International Trade and Income Differences

By Michael E. Waugh

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1. Motivation

- Many empirical studies showed that transport costs for exporters are asymmetric between rich and poor countries
- Olarreaga, Nicita and Kee (2006); Moreira, Volpe and Blyde (2008); Krueger, Schiff and Valdes (1988); IMF data on f.o.b. and c.i.f. prices
- Many theoretical models and empirical studies still assume symmetry in trade costs
- Waugh’s argument is based on the theoretical gravity equation and 3 observations on trade shares and aggregate price data of tradables across countries
1. Home bias for both rich and poor countries
2. Systematic correlation between bilateral trade shares and relative level of development
3. Aggregate tradable goods prices are similar between rich and poor countries

![Table 1—1996 Trade Share Data, $X_{ij}$, in Percent for Selected Countries](table1)

<table>
<thead>
<tr>
<th></th>
<th>US</th>
<th>Canada</th>
<th>Japan</th>
<th>Mexico</th>
<th>China</th>
<th>Senegal</th>
<th>Malawi</th>
<th>Zaire</th>
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</thead>
<tbody>
<tr>
<td>US</td>
<td>83.25</td>
<td>39.73</td>
<td>2.27</td>
<td>31.62</td>
<td>3.63</td>
<td>2.16</td>
<td>1.57</td>
<td>2.93</td>
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<tr>
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<td>3.78</td>
<td>49.21</td>
<td>0.21</td>
<td>0.72</td>
<td>0.32</td>
<td>0.56</td>
<td>0.67</td>
<td>0.51</td>
</tr>
<tr>
<td>Japan</td>
<td>3.04</td>
<td>2.01</td>
<td>92.56</td>
<td>1.59</td>
<td>6.99</td>
<td>1.34</td>
<td>2.65</td>
<td>0.82</td>
</tr>
<tr>
<td>Mexico</td>
<td>1.88</td>
<td>1.33</td>
<td>0.02</td>
<td>61.09</td>
<td>0.057</td>
<td>0.01</td>
<td>0</td>
<td>0.007</td>
</tr>
<tr>
<td>China</td>
<td>1.78</td>
<td>1.41</td>
<td>1.44</td>
<td>0.30</td>
<td>77.61</td>
<td>2.69</td>
<td>2.50</td>
<td>6.81</td>
</tr>
<tr>
<td>Senegal</td>
<td>0*</td>
<td>0*</td>
<td>0*</td>
<td>0</td>
<td>0*</td>
<td>52.68</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Malawi</td>
<td>0*</td>
<td>0*</td>
<td>0*</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>41.52</td>
<td>0</td>
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<tr>
<td>Zaire</td>
<td>0.003</td>
<td>0.005</td>
<td>0.003</td>
<td>0*</td>
<td>0*</td>
<td>0</td>
<td>0</td>
<td>51.53</td>
</tr>
</tbody>
</table>

*Notes: Entry in row $i$, column $j$, is the fraction of goods country $j$ imports from country $i$. Zeros with stars indicate the value is less than $10^{-4}$. Zeros without stars are zeros in the data.*
• To reconcile bilateral trade volumes and price data within a standard gravity model transport costs must be asymmetric between rich and poor countries:

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

• Assuming asymmetric trade costs gives much better fit for bilateral trade volumes (R² is 36% higher)

• Waugh argues that asymmetries in trade costs arise because of exporter effects rather than importer effects

• Asymmetry in trade costs are an important reason for differences in TFP and income per worker between countries (counterfactual analysis)
2. The theoretical model

• Close to Eaton and Kortum (2002) and Alvarez and Lucas (2007)

• 2 production sectors (non-tradable final good $y$, continuum of differentiated tradable goods $x \in [0,1]$ )

• Perfect competition in both sectors

• N countries endowed with labor $L_i$ and capital $K_i$, exogenous technology parameter $\lambda_i$ determines distribution of productivity $z_i(x)^{-\theta}$ for tradable goods

• Production factors: capital, labor and aggregate tradable goods $q_i$

• All variables are normalized by $L_i$
• Nested Cobb-Douglas production function for tradables

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

• Aggregate tradable good, \( m(x) \) is purchased from lowest cost producer across all countries (like in EK, 2002)

\[ q_i = \left[ \int_0^1 m(x) \frac{\eta - 1}{\eta} \, dx \right]^{\eta - 1}. \]

• \( z_i(x) \) is independently and exponentially distributed with parameter \( \lambda_i \), so \( z_i(x)^{-\theta} \) follows Fréchet-distribution

\[ Pr(z_i(x)^{-\theta} < c) = 1 - e^{-\lambda_i c^{\frac{1}{\theta}}}. \]
• Therefore interpretation of \( \theta \) is now opposite of EK (2002), \( \lambda_i \) is same as \( T_i \) in EK (2002)

• Iceberg transport costs for trade in tradable goods \( \tau_{ij} \) allowed to be asymmetric (\( \tau_{ij} \) composed of both policy and non-policy related barriers)

• Balanced trade (value of total imports = value of total exports, only tradable goods are traded)

• Consumer utility only depends on the final good

• Production function for the final good:

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

- Cobb-Douglas production technologies: fraction $\gamma$ of labor and capital (aggregate value added) and fraction $\beta$ of aggregate tradable good is allocated towards the final goods sector.

