Fixed costs seem better than Ricardian corner solutions for reconciling time series data on real exchange rate fluctuations with data on trade growth after liberalization experiences.

The “Armington” Elasticity

- Elasticity of substitution between domestic and foreign goods

- Crucial elasticity in international economic models

- International Real Business Cycle (IRBC) models:
  - Terms of trade volatility
  - Net exports and terms of trade co-movements

- Applied General Equilibrium (AGE) Trade models:
  - Trade response to tariff changes
The Elasticity Puzzle

- Time series (Business Cycles):
  - Estimates are low
  - Relative prices volatile
  - Quantities less volatile

- Panel studies (Trade agreement):
  - Estimates are high
  - Small change in tariffs (prices)
  - Large change in quantities
### Time Series Estimates: Low Elasticity (1.5)

<table>
<thead>
<tr>
<th>Study</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinert and Roland Holst (1992)</td>
<td>[0.1, 3.5]</td>
</tr>
<tr>
<td>Reinert and Shiells (1993)</td>
<td>[0.1, 1.5]</td>
</tr>
<tr>
<td>Gallaway et al. (2003)</td>
<td>[0.2, 4.9]</td>
</tr>
</tbody>
</table>

### Trade Liberalization Estimates: High Elasticity (9.0)

<table>
<thead>
<tr>
<th>Study</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clausing (2001)</td>
<td>[8.9, 11.0]</td>
</tr>
<tr>
<td>Head and Reis (2001)</td>
<td>[7.9, 11.4]</td>
</tr>
<tr>
<td>Romalis (2002)</td>
<td>[4.0, 13.0]</td>
</tr>
</tbody>
</table>

Why do the Estimates Differ?

• Time series – no liberalization:
  ○ Change in trade volume from goods already traded
  ○ Change mostly on the *intensive margin*

• Trade liberalization:
  ○ Change in intensive margin *plus*
  ○ New types of goods being traded
  ○ Change on the *extensive margin*
Modeling the Extensive Margin

• Model: extensive margin from export entry costs

• Empirical evidence of entry costs
  ○ Roberts and Tybout (1997)
  ○ Bernard and Wagner (2001)
  ○ Bernard and Jensen (2003)
The Effects of Entry Costs

• Business cycle shocks:
  ○ Small extensive margin effect

• Trade liberalization:
  ○ Big extensive margin effect

• Asymmetry creates different empirical elasticities
Model Overview

- Two countries: \( \{h, f\} \), with labor \( L \)
- Infinitely lived consumers
- No international borrowing/lending
- Continuum of traded goods plants in each country
  - Differentiated goods
  - Monopolistic competitors
  - Heterogeneous productivity
- Export entry costs
  - Differs across plants: second source of heterogeneity
- Non-traded good, competitive market: \( A \)
- Tariff on traded goods (iceberg): \( \tau \)
Uncertainty

- At date $t$, $H$ possible events, $\eta_t = 1, \ldots, H$
- Each event is associated with a vector of productivity shocks:

\[ z_t = \begin{bmatrix} z_h(\eta_t), z_f(\eta_t) \end{bmatrix} \]

- First-order Markov process with transition matrix $\Lambda$

\[ \lambda_{\eta\eta'} = \text{pr}(\eta_{t+1} = \eta' | \eta_t = \eta) \]
Traded Good Plants

- Traded good technology:
  \[ y(\phi, \kappa) = z\phi l \]

- Plant heterogeneity \((\phi, \kappa)\)
  - constant, idiosyncratic productivity: \(\phi\)
  - export entry cost: \(\kappa\)
  - plant of type \((\phi, \kappa)\)

- \(\nu\) plants born each period with distribution \(F(\phi, \kappa)\)

- Fraction \(\delta\) of plants exogenously die each period
Timing

\( \mu_{hx}(\phi, \kappa) \): plants of type \((\phi, \kappa)\) who paid entry cost

\( \mu_{hd}(\phi, \kappa) \): plants of type \((\phi, \kappa)\) who have not paid entry cost

\( \mu = (\mu_{hd}, \mu_{hx}, \mu_{fd}, \mu_{fx}) \)
Consumers

$$\max_{q,c^h(t),c^f(t)} \gamma \log(C) + (1 - \gamma) \log(A)$$

s.t.

