Gravity Models: Theoretical Foundations and related estimation issues

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Outline

1. Theoretical foundations
   - From Tinbergen (1962)….
   - … to Anderson and Van Wincoop (2003)

   - The question of zeros in the trade matrix (Helpman, Melitz and Rubinstein, 2005)

2. Empirical equations and some related estimation issues

The Gravity Model: what it is?

- Econometric model (ex-post analysis)
- Workhorse in a number of fields. It has been used to analyze the impact of GATT/WTO membership, RTAs, currency unions, migration flows, FDI between countries, disasters ...
- Initially, not based on a theoretical model

What explain its popularity?

- High explanatory power
- Data easily available
- There are established standard practices that facilitate the work of researchers

The gravity model: the origins

- Proposed by Tinbergen (1962) to explain international bilateral trade
- Called “gravity model” for its analogy with Newton’s law of universal gravitation

The gravity model: the origins

- **Newton's Law** of Universal Gravitation

$$F_{ij} = G \frac{M_i M_j}{D_{ij}^2}$$

F= attractive force; M= mass; D=distance; G = gravitational constant

- **Gravity Model** specification similar to Newton's Law

$$X_{ij} = \frac{K Y_i^{\alpha} Y_j^{\beta}}{T_{ij}^{\theta}}$$

Xij= exports from i to j; or total trade (i.e $X_{ij} + X_{ji}$)
Y= economic size (GDP, POP)
T =Trade costs

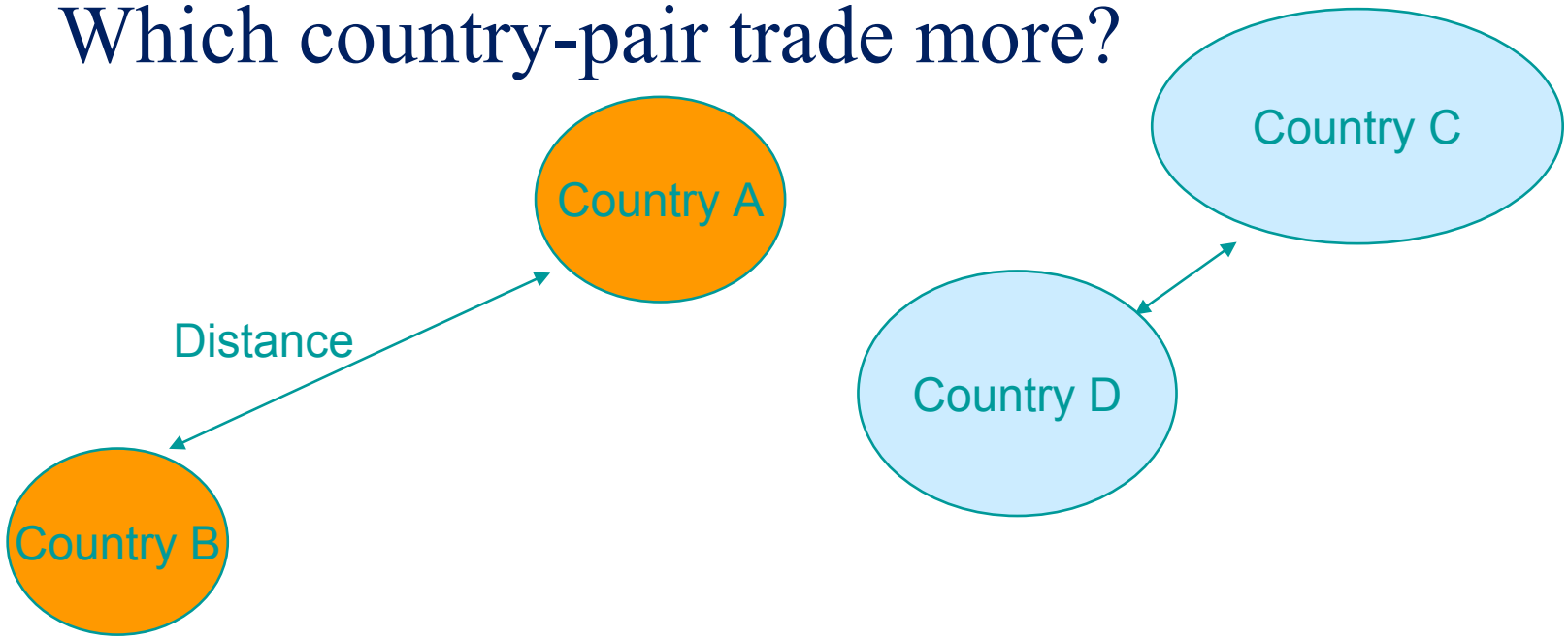
Standard proxies for trade costs in gravity equations

- Distance
- Adjacency
- Common language
- Colonial links
- Common currency
- Island, Landlocked
- Institutions, infrastructures, migration flows,...
- Surprisingly, bilateral tariff barriers often missing

The gravity model: the origins

Bilateral trade between any two countries is positively related to their size and negatively related to the trade cost between them

Which country-pair trade more?



