Asymmetric Trade Costs

In most of the models we’ve looked at, welfare gains from trade relatively small

• Look at cases where importance of trade is amplified

Asymmetric trade costs

• Poor countries have systematically higher trade costs, which reduces their TFP and welfare
Asymmetric Trade Costs

Waugh (2010) investigates whether differences in trade costs can explain differences in cross-country income per capita

- Uses an Eaton-Kortum (2003) framework

- Shows symmetric trade costs does a poor job fitting the data, while leaving little room for trade to matter

- Finds systematically asymmetric trade costs between rich and poor countries: eliminating these asymmetries would reduce cross-country inequality by one third
Framework

• $i = 1, \ldots, N$ countries, with labor $L_i$ and capital $K_i$

  • Normalize aggregate variables relative to $L_i$ (e.g. income per capita)

• continuum of tradable intermediate goods $x \in [0,1]$ (Eaton-Kortum)

• non-traded final consumption good

  • Consumer preferences only over this final good
Intermediate Goods Sector

- Continuum of tradable intermediate goods $x \in [0,1]$
  - Iceberg trade cost $\tau_{ij} \geq 1$ ($\tau_{ii} = 1$) to export from country $j$ to country $i$
- Cobb-Douglas production function
  $$m_i(x) = z_i(x)^{-\theta} \left[ k_i \eta_i^{1-a} \right]^\beta q_i^{1-\beta}$$
- $q_i$ is CES aggregate of tradable intermediate goods
  $$q_i = \left[ m(x) \frac{\eta-1}{\eta} \right]^{\frac{\eta}{\eta-1}}$$
- $z_i(x)$ is country $i$’s productivity for producing good $x$ ($z_i(x)^{-\theta}$ is efficiency)
  - Drawn from exponential distribution with parameter $\lambda_i \Rightarrow$ Frechet distribution in efficiency
  - $\lambda_i$ governs average productivity level, $\theta$ governs dispersion (opposite of EK – high $\theta$, high disp.)
Final Good Sector

Cobb-Douglas production function for non-traded final good

\[ y_i = \left[ k_i^\alpha n_i^{1-\alpha} \right]^\gamma q_i^{1-\gamma} \]

- Factor shares are constant across countries (same for intermediate goods)
  - Each country will allocate fraction \( \gamma \) of capital and labor to final good production
- Perfectly competitive
- Consumers spend all income on final good
Intermediate Price Index

The CES price index for the aggregate traded good in country $i$ is (represent goods by their productivity)

$$p_i = \left[ \int_0^\infty p_i(z)^{1-\eta} \pi(z) dz \right]^{\frac{1}{1-\eta}}$$

Where $p_i(z) = \min\{p_{i1}(z), \ldots, p_{iN}(z)\} = \min\{\tau_{i1}p_{11}(z), \ldots, \tau_{iN}p_{NN}(z)\}$, and $\pi(z)$ is density function of $z$

$$\pi(z) = \left( \prod_{i=1}^N \lambda_i \right) \exp \left( - \sum_{i=1}^N \lambda_i z_i \right)$$
Intermediate Price Index and Trade Shares

Price index can be expressed as

\[ p_i = \Upsilon \left\{ \sum_{j=1}^{N} \left[ r_j^{\alpha \beta} w_j^{(1-\alpha)\beta} p_j^{(1-\beta)} \tau_{ij} \right]^{-\frac{1}{\theta}} \lambda_j \right\}^{-\theta} \], \quad (1) \]

- \( \Upsilon \) depends only on model constants

Country \( i \)'s expenditure share on goods from country \( j \) is

\[ X_{ij} = \frac{\left[ r_j^{\alpha \beta} w_j^{(1-\alpha)\beta} p_j^{(1-\beta)} \tau_{ij} \right]^{-\frac{1}{\theta}} \lambda_j}{\sum_{l=1}^{N} \left[ r_l^{\alpha \beta} w_l^{(1-\alpha)\beta} p_l^{(1-\beta)} \tau_{il} \right]^{-\frac{1}{\theta}} \lambda_l}, \quad (2) \]
Balanced Trade and Wages

Wages determined by balanced trade for each country

\[
L_i p_i q_i X_{ii} + \sum_{j=1}^{N} X_{ij} = \sum_{j=1}^{N} L_j p_j q_j X_{ji} + L_i p_i q_i X_{ii}, \quad \forall i
\]

Note every country allocates same fraction of labor to traded sector \((1 - \gamma)\)

Therefore equilibrium wage rate will be given by

\[
w_i = \sum_{j=1}^{N} \frac{L_j}{L_i} w_j X_{ji}, \quad (3)
\]
Taking Model to Data

In model have an expressions for wages, trade shares, and price indices for tradable goods.

