What can gravity models tell us about logistics and exports?

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Outline

• Gravity vs trade
• Sources of transport costs
• Physics gravity vs economics gravity
• Logistics – typical gravity interpretation
• Extensions: 3rd country effects, macro vs micro
• Conclusion
Gravity

Mass 1

Force 1

Mass 2

Force 2

What can gravity models tell us about logistics and exports?
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Gravity equation

Exports_{12} = \beta_1 \times GDP_1 + \beta_2 \times GDP_2 - \text{"distance"}

Exports_{12} = \beta_1 \times GDP_1 + \beta_2 \times GDP_2 - \text{"trade costs"}

Exports_{12} = \beta_1 \times GDP_1 + \beta_2 \times GDP_2 - \text{"transport costs; other trade costs"}

\{\text{channels: money, time, complexity, uncertainty}\}

Exports_{12} = \beta_1 \times GDP_1 + \beta_2 \times GDP_2 - \gamma \times distance_{12} - \delta \times signatures_1 + \lambda \times infrastructure_1 + \xi \times FTA_{12} \ldots

\{\text{"reduced form"}\}

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Estimation (“econometrics”)
## Variations in transport costs

<table>
<thead>
<tr>
<th>Region or Economy</th>
<th>US$ per container</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Import</td>
<td>Export</td>
</tr>
<tr>
<td>OECD Average</td>
<td>1146</td>
<td>1090</td>
</tr>
<tr>
<td>World Average</td>
<td>1625</td>
<td>1404</td>
</tr>
<tr>
<td>Singapore</td>
<td>439</td>
<td>456</td>
</tr>
<tr>
<td>Chad</td>
<td>6150</td>
<td>5497</td>
</tr>
</tbody>
</table>

Table 1, the costs of transporting goods - source: World Bank *Doing Business Indicators*; [http://www.doingbusiness.org/ExploreTopics/TradingAcrossBorders/](http://www.doingbusiness.org/ExploreTopics/TradingAcrossBorders/)
Impediments to exports

- Natural/geographical
- Political (borders, free trade agreements)
- Technological (e.g., infrastructure, logistics)

<table>
<thead>
<tr>
<th></th>
<th>DENMARK</th>
<th>BURUNDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAYS</td>
<td>5</td>
<td>67</td>
</tr>
<tr>
<td>DOCUMENTS</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>SIGNATURES</td>
<td>2</td>
<td>29</td>
</tr>
</tbody>
</table>

Source: World Bank *Doing Business*
Exports are not Physics

• Firms *choose* to sell and people *choose* to buy
  – Exports = \( f(\text{demand}) = f(p/P)^{-1} = f(\text{distance/remoteness, relative logistics quality})^{-1} \)

• Countries *choose* to improve logistics
  – Exports\(_{12}\) = \( \beta_1 \times \text{GDP}_1 + \beta_2 \times \text{GDP}_2 + \xi \times \text{Logistics}_2 + (\text{unobserved factor}) \)
  • “Endogeneity” / “reverse causality”
  • “Does better infrastructure lead to more exports or do higher trade volumes lead to more infrastructure?”
Effects usually assumed (log) linear

Exports_{12} = \beta_1 \times \text{GDP}_1 + \beta_2 \times \text{GDP}_2 - \gamma \times \text{distance}_{12} - \delta \times \text{signatures}_1 + \lambda \times \text{infrastructure}_1 + \xi \times \text{FTA}_{12} ...

• What about “binding” constraints, supply-chain analysis, optimization, interactions between factors?
Exports and logistics

Behar, Manners and Nelson (forthcoming)

- Gravity model using Logistics Performance Index (LPI) based on 6 sub-indicators (Arvis et al, 2007) - specifically 4 referring to international logistics “International Logistics Index”.
  i. Efficiency of the clearance process by customs and other border agencies
  ii. Transport and information technology infrastructure
  iii. Local logistics industry competence
  iv. Ease and affordability of international shipments
  v. The facility to track and trace shipments
  vi. The timeliness with which shipments reach their destination

(New and improved versions now available)
What can gravity models tell us about logistics and exports?