The gravity model: the origins Estimated gravity equation ...

Newton's Law-based Normal Trade

$$ln\,(X_{ij}) =$$

$$= C + a\,ln(Y_i) + b\,ln(Y_j) + c\,ln(dist_{ij}) + \boldsymbol{u}_{ij}$$

Theoretical foundations for the gravity equation

Deardoff (1998) “I suspect that just about any plausible model of trade would yield something very like the gravity equation”

Theoretical foundations of gravity equation: historical evolution

- Anderson (1979)
  - Armington assumption (i.e. goods differentiated by country of origin)
- Bergstrand (1990)
  - Anderson and Monopolistic competition
  - But, he continue using existing price indexes instead of those derived through the theory
- Van Wincoop (2003)
  - Monopolistic competition
  - Provide a practical way to estimate gravity coefficients in a cross section
- Helpman et al. (2006)
  - Heterogenous firms model of trade

A theoretical foundation of the gravity equation: Anderson and Van Wincoop (2003) ..

Step 1: The expenditure share identity

$p_{ij}x_{ij} = s_{ij}E_j$

where p_{ij} = import price

Step 2: Share depends on relative prices

Assuming a CES demand function and that all goods are traded

$s_{ij} = (p_{ij}/P_j)^{1-\sigma}$

where $P_j = \Sigma_i n_i((p_{ij})^{1-\sigma})^{1/(1-\sigma)}$ is the CES price index

A theoretical foundation of the gravity equation: Anderson and Van Wincoop (2003)

Step 3: adding the pass-through equation

$p_{ij} = p^o_i t_{ij}$

superscript o denotes producer price
t = bilateral trade costs

Step 4: aggregating across varieties

$X_{ij} = n_i s_{ij} E_j = n_i (p^o_i t_{ij} / P_j)^{1-\sigma} E_j$

A theoretical foundation of the gravity equation: Anderson and Van Wincoop (2003)

Step 5: using GE condition (summing over all markets, including country i's own market)

$$Y_i = \Sigma_i X_{ij}$$

Solving for $n_i p_i$ and substituting in eq. in Step 4 yields:

A theoretical foundation of the gravity equation: Anderson and Van Wincoop (2003)

Step 6: the reduced form of a intra-industry trade model

$$X_{ij} = \frac{Y_i Y_j}{\Pi_i} \left(\frac{t_{ij}}{P_j} \right)^{1-\sigma}$$

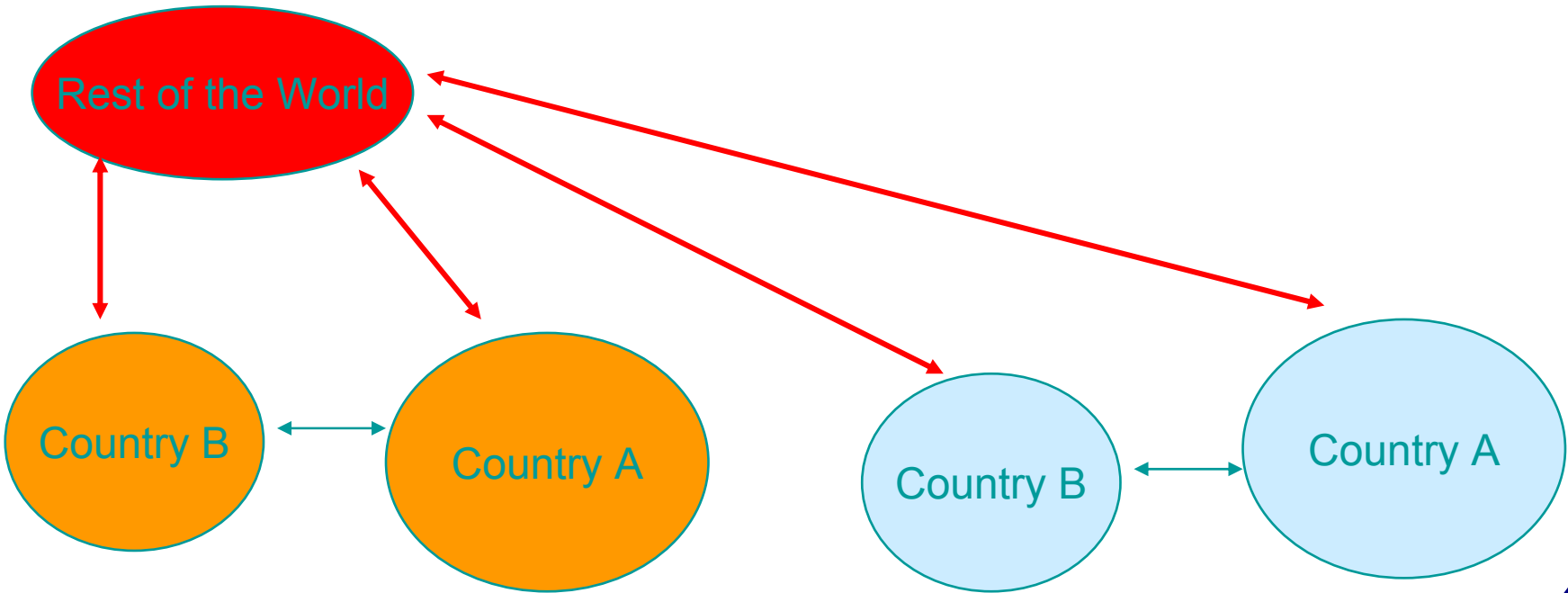
where $\Pi_i=(\Sigma_i t_{ij}^{1-\sigma} E_j/P_j^{1-\sigma})^{1/(1-\sigma)}$