Countries are characterized by labor supply, $L_i$, capital supply, $K_i$, technology parameter, $\lambda_i$, and trade costs $\{\tau_{ij}, \tau_{ji}\}_{j=1,\ldots,N}$

- Take $L_i$ and $K_i$ directly from data
- Trade costs often modeled using a symmetric gravity equation (distance, shared language, border, etc)
  - Use price data to show enforced symmetry is at odds with data
- $\lambda_i$ backed out from model
Trade Data and Expenditure Shares

Sample of 76 countries

• Account for 90 percent of world GDP in base year, 1996

• Data on imports, exports, and gross production for 34 BEA manufacturing industries

Compute expenditure shares as

\[ X_{ij} = \frac{\text{Imports}_{ij}}{\text{Gross Mfg. Production}_i - \text{Total Exports}_i + \text{Imports}_i} \]

Where Total Exports is for world, and Imports is just for sample. Can compute domestic expenditures as

\[ X_{ii} = 1 - \sum_{j=1}^{N} X_{ij} \]
### Table 1—1996 Trade Share Data, $X_{ij}$, in Percent for Selected Countries

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**Observation 1:** “Home bias” for both rich and poor countries
### Computed Expenditure Shares

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**Observation 2:** Poor country expenditure shares high for goods from rich countries
(Rich) (low) (poor)
Observation 2A: Disparity in trade shares larger, the higher disparity is in relative income

- Run regression $\log X_{ji} / X_{ij} = \text{constant} + \beta_y \log y_j / y_i$. Constant is zero, $\beta_y = 2.40$
Price Data

In model $p_i$ are aggregate price indices for tradable goods

- Non-traded goods, plus not all tradable goods actually traded in equilibrium

Data from United Nations International Comparison Program (ICP)

- Collect prices on standardized basket of goods and services across countries
- Construct tradable price indices in 1996 using Penn World Table
Tradable Price Indices

Figure 1. Price of Tradable Goods: Similar Between Rich and Poor Countries

Waugh (2010)
Observation 3: Tradable price indices similar between rich and poor countries

Figure 1. Price of Tradable Goods: Similar Between Rich and Poor Countries

Waugh (2010)
Implications and Arbitrage Condition

From equations for price indices and trade shares in model have

$$\frac{X_{ij}}{X_{jj}} = \tau_{ij} \frac{1}{\sigma} \left( \frac{p_j}{p_i} \right)^{-\frac{1}{\sigma}}$$

Which says that if $p_i > p_j$ then country $i$ should purchase relatively more goods from country $j$

- Conversely, if trade costs high, should purchase relatively less goods from country $j$
Implications and Arbitrage Condition

Using previous equation twice

\[
\left( \frac{X_{ij} X_{ii}}{X_{ji} X_{jj}} \right) \left( \frac{p_j}{p_i} \right)^{\frac{2}{\theta}} = \left( \frac{\tau_{ij}}{\tau_{ji}} \right)^{-\frac{1}{\theta}}
\]

• In symmetric world \((X_{ij}/X_{ji})(X_{ii}/X_{jj}) = 1\)

• Deviations from symmetric trade shares occur because of asymmetries in prices or in trade costs
  • Didn’t see evidence of systematic asymmetries in price indices of tradable goods
  • Indicates likely systematic asymmetries in trade costs
Suppose three countries. Country 1 is rich, country 2 is middle income, and country 3 is poor.

- Observe following bilateral (normalized) trade share matrix for $X_{ij}/X_{ii}$

\[
\begin{pmatrix}
1 & \frac{X_{21}}{X_{22}} & \frac{X_{31}}{X_{33}} \\
\frac{X_{12}}{X_{11}} & 1 & 0 \\
\frac{X_{13}}{X_{11}} & 0 & 1
\end{pmatrix}
\]

where \( \frac{X_{21}}{X_{22}} = \frac{X_{31}}{X_{33}} \)

and \( \frac{X_{12}}{X_{11}} > \frac{X_{13}}{X_{11}} \)
Modeling Asymmetric Trade Costs: Simple Example

Suppose labor only factor of production and labor endowment constant across countries.

