ECBS 6060: International Trade
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Lecture 3: The gravity equation of trade volumes. Trade costs.

Outline

- Today we start with our second question:
  - Why do we trade so little?
- We first establish the empirical patterns (little relative to what?).
- Then we turn to *trade costs* as a potential reason for the missing trade.
  - New models help quantify trade frictions and the gains from trade.

The missing trade

The missing trade

- Although trade has increased dramatically over time, it is till lower than predicted by theory.
- We use two benchmarks:
  1. frictionless trade with complete specialization
  2. domestic vs foreign trade

The gravity equation

Deriving the gravity equation

- We can derive the gravity equation of trade volumes from any model that features complete specialization.
- *Complete specialization* means that each good is produced in *only one country*.

Preferences

- With identical, homothetic preferences and free trade:

$$e(p, u^j) = u^j P(p).$$

- Demand for good i in country j:

$$c_i^j(p) = u^j P_i(p).$$

- Substituting out u^j:

$$c_i^j(p) = E^j \frac{P_i(p)}{\sum_{i'} p_{i'} P_{i'}(P)} \equiv E^j b_i(p).$$

1. Each country consumes the goods in the same proportion, $b_i(p)$.
2. The income elasicity of each good is 1 for each country.

The supply side

- Because of complete specialization, each good is only produced in one country.
- Suppose good i is produced in country j:

$$\sum_{k \in J} c_i^k = x_i^j.$$

- How much of this good does country k buy?

$$\frac{c_i^k}{\sum_{k' \in J} c_i^{k'}} = \frac{E^k}{E^w}.$$

- The export of good i from country j to country k:

$$x_i^{j \to k} = \frac{E^k}{E^w} x_i^j.$$

The volume of trade

- First we multiply by p_i to get the value of the trade flow.
- Let us add up all the goods that country j produces:

$$T^{j\to k} = \sum_i p_i x_i^{j\to k} = \frac{E^k}{E^w} \sum_i p_i x_i^j = \frac{E^j E^k}{E^w}.$$

- This is exactly the gravity equation.

Reasons for complete specialization

Armington assumption

Armington (1969) assumes that consumers value each country's production *as separate goods*. Complete specialization by assumption.

Krugman model

Because firms choose to differentiate their products (to economize on fixed costs), complete specialization is *endogenously* obtained.

Ricardian models

In Dornbusch, Fisher, Samuelson (1977) [see later], each good is only produced in one country.

Frictionless gravity

- The gravity equation without trade costs:

$$T^{j\to k} = \frac{E^j E^k}{E^w}.$$

- We can measure all four variables involved.
- We can then see whether the LHS of the gravity equation is lower than the RHS.
- Let us look at a simple example.

Exports of Hungary

- In 2006, the Hungarian industry sold EUR 86 billion worth of manufactured goods.
  - 40 billion of this went to Hungary,
  - 46 billion were exported.
- Are these numbers consistent with gravity?

Income differences

- Total (nominal) GDP of Hungary was around \$138 billion.
- Total (nominal) GDP of the world was around \$54.6 trillion.
- The rest of the world has a 0.9975 share in world income.
- They should buy 0.9975 fraction of Hungarian output.
  - EUR 85.78 billion

Missing trade

- Relative to this 85.8 billion, only 46 billion is exported.
- 47% of trade is *missing*.

A model with trade costs

A model with trade costs

- Take a differentiated good model.
- Complete specialization.
- But trade is costly.

How to model trade costs?

- Shipping a good from country j to k costs τ^{jk}.
- But in what units?
- Standard assumption (due to Samuelson, 1954): in units of the good being shipped, "iceberg cost".

Iceberg shipping costs

- Only a certain *fraction* of the good arrives at the destination.
  - iceberg melts
  - grain spills
  - china breaks
  - goods get stole by pirates
  - fuel trucks consume fuel
- To ensure that 1 unit arrives, one has to ship $\tau^{jk} > 1$ units of the good.

Why this assumption is convenient

1. Transportation impacts no other market.
2. Implies a *proportional* (rather than additive) increase in the good's price.
    - Works well with constant markups
    - and isoelastic demand.