$$C = \left[ \int_{t \in I_h^h(\mu)} c^h(t)^\rho dt + \int_{t \in I_f^h(\mu)} c^f(t)^\rho dt \right]^{1/\rho}$$

$$\int_{t \in I_h^h(\mu)} p^h(t)c^h(t) dt + \int_{t \in I_f^h(\mu)} (1 + \tau)p^f(t)c^f(t) dt + p_{hA}A = L + \Pi_h$$
Non-traded Good

$$\max \ p_{hA} (\eta, \mu) A - l$$

s.t.  \( A = z_h (\eta) l \)

Normalize \( w_h = 1 \), implying \( p_{hA} (\eta, \mu) = z_h (\eta) \)
Traded Goods: Static Profit Maximization

\[ \pi_d \left( p_h^l, l; \phi, \kappa, \eta, \mu \right) = \max_{p_h^l, l} p_h^l \ z(\eta) \phi l - l \]

s.t. \[ z(\eta) \phi l = \tilde{c}_h \left( p_h^l; \eta, \mu \right) \]

\[ \pi_x \left( p_f^l, l; \phi, \kappa, \eta, \mu \right) = \max_{p_f^l, l} p_f^l \ z(\eta) \phi l - l \]

s.t. \[ z(\eta) \phi l = \tilde{c}_h \left( p_f^l; \eta, \mu \right) \]

Pricing rules:

\[ p_h^l (\phi, \kappa, \eta, \mu) = p_f^l (\phi, \kappa, \eta, \mu) = \frac{1}{\rho \phi z(\eta)} \]
Dynamic Choice: Export or Sell Domestically

- Exporter’s Value Function:

\[ V_x(\phi, \kappa, \eta, \mu) = d(\eta, \mu)(\pi_d(\phi, \kappa, \eta, \mu) + \pi_x(\phi, \kappa, \eta, \mu)) + (1 - \delta) \beta \sum_{\eta'} V_x(\phi, \kappa, \eta', \mu') \lambda_{\eta \eta'} \]

s.t. \( \mu' = M(\eta, \mu) \)

- \( d(\eta, \mu) = \) multiplier on budget constraint
• Non-exporter’s Value Function:

\[
V_d (\phi, \kappa, \eta, \mu) = \\
\max \left\{ \pi_d (\phi, \kappa, \eta, \mu) d (\eta, \mu) + \beta (1 - \delta) \sum_{\eta'} V_d (\phi, \kappa, \eta', \mu') \lambda_{\eta\eta'}, \right. \\
\left. \left[ \pi_d (\phi, \kappa, \eta, \mu) - \kappa \right] d (\eta, \mu) + \beta (1 - \delta) \sum_{\eta'} V_x (\phi, \kappa, \eta', \mu') \lambda_{\eta\eta'} \right\} \\
\text{s.t. } \mu' = M (\eta, \mu)
\]
Equilibrium

- Cutoff level of productivity for each value of the entry cost

- For a plant of type $(\phi, \kappa)$
  
  If $\phi \geq \hat{\phi}_\kappa(\eta, \mu)$ export and sell domestically

  If $\phi < \hat{\phi}_\kappa(\eta, \mu)$ only sell domestically

- In Equilibrium
  
  - “Low” productivity/“high” entry cost plants sell domestic
  - “High” productivity/“low” entry cost plants also export
  - Similar to Melitz (2003)
Determining Cutoffs

• For the cutoff plant:
  ○ entry cost = discounted, expected value of exporting

• $\hat{\phi}_\kappa (\eta, \mu)$ is the level of productivity, $\phi$, that solves:

$$d (\eta, \mu) = (1 - \delta) \beta \left[ \sum_{\eta'} V_x (\phi, \kappa, \eta', \mu') \lambda_{\eta'} - \sum_{\eta'} V_d (\phi, \kappa, \eta', \mu') \lambda_{\eta'} \right]$$

  entry cost $\quad$ expected value of exporting
Finding the Cutoff Producer

Costs and Benefits

Value of Exporting: Steady State

Entry Cost

Non-Exporters

Exporters

\( \hat{\phi}_{SS} \)

Firm Productivity \( (\phi) \)
Choosing Parameters

- Set $\sigma = \frac{1}{1 - \rho} = 2$ and $\tau = 0.15$

- Calibrate to the United States (1987) and a symmetric partner.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Annual real interest rate (4%)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Share of manufactures in GDP (18%)</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Annual loss of jobs from plant deaths as percentage of employment (Davis et. al., 1996) (6%)</td>
</tr>
</tbody>
</table>
Other Parameters

- Distribution over new plants:

\[ F_\kappa(\phi) = \frac{1}{\phi^{\theta_\phi}} \quad F_\phi(\kappa) = \frac{1}{(\bar{\kappa} - \kappa)^{\theta_\kappa}} \]