- Normalize $w_1$ and $\lambda_1$ to 1.

- Can write observed normalized trade shares in terms of $\{\lambda_2, \lambda_3, \tau_{12}, \tau_{21}, \tau_{13}, \tau_{31}\}$

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<tr>
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Difficulty: Six unknowns, but only four informative moments. Need additional restrictions.
Modeling Asymmetric Trade Costs: General Problem

In model with $N$ countries, have $N^2$ parameters to estimate, but only $N^2 - N$ informative moments

Parameters:

- Trade costs: $\tau_{ij}$. Impose $\tau_{ii} = 1 \Rightarrow N^2 - N$ parameters

- Productivities: $\lambda_i$. $N$ parameters

Informative Moments:

- Bilateral normalized trade share matrix: $X_{ij}/X_{ii}$. Identity $X_{ii}/X_{ii} = 1 \Rightarrow N^2 - N$ moments
Go back to simple example. Suppose trade costs determined by exporter effects

- $\{\tau_{21}, \tau_{31}\} = \bar{\tau}$, so cost for countries 2 and 3 to import from country 1 is same

Implication 1: Since normalized trade shares equal $X_{21}/X_{22} = X_{31}/X_{33}$, therefore $w_2^{-1/\theta} \lambda_2 = w_3^{-1/\theta} \lambda_3$

- Cost of producing a good is the same on average across middle income and poor country
Modeling Asymmetric Trade Costs, Option 1: Export Effects

Suppose trade costs determined by exporter effects

- \( \{\tau_{21}, \tau_{31}\} = \bar{\tau} \), so cost for countries 2 and 3 to import from country 1 is same

**Implication 1:** Since normalized trade shares equal \( X_{21}/X_{22} = X_{31}/X_{33} \), therefore \( w_2 \frac{1}{\theta} \lambda_2 = w_3 \frac{1}{\theta} \lambda_3 \)

- Cost of producing a good is the same on average across middle income and poor country

**Implication 2:** Since U.S. imports more from country 2 than country 3 \( X_{12} > X_{13} \), therefore \( \tau_{12} < \tau_{13} \)

- Higher trade costs for poor country (relative to middle income country) to export to rich country
Modeling Asymmetric Trade Costs, Option 1: Export Effects

Suppose trade costs determined by exporter effects

\( \{\tau_{21}, \tau_{31}\} = \bar{\tau} \), so cost for countries 2 and 3 to import from country 1 is same

Implication 3: Suppose unit costs (depend on wages and productivity) equal across countries 2 and 3.

• Balanced Trade implies

\[
\frac{X_{12}}{X_{21}} = w_2 > \frac{X_{13}}{X_{31}} = w_3
\]

• Therefore country 2 is more productive than country 3 \((\lambda_2 > \lambda_3)\), and also richer than country 3.
Modeling Asymmetric Trade Costs, Option 2: Importer Effects

Suppose trade costs determined by importer effects

- $\{\tau_{13}, \tau_{13}\} = \tilde{\tau}$, so cost for countries 2 and 3 to export to country 1 is same

Implication 1: Since U.S. imports more from country 2 than country 3 ($X_{12} > X_{13}$), $\Rightarrow \frac{1}{\theta} \lambda_2 > \frac{1}{\theta} \lambda_3$

- Cost of producing a good is less on average in middle income country compared to poor country

Implication 2: Since normalized trade shares equal ($X_{21}/X_{22} = X_{31}/X_{33}$), therefore $\tau_{21} < \tau_{31}$

- Higher trade costs for poor country (relative to middle income country) to import from rich country
Modeling Asymmetric Trade Costs, Option 1: Import Effects

Suppose trade costs determined by importer effects

• \( \{\tau_{13}, \tau_{13}\} = \bar{\tau} \), so cost for countries 2 and 3 to export to country 1 is same

Implication 3: Unit cost no longer equal across countries.