P and Π = Multilateral Resistance Terms

A theoretical foundation for the gravity equation: the intuition

Countries' distance from the "Rest of the World" matters for their bilateral trade

Which country-pair trade more?



A theoretical foundation for the gravity equation: the intuition

The important contribution of Anderson and Van Wincoop's paper has been to highlight that bilateral trade is determined by *relative* trade costs

Estimated gravity equation ...Theoretically Founded "Normal" Trade

Normal trade with resistances

$$ln\,(X_{ij}) =$$

$$= K + a\,ln(Y_i) + b\,ln(Y_j) + c\,ln(bilateral\ trade\ barriers_{ij}) + d\,ln(MRT_i) + e\,ln(MRT_j) + u_{ij}$$

MRT= Multilateral Resistance Term

MRT are not observable.

Multilateral Trade Resistances and the gravity equation

3 ways to take MTR into account:

1. Use an iterative method to solve MRT as function of observable (see Anderson and Van Wincoop, 2003)
2. Calculate Remoteness (trade/GDP weighted average distances from the rest of the world) whereby $\text{Remoteness}_i = \sum j \ \text{distance}_{jj}/(\text{GDP}_j/\text{GDP}_W)$
3. Use country fixed effects for importers and for exporters

Country-specific fixed effects

- Importer (exporter) dummy= it is a 0,1 dummy that denotes the importer (exporter)
- They control for unobserved characteristics of a country, i.e. any country characteristic that affect its propensity to import (export)
- They are used to proxy each country's remoteness
- They do not control for unobserved characteristics of pair of countries e.g. they have a RTA in place (need country pair fixed effects for this)

Estimated gravity equation ...using fixed effects: Cross Country Analysis

In cross country analysis MRT are fixed. Therefore, using country fixed effects yields consistent estimations

$$ln\,(X_{ij}) = K + c\,ln(bilateral\ trade\ barriers_{ij}) + \\ + \Sigma\, d_i\, I_i + \Sigma\, e_i\, I_j + u_{ij}$$

Where I=country specific dummies

There are 2n dummies.

Total observations= n(n-1)

It is Impossible to estimate the coefficient for GDP and other country-specific variables

Estimated gravity equation ...using fixed effects: Panel Data (1)

It is now POSSIBLE to estimate the coefficient for GDP and other country-specific variables

$$ln\,(X_{ij})_t = K + a\,ln(Y_i)_t + b\,ln(Y_j)_t + c\,ln(bilateral\ trade\ barriers_{ij})_t + \Sigma\, d_i\, I_i + \Sigma\, e_i\, I_j + u_{ij}$$

Where I=country specific dummies

There are 2n such dummies

Total observations= n(n-1)T

- It is still not possible to estimate time-invariant country specific characteristics (eg. Island, landlockedness)
- There may be a bias due to the variation over time of MTRs

Estimated gravity equation ... using time-varying fixed effects: Panel Data (2)

In the case of a panel, MRTs may change over time (variation in transport costs or composition of trade)

$$ln\,(X_{ij})_t = K + c\,ln(\text{bilateral trade barriers}_{ij})t + \Sigma\, d_{it}\, I_{it} + + \Sigma\, e_{it}\, I_{jt} + \Sigma\, f_\tau\, L_\tau + u_{ij}$$

Where I=time-varying country specific dummies;

L=time dummy (to take global inflation trends into account)

There are 2nT+T dummies, where T denotes the time period

Impossible to estimate the coefficient of GDP

Estimated gravity equation ... using country-pair fixed effects: Panel Data (3)

address the bias due to the correlation between the bilateral trade barriers and the MRTs

$$ln\,(X_{ij})_t = K + a\,ln(Y_i)t + b\,ln(Y_j)t + c\,ln(\text{bilateral trade barriers}_{ij})t + \Sigma\, d_{ij}\, I_{ij} + u_{ij}$$

Where I= country-pair dummies; There are n(n-1)/2 such dummies

Disadvantage: coefficients of bilateral variables are estimated on the time dimension of the panel AND cannot estimate coefficient for distance, common border, common language ...