Consumer vs producer prices

- *Consumer price* is

$$\tilde{p} = \tau p.$$

Demand with iceberg trade costs

- Consumers value all products symmetrically.
  - But prices are now assymetric.
- Utility:

$$U = \left[\sum_{i=1}^{n} x_i^{\alpha} \right]^{1/\alpha} \quad 0 < \alpha < 1$$

- The demand for product i:

$$x_i = E \frac{(\tau_i p_i)^{-\varepsilon}}{\sum_{j=1}^{n} (\tau_j p_j)^{1-\varepsilon}}$$

Deriving the gravity equation

- Suppose each country produces one differentiated variety (Armington assumption).
  - Same results with monopolistic competition (Krugman).
  - Similar results with Ricardian model (Eaton-Kortum).
- Demand for good j in country k:

$$T^{j\to k} = \frac{(\tau^{j\to k} p^j)^{1-\varepsilon}}{\sum_{i=1}^n (\tau^{i\to k} p^i)^{1-\varepsilon}} E^k$$

- Add up across all ks to get total production:

$$E^j = \sum_{k=1}^n \frac{(\tau^{j\to k} p^j)^{1-\varepsilon} E^k}{\sum_{i=1}^n (\tau^{i\to k} p^i)^{1-\varepsilon}}$$

Deriving the gravity equation

- Substitute out p^j.
- Express in terms of the usual gravity terms:

$$T^{j\to k} = \frac{E^k E^j}{E^w}\left(\frac{\tau^{j\to k}}{\Pi^j P^k}\right)^{1-\varepsilon}$$

- Π^j is the average trade cots of a typical *producer* in country j:

$$\Pi^j = \left[\sum_k \frac{E^k}{E^w}\left(\frac{\tau^{j\to k}}{P^k}\right)^{1-\varepsilon}\right]^{1/(1-\varepsilon)}$$

- P^k is the average trade cost of a typical *consumer* in country k.

$$P^k = \left[\sum_j \frac{E^j}{E^w}\left(\frac{\tau^{j\to k}}{\Pi^j}\right)^{1-\varepsilon}\right]^{1/(1-\varepsilon)}$$

Bilateral trade costs

- The higher $\tau^{j\to k}$, the lower the trade between countries j and k.

$$\frac{\partial \ln T^{j\to k}}{\partial \ln \tau^{j\to k}} = 1 - \varepsilon$$

- The higher the elasticity of substitution, the stronger the trade impact of trade costs.
  - Why?
- Estimates of ε range from 2 to 10.

Bilateral trade costs

- Trade costs are not often measured directly.
- Instead,
$$\ln \tau^{j\to k} = \gamma_0 + \gamma_1 \ln d^{j\to k} + \gamma_2 Z^{j\to k} + u^{j\to k}.$$
- Hence loglinear gravity equation:
$$\ln T^{j\to k} = \beta_0 + \beta_1 \ln E^j + \beta_2 \ln E^k - \beta_3 \ln d^{j\to k} - \beta_4 Z^{j\to k} + \tilde{u}^{j\to k}.$$
  - What is β_3?
  - What is included in $\tilde{u}^{j\to k}$?

Multilateral trade costs

- The terms Π^j and P^k capture *multilateral resistence*:
    - A consumer in a distant, secluded island pays high prices on almost everything.
- Only *relative transport costs* matter.
    - For this consumer, a transport cost of 20% may not be that high.
- Because of their nonlinear nature, it is difficult to estimate these average trade costs.

Estimates of trade costs

Estimates of trade costs

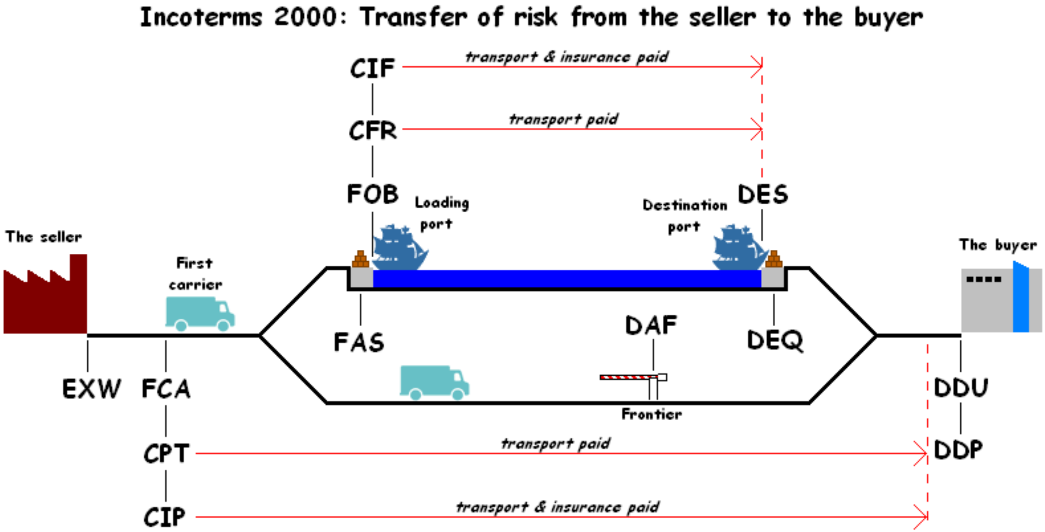
There are three ways to estimate trade costs:

1. direct measures
   - transportation costs and time
   - tariffs etc
2. indirect estimates from trade volumes
   - trade is lower
3. indirect estimates from prices
   - prices are higher

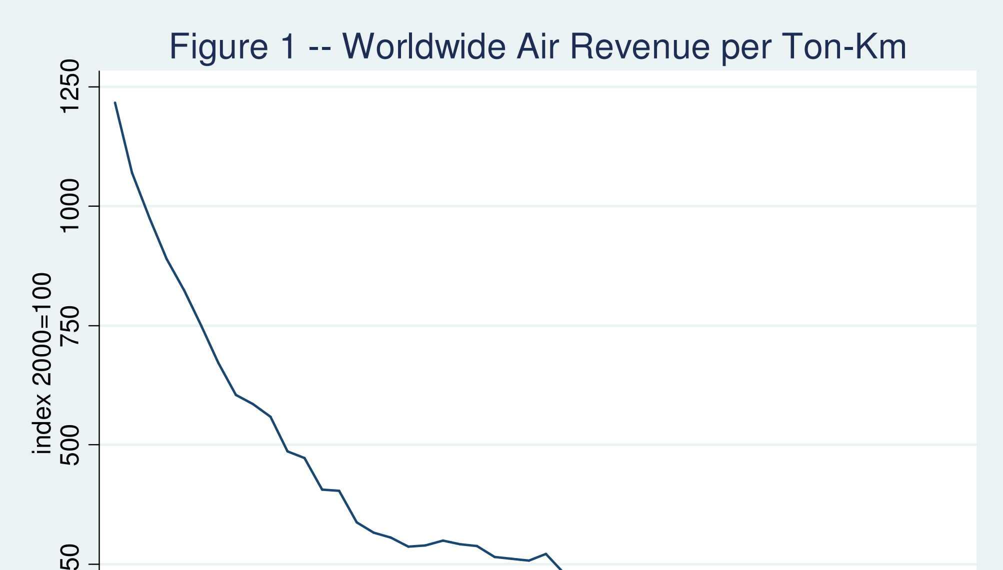
Direct measures

- Price quotes from shipping companies.
- Observed trade costs on actual transactions.
- Prices (and values) are often recorded at multiple *parities*:
  - ex works (EXW): good has not been moved yet
  - free on board (FOB): good is loaded onto ship
  - cost, insurance, freight (CIF): good is delivered to destination port
  - (plus many others)
- Exports are usually recorded at FOB.
- Imports are CIF.