• Still have country 2 is more productive than country 3 \( (\lambda_2 > \lambda_3) \)

• To fit observed trade shares, need difference in productivities to be even larger

\[
\frac{\lambda_2}{\lambda_3} > \frac{\lambda_2}{\lambda_3} > 1
\]

\( \text{import effects} \quad \text{export effects} \)
Estimating Technology and Trade Costs: Benchmark

Benchmark is structural gravity equation as in Eaton-Kortum (2003)

\[
\log \left( \frac{X_{ij}}{X_{ii}} \right) = S_j - S_i - \frac{1}{\theta} \log \tau_{ij}
\]

Where \( S_i \) is a country fixed effect

\[
S_i \equiv \log \left[ r_i^{\alpha\beta/\theta} w_i^{(1-\alpha)\beta/\theta} p_i^{(1-\beta)/\theta} \lambda_i \right]
\]

And trade costs are modeled as

\[
\log \tau_{ij} = d_k + b_{ij} + ex_j + \epsilon_{ij}
\]

Where \( d_k \) is one of six distance intervals, \( b_{ij} \) is shared border dummy, \( \epsilon_{ij} \) is trade costs from other factors

- \( ex_j \) is exporter fixed effect. In simple example \( \{ \tau_{21}, \tau_{31} \} = \tilde{\tau} = \exp[ex_1] \)
Estimating Technology and Trade Costs: Alternative

Alternative is to model trade costs as

$$ \log \tau_{ij} = d_k + b_{ij} + m_i + \epsilon_{ij} $$

Where $d_k$ is one of six distance intervals, $b_{ij}$ is shared border dummy, $\epsilon_{ij}$ is trade costs from other factors

- $m_i$ is a importer fixed effect. In simple example \{\tau_{12}, \tau_{13}\} = \bar{\tau} = \exp[m_1] $
Exporter vs Importer Fixed Effects

Consider simple 3 country example. Bilateral trade cost matrix for exporter fixed effects are:

$$
\begin{pmatrix}
1 & \exp(e_{x1}) & \exp(e_{x1}) \\
\exp(e_{x2}) & 1 & \exp(e_{x2}) \\
\exp(e_{x3}) & \exp(e_{x3}) & 1
\end{pmatrix}
$$

Bilateral trade cost matrix for importer fixed effects are

$$
\begin{pmatrix}
1 & \exp(m_2) & \exp(m_3) \\
\exp(m_1) & 1 & \exp(m_3) \\
\exp(m_1) & \exp(m_2) & 1
\end{pmatrix}.
$$
Recovering Technology

After estimating gravity equation to get estimated $\hat{S}_i$ and $\hat{t}_{ij}$, estimated traded aggregate price index is

$$
\hat{p}_i = \Upsilon \left\{ \sum_{j=1}^{N} e^{\hat{S}_j \hat{t}_{ij}} \right\}^{-\theta}
$$

Combine with equilibrium condition we derived earlier

$$
p_i = \Upsilon \left\{ \sum_{j=1}^{N} \left[ r_j^{\alpha \beta} w_j^{(1-\alpha)\beta} p_j^{(1-\beta)} \tau_{ij} \right]^{1 \theta} \right\}^{-\theta}
$$

Therefore can estimate $\left[ r_j^{\alpha \beta} w_j^{(1-\alpha)\beta} p_j^{(1-\beta)} \tau_{ij} \right]^{1 \theta} \lambda_j$

- Get wages from bilateral trade shares $w_i = \sum_{j=1}^{N} \frac{L_j}{L_i} w_j X_{ji}$

- Get rental rates from capital-labor ratio. Then can back out technology parameters: $\lambda_i$
Estimating $\theta$

Benchmark approach is to follow Eaton and Kortum (2002)

- Note that $\tau_{ij} \geq \frac{p_i(x)}{p_j(x)} \forall x$, otherwise arbitrage opportunity, therefore can estimate trade costs as

$$\log \hat{\tau}_{ij} = \max_x \left\{ \log(p_i(x)) - \log(p_j(x)) \right\}$$

- Get the prices from the Penn World Table database

- Combine with normalized trade shares to back out $\theta$

$$\frac{X_{ij}}{X_{jj}} = \tau_{ij}^{-\theta} \left( \frac{p_j}{p_i} \right)^{-\frac{1}{\theta}}$$
Estimating $\theta$: Alternative

May be case that $\theta$ differs across rich and poor countries

- Divide sample into OECD and non-OECD countries
- Follow procedure and estimate separate $\theta$ for each sample

Results:

- Benchmark estimates $1/\theta$ of 5.5
- Asymmetric $\theta$ estimates $1/\theta_{\text{rich}}$ of 5.5 and $1/\theta_{\text{poor}}$ of 7.9
  - Asymmetric $\theta$ can’t explain observations noted at beginning (asymmetric trade shares)
Income per Worker