- \(\bar{\kappa}, \phi, \nu, \theta_\phi, \theta_\kappa\) jointly determine:
  
  - Average plant size (12 employees)
  - Standard deviation of plant sizes (892)
  - Average exporting plant size (15 employees)
  - Standard deviation of exporting plant sizes (912)
  - Fraction of production that is exported (9%)
Plant Size Distribution:
All Plants

Plant Size Distribution:
Exporting Plants

Employees per Plant (log scale)

Data Model

Employees per Plant (log scale)
Productivity Process

• Two shocks, low and high:

\[ z_i = 1 - \varepsilon \]
\[ z_i = 1 + \varepsilon \]

• Countries have symmetric processes with Markov Matrix

\[
\Lambda_i = \begin{bmatrix}
\bar{\lambda} & 1 - \bar{\lambda} \\
1 - \bar{\lambda} & \bar{\lambda}
\end{bmatrix}
\]

• \( \varepsilon \): standard deviation of the U.S. Solow Residuals (1.0%)

• \( \bar{\lambda} \): autocorrelation of the U.S. Solow Residuals (0.90)
How does Trade Liberalization Differ from Business Cycles?

- Trade liberalization
  - Permanent changes
  - Large magnitudes

- Business cycles
  - Persistent, but not permanent changes
  - Small magnitudes
Developing Intuition: Persistent vs. Permanent Shocks

• 1% positive productivity shock in foreign country
  ○ Shock is persistent – autocorrelation of 0.90

• 1% decrease in tariffs
  ○ Change in tariffs is permanent
Response to 1% Productivity Shock
Autocorrelation = 0.90

Value of Exporting: 1% Productivity Shock
Value of Exporting: Steady State

Costs and Benefits

Entry Cost

Firm Productivity ($\phi$)

$\hat{\phi}_{bc} \quad \hat{\phi}_{ss}$
Response to a 1% Foreign Productivity Shock

Increase in imports on intensive margin $= 1.89\%$
Increase in imports on extensive margin $= 0.16\%$

\[
\text{Total increase in imports} = 2.05\%
\]

Change in consumption of home goods $= -0.10\%$

\[
\frac{\% \text{ Change Imports/Dom. Cons.}}{\% \text{ Change Price}} = \frac{2.17}{0.99} = 2.19
\]
Response to 1% Permanent Decrease in Tariffs

Value of Exporting:
1% Decrease in Tariffs

Value of Exporting:
1% Productivity Shock

Value of Exporting:
Steady State

Entry Cost

Firm Productivity ($\phi$)
Response to a 1% Tariff Reduction

Increase in imports on intensive margin = 1.42%
Increase in imports on extensive margin = 3.04%
Total increase in imports = 4.46%

Change in consumption of home goods = -0.33%

\[
\frac{\text{% Change Imports/Dom. Cons.}}{\text{% Change Tariff}} = \frac{4.81}{1.00} = 4.81
\]
Quantitative Results

• Two experiments

• Trade liberalization
  ○ Eliminate 15% tariff
  ○ Compute elasticity across tariff regimes

• Time series regressions
  ○ Use model to generate simulated data
  ○ Estimate elasticity as in the literature
## Trade Liberalization Elasticity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Entry Costs (% change)</th>
<th>No Entry Costs (% change)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exports</td>
<td>87.1</td>
<td>30.5</td>
</tr>
<tr>
<td>Imports/Dom. Cons.</td>
<td>93.0</td>
<td>32.2</td>
</tr>
<tr>
<td>Exporting Plants</td>
<td>37.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Implied Elasticity</td>
<td>6.2</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Elasticity in the Time Series

- Simulate: produce price/quantity time series
- Regress:

\[
\log \left( \frac{C_{f,t}}{C_{h,t}} \right) = \alpha + \sigma \log \left( \frac{p_{h,t}}{p_{f,t}} \right) + \varepsilon_t
\]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>-0.015</td>
</tr>
<tr>
<td>(standard error)</td>
<td>(6.36e-04)</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>1.39</td>
</tr>
<tr>
<td>(standard error)</td>
<td>(0.06)</td>
</tr>
<tr>
<td>R- squared</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Conclusion

• Gap between dynamic macro models and trade models
  ○ Partially closes the gap
  ○ Modeling firm behavior as motivated by the data
  ○ Step towards better modeling of trade policy

• Single model can account for the elasticity puzzle
  ○ Time series elasticity of 1.4
  ○ Trade liberalization elasticity of 6.2