- Rest of equilibrium equations follow from same reasoning than EK (2002) (probabilistic computations).

- Only 3 equations determine the equilibrium.

- Aggregate price index of tradables in country $i$

\begin{equation}
  p_i = \gamma \left\{ \sum_{j=1}^{N} \left[ r_j^{\alpha \beta} w_j^{\alpha (1-\alpha) \beta} p_j^{(1-\beta) \tau_{ij}} \right]^{-\frac{1}{\theta}} \lambda_j \right\}^{-\theta}
\end{equation}
• Country i’s expenditure share on tradables from country j (equals fraction of tradable goods that i imports from j):

\[
X_{ij} = \frac{\left[ r_j^{\alpha\beta} w_j^{(1-\alpha)\beta} p_j^{(1-\beta)} \tau_{ij} \right]^{-\frac{1}{\theta}} \lambda_j}{\sum_{\ell=1}^{N} \left[ r_{\ell}^{\alpha\beta} w_{\ell}^{(1-\alpha)\beta} p_{\ell}^{(1-\beta)} \tau_{i\ell} \right]^{-\frac{1}{\theta}} \lambda_{\ell}}
\]

(2)

• equilibrium wage rate for each country i:

\[
w_i = \sum_{j \neq i}^{N} \frac{L_j}{L_i} w_j X_{ji}
\]

(3)
• from (1) and (2) we get:

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

(4)

• dividing (4) by opposing expression:

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

(5)

• Observations 1-3 and (5) imply, that exporting costs for poor countries are higher than for rich ones
3. Estimation strategy and data

• **Objective:** Structural estimation of asymmetric trade costs and technology parameters using cross-sectional data on bilateral trade volumes and a specific functional form for trade costs.

• Benchmark year is 1996, 77 countries in the sample (represent over 90% of world GDP).

• Tradable goods sector corresponds to manufactures, aggregation across all 34 BEA manufacturing industries.

• Trade shares are computed in the following way:

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

\[
X_{ii} = 1 - \sum_{j \neq i}^{N} X_{ij}.
\]
• Trade and production data for manufactures from Feenstra et al. (1997), UNIDO, OECD and World Bank

• Aggregate price indices for manufactures (tradables) are constructed from UN-ICP and PWT data (1996)

• Disaggregated price data for estimation of $\theta$ comes from PWT (1985)

• Distance data comes from CEPII

• Dividing $X_{ij}$ by $X_{ii}$ (from (2)):

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

(6)

Where $S_i$ is defined as:

\[
\log \left[ r_i^{\alpha \beta / -\theta} w_i^{(1 - \alpha) \beta / -\theta} p_i^{(1 - \beta) / -\theta} \lambda_i \right]
\]
Due to asymmetry of trade costs restrictions on parameter space are necessary (restrictions on trade costs: exporter fixed effects vs. importer fixed effects)

Benchmark estimation with exporter fixed effects ($ex_j$):

$$\log(\tau_{ij}) = d_k + b_{ij} + ex_j + \epsilon_{ij}$$  \hspace{1cm} (7)

$d_k$ is distance as a categorical variable, $b_{ij}$ is the border dummy and $\epsilon_{ij}$ are assumed to be orthogonal to the regressors

Alternative approach with importer fixed effects ($m_i$):

$$\log(\tau_{ij}) = d_k + b_{ij} + m_i + \epsilon_{ij}$$  \hspace{1cm} (8)
• Estimating (6) using (7) or (8) by OLS leads to estimates for $S_i$ and by specifying a certain $\theta$ also for $\tau_{ij}$

• Then we can recover $p_i$ from (1):

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

• Using the definition of $S_i$ and the estimates for $p_i$ and $S_i$, we can compute the convolution of

$$r_i^{\alpha\beta/-\theta} w_i^{(1-\alpha)\beta/-\theta} \lambda_i$$

• Using (3), data on labor endowments and trade shares gives wages, which together with data on capital-labor ratios determine rental rates and finally we get each countries $\lambda_i$
Estimating $\theta$