Income per worker is measured using wages and capital income relative to final price index

\[ y_i = \frac{w_i + r_i k_i}{p_i^y} \]

- Where wages, rental rates, capital/labor ratio, and final good price form penn-world tables

- Factor shares are set as \( \alpha = \frac{1}{3}, \beta = \frac{1}{3}, \gamma = \frac{3}{4} \), recall

\[ m_i(x) = z_i(x)^{-\theta} \left[ k_i^\alpha n_i^{1-\alpha} \right]^{\beta} q_i^{1-\beta} \]

\[ y_i = \left[ k_i^\alpha n_i^{1-\alpha} \right]^\gamma q_i^{1-\gamma} \]
## Exporter Effects Results

Estimate gravity equation with exporter effects

<table>
<thead>
<tr>
<th>Summary statistics</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>4,242</td>
<td>TSS: 4,924</td>
<td>SSR: 851</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geographic barriers</th>
<th>Parameter estimate</th>
<th>Standard error</th>
<th>% effect on cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0, 375)</td>
<td>−4.66</td>
<td>0.21</td>
<td>133.3</td>
</tr>
<tr>
<td>[375, 750)</td>
<td>−5.60</td>
<td>0.14</td>
<td>177.1</td>
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<tr>
<td>[750, 1,500)</td>
<td>−6.16</td>
<td>0.09</td>
<td>206.3</td>
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<tr>
<td>[1,500, 3,000)</td>
<td>−7.22</td>
<td>0.06</td>
<td>271.3</td>
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<tr>
<td>[3,000, 6,000)</td>
<td>−8.44</td>
<td>0.04</td>
<td>363.9</td>
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<tr>
<td>[6,000, maximum]</td>
<td>−9.37</td>
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<tr>
<td>Shared border</td>
<td>0.77</td>
<td>0.16</td>
<td>−13.0</td>
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</tbody>
</table>

*Note: All parameters were estimated by OLS. For an estimated parameter $\hat{b}$, the implied percentage effect on cost is $100 \times (e^{-\hat{b}} - 1)$ with $\theta = 0.1818$. |
## Exporter Effects Results

Estimate gravity equation with exporter effects

<table>
<thead>
<tr>
<th>Country</th>
<th>$ex_j$</th>
<th>Standard error</th>
<th>Percent cost</th>
<th>$\hat{S}_j$</th>
<th>Standard error</th>
<th>$\left( \frac{\lambda_{it}}{\lambda_{ij}} \right)^{\theta}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>5.40</td>
<td>0.24</td>
<td>-62.5</td>
<td>0.54</td>
<td>0.17</td>
<td>1.00</td>
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<td>0.19</td>
<td>1.60</td>
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<tr>
<td>Australia</td>
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<td>0.18</td>
<td>1.42</td>
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<td>0.93</td>
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<td>1.21</td>
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<tr>
<td>Switzerland</td>
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<td>-32.8</td>
<td>0.75</td>
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<td>0.75</td>
</tr>
<tr>
<td>Chile</td>
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<td>-35.2</td>
<td>-0.39</td>
<td>0.18</td>
<td>1.89</td>
</tr>
</tbody>
</table>
Exporter Fixed Effects Higher for Poorer Countries

Figure 2. Exporter Fixed Effect: Easy for Rich Countries to Export, Difficult for Poor Countries

Waugh (2010)
Implied Prices for Exporter Fixed Effects

Panel A. $S_i$ from model with exporter fixed effect

1996 GDP per worker: US = 1

Waugh (2010)
Panel A. Price data and benchmark model

Price of tradables: US = 1

Benchmark model

Data, best fit

1996 GDP per worker: US = 1

Waugh (2010)
Implied Prices for Importer Fixed Effects

Panel B. $S_f$ from model with importer fixed effect

1996 GDP per worker: $US = 1$

Waugh (2010)
Implied Prices for Importer Fixed Effects

Panel B. Price data and model with importer fixed effects

Price of tradables: US = 1

1996 GDP per worker: US = 1

Data, best fit

Model with importer fixed effects

Waugh (2010)
Income in Model vs Data

Figure 5. Income per Worker: Data and Benchmark Model

Waugh (2010)
Welfare Gains From Trade

Figure 8: Welfare Gains: Calibrated Model to Frictionless Trade

Waugh (2010)