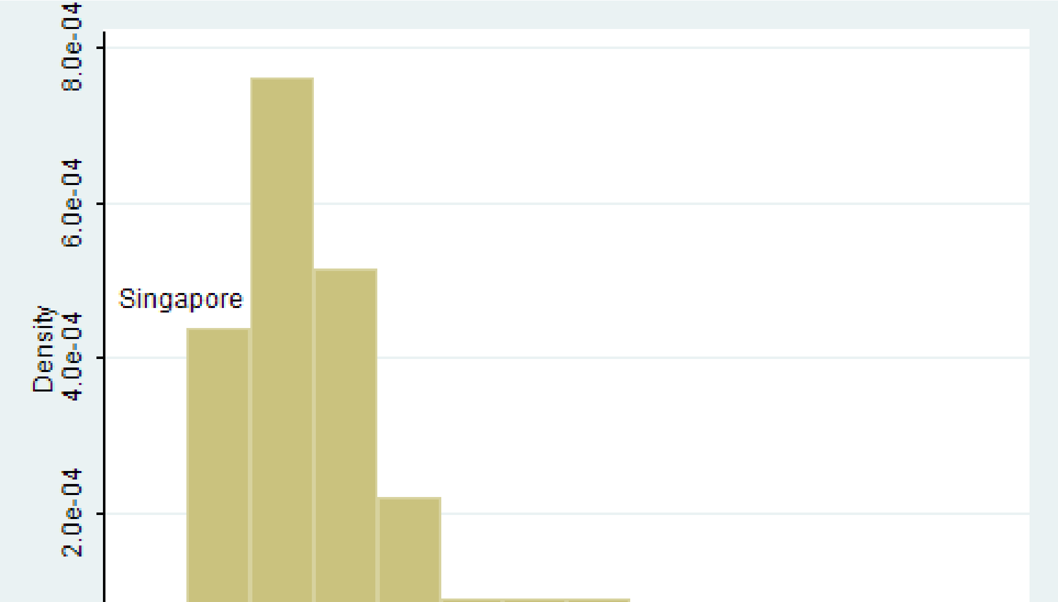
Transport costs



Air freight charges over time



Costs of container imports



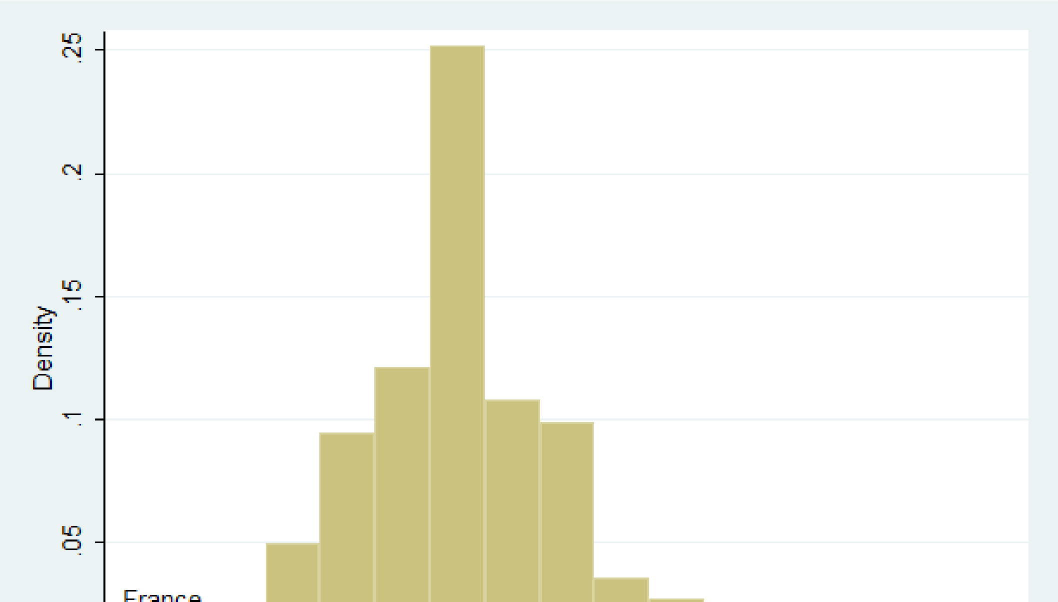
Direct measures

- US import data contains values both at CIF and at FOB.
- The difference is insurance and shipping.
- Hummels (2001, wp) relates these shipping costs to distance, mode of shipping, industry etc.
- In *ad valorem* terms, they vary between 3-4% (computer and office equipment) to over 20% (coal, gas, fertilizers).
  - Table 1 here.