- Using disaggregated price data (PWT 1985) to get another estimate for $\tau_{ij}$ (same as EK (2002))

$$\log \hat{\tau}_{ij} = \max_{\ell} 2 \left\{ \log(p_i(\ell)) - \log(p_j(\ell)) \right\}.$$  

- Using these estimates for $\tau_{ij}$, data on aggregate price indices and bilateral trade volumes (for 1985), we get an estimate for $\theta$ by estimating (4)

- Benchmark estimate across all countries is 0.18 (or $1/\theta = 5.5$)

- assumption: $\theta$ is time invariant

- Robustness check shows, that $\theta$ is slightly higher for poor countries!
Calibration of the model

- For counterfactual simulations we need to compute equilibrium prices and calibrate parameter values.

- Data on labor endowments and capital labor ratios from Caselli (2005) are used to compute equilibrium prices.

- Parameter $\alpha$ is set to 0.33 (capital share of total income, consistent with income accounting literature).

- Parameter $\beta$ (share of value added in gross manufacturing production) is calculated using data from UNIDO (1996) ($\beta=0.33$).

- Parameter $\gamma$ (share of value added in non tradable goods production) is set to 0.75.
4. Results

- $R^2$ is 0.83 with exporter or importer fixed effects (only 0.61 without asymmetric trade costs, which is same as standard approaches)

<table>
<thead>
<tr>
<th>Summary statistics</th>
<th>TSS</th>
<th>SSR</th>
<th>$\sigma^2_{\epsilon}$</th>
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<tbody>
<tr>
<td>Observations</td>
<td>4,242</td>
<td>4,924</td>
<td>851</td>
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<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>
</tr>
<tr>
<td>[3,000, 6,000)</td>
<td>-8.44</td>
<td>0.04</td>
<td>363.9</td>
</tr>
<tr>
<td>[6,000, maximum]</td>
<td>-9.37</td>
<td>0.05</td>
<td>449.7</td>
</tr>
<tr>
<td>Shared border</td>
<td>0.77</td>
<td>0.16</td>
<td>-13.0</td>
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Note: All parameters were estimated by OLS. For an estimated parameter $\hat{b}$, the implied percentage effect on cost is $100 \times (e^{-\theta \hat{b}} - 1)$ with $\theta = 0.1818$. 
<table>
<thead>
<tr>
<th>Country</th>
<th>$ex_i$</th>
<th>Standard error</th>
<th>Percent cost</th>
<th>$\hat{S}_i$</th>
<th>Standard error</th>
<th>$\left(\frac{\lambda_{us}}{\lambda_i}\right)^g$</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>
</tr>
<tr>
<td>Argentina</td>
<td>1.62</td>
<td>0.26</td>
<td>-25.5</td>
<td>0.69</td>
<td>0.19</td>
<td>1.60</td>
</tr>
<tr>
<td>Australia</td>
<td>2.50</td>
<td>0.25</td>
<td>-36.4</td>
<td>0.11</td>
<td>0.18</td>
<td>1.42</td>
</tr>
<tr>
<td>Austria</td>
<td>1.35</td>
<td>0.24</td>
<td>-21.8</td>
<td>0.77</td>
<td>0.17</td>
<td>0.93</td>
</tr>
<tr>
<td>Belgium</td>
<td>5.13</td>
<td>0.24</td>
<td>-60.7</td>
<td>-1.55</td>
<td>0.17</td>
<td>1.21</td>
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<td>Benin</td>
<td>-3.71</td>
<td>0.41</td>
<td>96.3</td>
<td>-0.25</td>
<td>0.23</td>
<td>10.40</td>
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<td>0.27</td>
<td>8.03</td>
<td>0.54</td>
<td>0.21</td>
<td>2.92</td>
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<td>Bolivia</td>
<td>-2.61</td>
<td>0.31</td>
<td>60.7</td>
<td>-0.09</td>
<td>0.21</td>
<td>3.83</td>
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<td>Brazil</td>
<td>2.21</td>
<td>0.25</td>
<td>-33.0</td>
<td>1.27</td>
<td>0.18</td>
<td>1.30</td>
</tr>
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<td>Central African Republic</td>
<td>-4.04</td>
<td>0.52</td>
<td>109</td>
<td>0.33</td>
<td>0.24</td>
<td>3.46</td>
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<td>Canada</td>
<td>3.32</td>
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<td>-45.2</td>
<td>0.11</td>
<td>0.17</td>
<td>0.99</td>
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<tr>
<td>Switzerland</td>
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<td>-32.8</td>
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<td>0.75</td>
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<tr>
<td>Chile</td>
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<td>0.26</td>
<td>-35.2</td>
<td>-0.39</td>
<td>0.18</td>
<td>1.89</td>
</tr>
<tr>
<td>China-Hong Kong</td>
<td>4.40</td>
<td>0.24</td>
<td>-55.0</td>
<td>0.76</td>
<td>0.17</td>
<td>1.85</td>
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<td>0.30</td>
<td>31.4</td>
<td>-0.43</td>
<td>0.20</td>
<td>4.75</td>
</tr>
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<td>Colombia</td>
<td>-0.45</td>
<td>0.26</td>
<td>8.51</td>
<td>0.63</td>
<td>0.19</td>
<td>2.62</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>-0.96</td>
<td>0.28</td>
<td>19.0</td>
<td>0.01</td>
<td>0.20</td>
<td>2.51</td>
</tr>
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<td>Denmark</td>
<td>1.67</td>
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<td>0.81</td>
<td>0.17</td>
<td>0.88</td>
</tr>
<tr>
<td>Dominican Republic</td>
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<td>30.1</td>
<td>-0.49</td>
<td>0.21</td>
<td>2.30</td>
</tr>
<tr>
<td>Ecuador</td>
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<td>0.29</td>
<td>21.9</td>
<td>0.06</td>
<td>0.20</td>
<td>2.76</td>
</tr>
</tbody>
</table>
• Exporter fixed effects (expressed as % change on trade costs) decrease with income per worker (poor countries have higher costs of exporting!)