### Coefficients of log bilateral exports

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log GDP</td>
<td>0.922**</td>
<td>[0.0157]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Logistics (ILI)</td>
<td>0.597***</td>
<td>[0.0556]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Log Distance</td>
<td>-1.467***</td>
<td>[0.0496]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Border</td>
<td>1.071***</td>
<td>[0.176]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Colony</td>
<td>0.501***</td>
<td>[0.133]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Language</td>
<td>0.646***</td>
<td>[0.0956]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Samecountry</td>
<td>0.398</td>
<td>[0.243]</td>
<td></td>
</tr>
<tr>
<td>Religion</td>
<td>0.826***</td>
<td>[0.143]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Landlocked</td>
<td>-0.648***</td>
<td>[0.0653]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Island</td>
<td>-0.410***</td>
<td>[0.0694]</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Constant</td>
<td>-33.18***</td>
<td>[0.602]</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

**N** 6939

Significance levels: * p<0.1, ** p<0.05, *** p<0.01. Std errors in brackets.

1 standard deviation improvement in logistics (0.4) would increase a country’s exports by: $\exp(0.4 \times 0.597) - 1 = 27\%$ (typical interpretation).
Third country effects

- Most gravity models are used to assess what happens to exports after a change in logistics (transport costs) between two countries assuming no change by anybody else.
- But the trade between two countries depends not only on logistics of one country but on how this compares to everybody else, so the effect of improved logistics must take this into account.
- Anderson & van Wincoop (2003): ignoring 3rd country effects can lead to a 20-fold overestimate of the effects of international border!
- Behar and Nelson (2012): if everybody reduces trade costs, trade falls between most country pairs. 3rd country effects reduce the impact on global trade by two thirds.
The algebra of gravity

\[ M_{12} = Y_1 Y_2 \left( \frac{T_{12}}{P_1 P_2} \right)^{1-\sigma}, \sigma > 1 \]

\[ m_{12} = y_1 + y_2 - (\sigma - 1)t_{12} + (\sigma - 1)[p_1 + p_2] \]

\[ \frac{\partial m_{12}}{\partial \text{Logistics}_2} = -(\sigma - 1) \frac{\partial t_{12}}{\partial \text{Logistics}_2} \]

\[ \frac{dm_{12}}{d\text{Logistics}_2} = -(\sigma - 1) \left\{ \frac{\partial t_{12}}{\partial \text{Logistics}_2} - \frac{\partial [p_1 + p_2]}{\partial \text{Logistics}_2} \right\} \]

{...}
Third country effects and logistics

\[
\frac{\partial \ln(\text{exports}_{12})}{\partial \text{logistics}_2} \approx (\text{GDP share})_2 \lambda, \\
\text{but gravity coefficient } \tilde{\lambda} \approx \frac{\lambda}{\text{number of countries}}
\]

<table>
<thead>
<tr>
<th>Exporter</th>
<th>Share</th>
<th>Homogeneous</th>
<th>Heterogeneous</th>
<th>Exporter</th>
<th>Share</th>
<th>Homogeneous</th>
<th>Heterogeneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>5.34%</td>
<td>3.50</td>
<td>3.93</td>
<td>Djibouti</td>
<td>0.00%</td>
<td>0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Brazil</td>
<td>1.90%</td>
<td>1.29</td>
<td>1.53</td>
<td>Gambia</td>
<td>0.00%</td>
<td>0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>India</td>
<td>1.82%</td>
<td>1.24</td>
<td>1.45</td>
<td>Liberia</td>
<td>0.00%</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Mexico</td>
<td>1.81%</td>
<td>1.23</td>
<td>1.35</td>
<td>Solomon</td>
<td>0.00%</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Russia</td>
<td>0.99%</td>
<td>0.68</td>
<td>0.81</td>
<td>Guinea-Bissau</td>
<td>0.00%</td>
<td>0.000</td>
<td>0.001</td>
</tr>
<tr>
<td>Argentina</td>
<td>0.89%</td>
<td>0.61</td>
<td>0.72</td>
<td>Comoros</td>
<td>0.00%</td>
<td>0.000</td>
<td>0.001</td>
</tr>
</tbody>
</table>


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Trade costs and the margins of trade

• Intensive margin: quantity of a product exported (to a particular destination) by a firm

• Extensive margin: new products / firms exporting (to a particular destination)

• Empirical studies:
  – Gravity/macro data + theory (eg logistics)
  – Firm-level data (Bernard et al)

• Transactions level data (customs authorities):
References

Conclusion

• Economists study the impact of transport costs on trade using gravity models
• Countries with better logistics export more
• But:
  – This varies between countries
  – Further work needed on micro data
• Log-linear specification is a major simplification