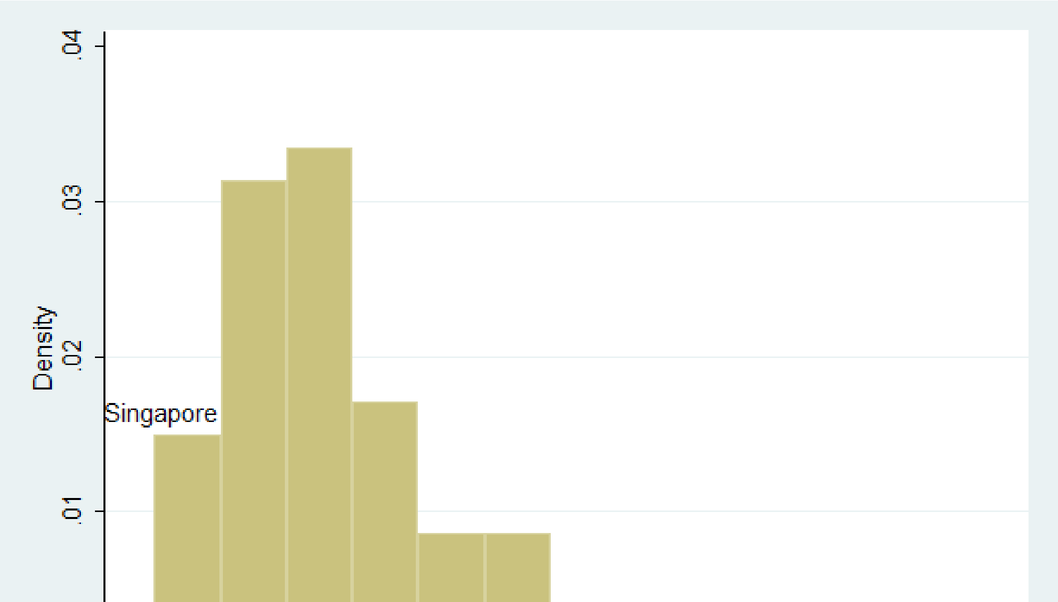
Indirect shipping costs

- There are all kinds of nonpecuniary costs involved:
  1. time
  2. administration
  3. reliability
- The World Bank collects data on these from 181 countries (doingbusiness.org).

Administrative costs of imports



Time costs of imports



Indirect inference

Indirect inference

- We can infer trade costs indirectly from trade volumes as follows.
- Suppose we believe that
$$\ln \tau^{j \to k} = \gamma Z^{j \to k},$$
where Z is some observable (do countries j and k speak a common language, do they have a common currency etc).
- Plug it into the gravity equation
$$\ln T^{j \to k} = \beta_0 + \beta_1 \ln E^j + \beta_2 \ln E^k - \delta Z^{j \to k} + \tilde{u}^{j \to k}.$$
- The effect of Z on trade costs:
$$\gamma = \delta / (\sigma - 1).$$

Issues with indirect inference

1. Our model may be incorrect. (For example, complete vs incomplete specialization.)
2. The error term may not be orthogonal to Z.
3. We can only identify *slopes*, not *levels*.

Examples of indirect inference

- Anderson and van Wincoop (2004, JEL) provides a survey of trade cost estimates.
- Ad valorem equivalents:
    1. different languages: 7%
    2. different currencies: 14%
    3. national border (as opposed to state/province border): 28%
    4. non-adjacent countries: 8%

Appendix

CES review

- Take the following CES utility function:

$$u(x_1, x_2) = [x_1^\alpha + x_2^\alpha]^{1/\alpha},$$

  and define $\varepsilon = 1/(1-\alpha)$, $\alpha = 1 - 1/\varepsilon$
- Maximize utility subject to prices p_1 and p_2:

$$p_1 x_1 + p_2 x_2 = E$$

- What is the relative demand for x_1 and x_2?

Utility maximization

- The marginal rate of substitution

$$\frac{u_1}{u_2} = \frac{x_1^{\alpha-1}}{x_2^{\alpha-1}} = \left(\frac{x_1}{x_2}\right)^{-1/\varepsilon}$$

- In the optimum, this equals the relative price, p_1/p_2:

$$\frac{x_1}{x_2} = \left(\frac{p_1}{p_2}\right)^{-\varepsilon}$$

- The relative demand is loglinear in relative prices.
  - The elasticity of substitution is constant at ε.

Cost minimization

- In parallel, we can solve the cost minimization problem.
- Minimize $E = p_1 x_2 + p_2 x_2$ subject to $u(x_1, x_2) = u_0$.
  - FOC:

$$p_i = \lambda x_i^{\alpha-1}$$

$$E = u_0 \left[p_1^{1-\varepsilon} + p_2^{1-\varepsilon} \right]^{1/(1-\varepsilon)}$$

- The term

$$P \equiv \left[p_1^{1-\varepsilon} + p_2^{1-\varepsilon} \right]^{1/(1-\varepsilon)}$$

  is the *ideal price index*.