**Figure 2. Exporter Fixed Effect: Easy for Rich Countries to Export, Difficult for Poor Countries**
In order to discriminate between exporter and importer fixed effects model, look at estimated $S_i$ plotted against income per worker.
• Note: In the model $S_i$ is a monotonically decreasing function of the unit cost of a producer with the average productivity level $\lambda_i$ in country $i$.

• Differences in domestic unit costs between countries map into differences in aggregate price indices of tradables and income differences.
Discriminate between exporter/importer fixed effects model:

1. Compute price indices predicted by the model and compare them with real aggregate price indices of tradables

2. Compute income per worker predicted by the model and compare with data on GDP per worker
Panel B. Price data and model with importer fixed effects

1996 GDP per worker: US = 1

Data, best fit

Model with importer fixed effects
Figure 5. Income per Worker: Data and Benchmark Model.
Summary

• Both approaches of modeling asymmetric trade costs predict bilateral trade volumes equally well and lead to same estimates for determinants of trade costs (distance, border dummy)

• But exporter fixed effects model fits real data on aggregate price indices and real income per worker much better

• Importer fixed effects model predicts higher aggregate price indices for poor countries and therefore overestimates the variance of real income per worker across countries

• Waugh (2010) finds that bilateral trade costs are asymmetric, poor countries face higher costs of exporting than rich countries (costs of importing do not correlate with level of development)
5. Counterfactual simulations

- Using the calibrated model, change trade costs exogenously (comparative statics)
- Eliminating asymmetry \((\tau_{ij} = \min(\tau_{ij}, \tau_{ji}))\) reduces income differences by 59% relative to complete elimination of trade costs
- Introducing average trade costs of OECD countries reduces income differences by only 41%

<table>
<thead>
<tr>
<th>TABLE 4—INCOME DIFFERENCES WITH COUNTERFACTUAL TRADE COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>var [log(y)]</td>
</tr>
<tr>
<td>(y_{90}/y_{10})</td>
</tr>
<tr>
<td>Mean change in y, percent</td>
</tr>
</tbody>
</table>
• Mechanism behind reductions in income differences ($y_i$ is real GDP per worker):

$$y_i = A_i k_i^\alpha,$$

with

$$A_i = \frac{-\theta(1 - \gamma)}{\beta} \frac{\theta(1 - \gamma)}{\lambda_i}$$

• TFP is decomposed into an endogenous trade factor and an exogenous domestic factor

• Lower trade costs lead to more specialization and imports from lower cost producers ($X_{ii} < 1$), which raises TFP and GDP per worker

• Elimination of asymmetric trade costs leads to decrease in variance of GDP per worker, because $X_{ii}$ decreases more for poor countries than for rich ones

• Therefore observation 1 ($X_{ii}$ is same across level of development) is only due to asymmetric trade costs!
6. Conclusions

- Waugh (2010) finds that trade costs are asymmetric across levels of development (poor countries face higher costs of exporting than rich countries)

- These asymmetric trade costs explain an important part of the differences in TFP and income per worker across countries.

- Waugh's argument for exporter fixed effects relies on the observation that aggregate price indices for tradables do not vary systematically across levels of development (robustness check supports his view).

- Furthermore, there are other empirical studies on costs of exporting that support Waugh's findings.