ni}) = \sum_{n=1}^{N} (L_n + M_n)(d_{ni})^{-\varphi} c^{-\varphi} \sum_{k=1}^{K} \lambda_{k,n} e^{-\Xi_{k,n,d_{ni}}^{-\varphi}c^\varphi}.
\]
IV. The Measures of Producers and Sellers

- Measure of producers solves:

\[ M_i = \int_0^\infty (1 - e^{-\eta_i^W(c)})d\mu_{ii}(c) \]
\[ = T_i \Xi_i \int_0^\infty (1 - e^{-\eta_i^W(c)})\theta c^{\theta-1}dc. \]

- Requires solving for a fixed point since \( \eta_i^W(c) \) itself depends on the measure of customers for intermediates \( M_n \) in each market \( n \).
• Measure of firms selling in \( n \), \( N_n \)

\[
N_n = \int_0^\infty (1 - e^{-\eta_n(c)}) d\mu_n(c) \\
= \gamma_n \int_0^\infty (1 - e^{-\eta_n(c)}) \theta c^{\theta-1} dc.
\]

• Measure of exporters to \( i \) from \( n \)

\[
N_{ni} = \pi_{ni} N_n.
\]
Simulating Firm-Level Outcomes
### Table 4: Firm-Level Results of Simulation

<table>
<thead>
<tr>
<th></th>
<th>L=0.001</th>
<th>L=0.009</th>
<th>L=0.09</th>
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<th>L=0.3</th>
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<tbody>
<tr>
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<tr>
<td>producing</td>
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<td>8.2</td>
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<td>37.7</td>
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<td>18.6</td>
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<td>13.2</td>
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<tr>
<td>Fraction of firms:</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>exporting</td>
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<tr>
<td>selling domestically</td>
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<td>0.71</td>
<td>0.88</td>
<td>0.92</td>
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<td>Mean # customers per firm:</td>
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<td></td>
</tr>
<tr>
<td></td>
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<td>1.19</td>
<td>2.28</td>
<td>3.58</td>
<td>4.65</td>
<td>5.62</td>
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<tr>
<td>Size distribution (percentiles):</td>
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<tr>
<td>25th</td>
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<td>1</td>
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<td>75th</td>
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<td>3</td>
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<td>4</td>
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<td>2</td>
<td>6</td>
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<td>21</td>
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<tr>
<td>99th</td>
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<td>4</td>
<td>15</td>
<td>30</td>
<td>43</td>
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</table>
Table 5: Firm-Level Results with Different Trade Costs

<table>
<thead>
<tr>
<th></th>
<th>Trade Cost (small country, L=0.009)</th>
<th></th>
<th>Trade Cost (large country, L=0.3)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>10.00</td>
<td>1.80</td>
<td>1.20</td>
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<tr>
<td>Measures of firms:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>producing</td>
<td>0.00</td>
<td>0.03</td>
<td>0.05</td>
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<tr>
<td>selling</td>
<td>0.00</td>
<td>0.07</td>
<td>0.34</td>
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<tr>
<td>Measures normalized by Labor:</td>
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<tr>
<td>producing</td>
<td>0.4</td>
<td>3.4</td>
<td>5.8</td>
</tr>
<tr>
<td>selling</td>
<td>0.4</td>
<td>8.1</td>
<td>37.7</td>
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<tr>
<td>Fraction of firms:</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>exporting</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>selling domestically</td>
<td>1.00</td>
<td>0.41</td>
<td>0.15</td>
</tr>
<tr>
<td>Mean # customers per firm:</td>
<td>1.01</td>
<td>1.06</td>
<td>1.19</td>
</tr>
<tr>
<td>Size distribution (percentiles):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25th</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>50th</td>
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</tr>
<tr>
<td>75th</td>
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<td>90th</td>
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<tr>
<td>99th</td>
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<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
Implications

- A continuum of potential producers and workers

- Thus simple expressions for aggregate such as total consumption, production, and trade flows

- But individual producers buy from and sell to only a finite number of customers which can vary enormously from firm to firm (like Klette and Kortum, 2004).
• Individual firms are heterogeneous in size for four reasons:

1. As in Melitz, BEJK, or EKK I, in terms of underlying efficiency.

2. The efficiency of the input suppliers they hook up with.

3. How many buyers they hook up with.

4. How big those buyers are.
• Heterogeneity in unit cost, as in the Melitz, BEJK, or EKK can’t explain why an efficient producer would ever skip over a market that a less efficient producer from the same source would sell in.

• It also can’t explain why two producers from the same source don’t sell in the same proportion in the markets where both do sell.

• EKK I resorted to market-specific taste and entry cost shocks for an explanation.
- Larger markets attract more sellers, but not proportionately more, in line with evidence on entry.

- BEJK could not do this at all while Melitz requires entry costs that vary with market size with a particular elasticity (EKK).