A solution: Use random effects and the Hausman test to choose between random and fixed effect estimation

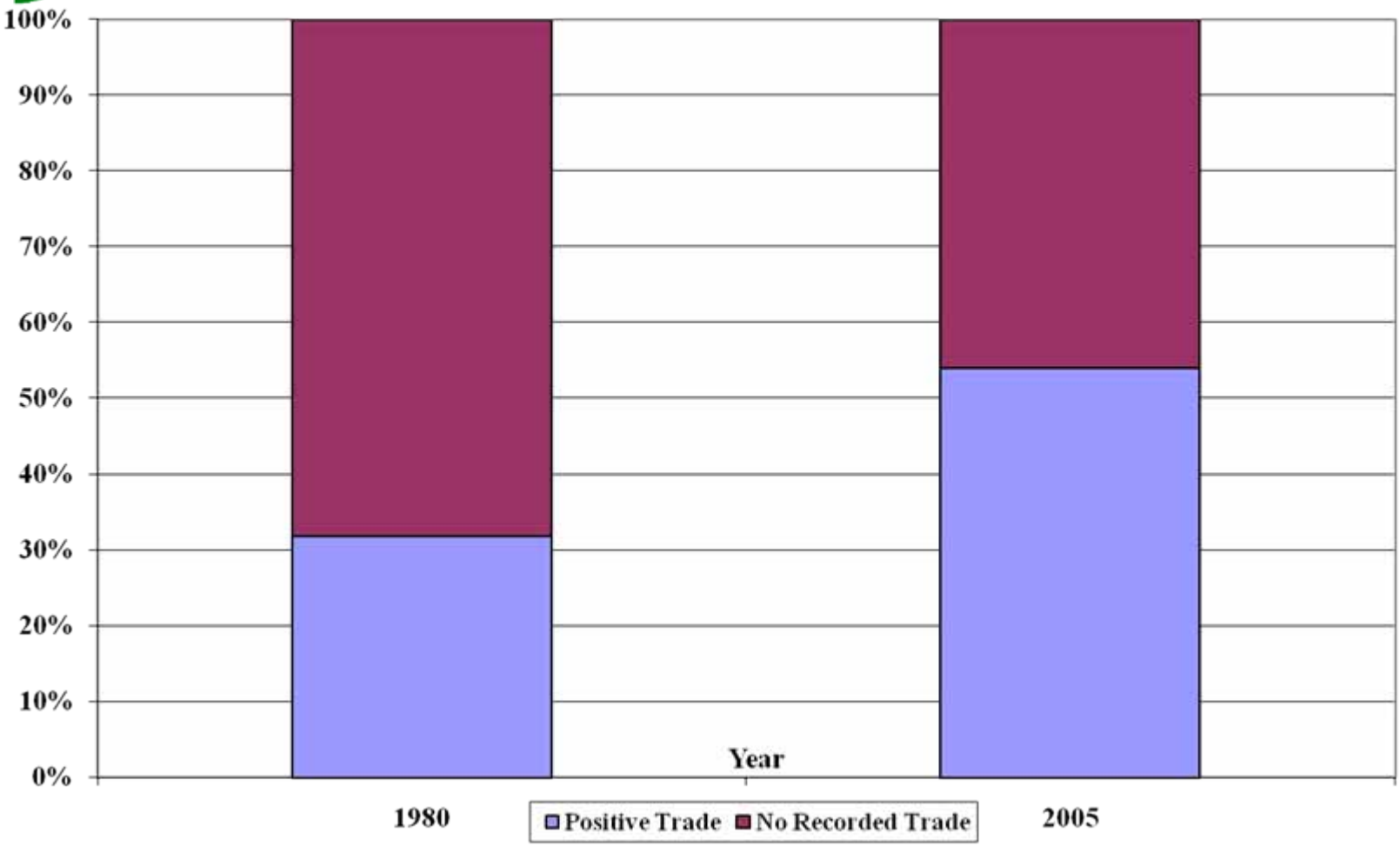
How to proceed?

- Sensitivity analysis, test the robustness of the results to alternative specifications of the gravity equations
- Report the results for the different equations estimated

Recent Theoretical Developments

- Recently, Helpman et al. (2006) derived a gravity equation from an heterogeneous firms model of trade
- The importance of this derivation relates to three issues that previous models of trade could not explain:
  - ***zero**-trade observations*
  - **Asymmetric** trade flows
  - The **extensive margin** of trade: more countries trade over time

The incidence of zero trade



How to handle zero-trade data?

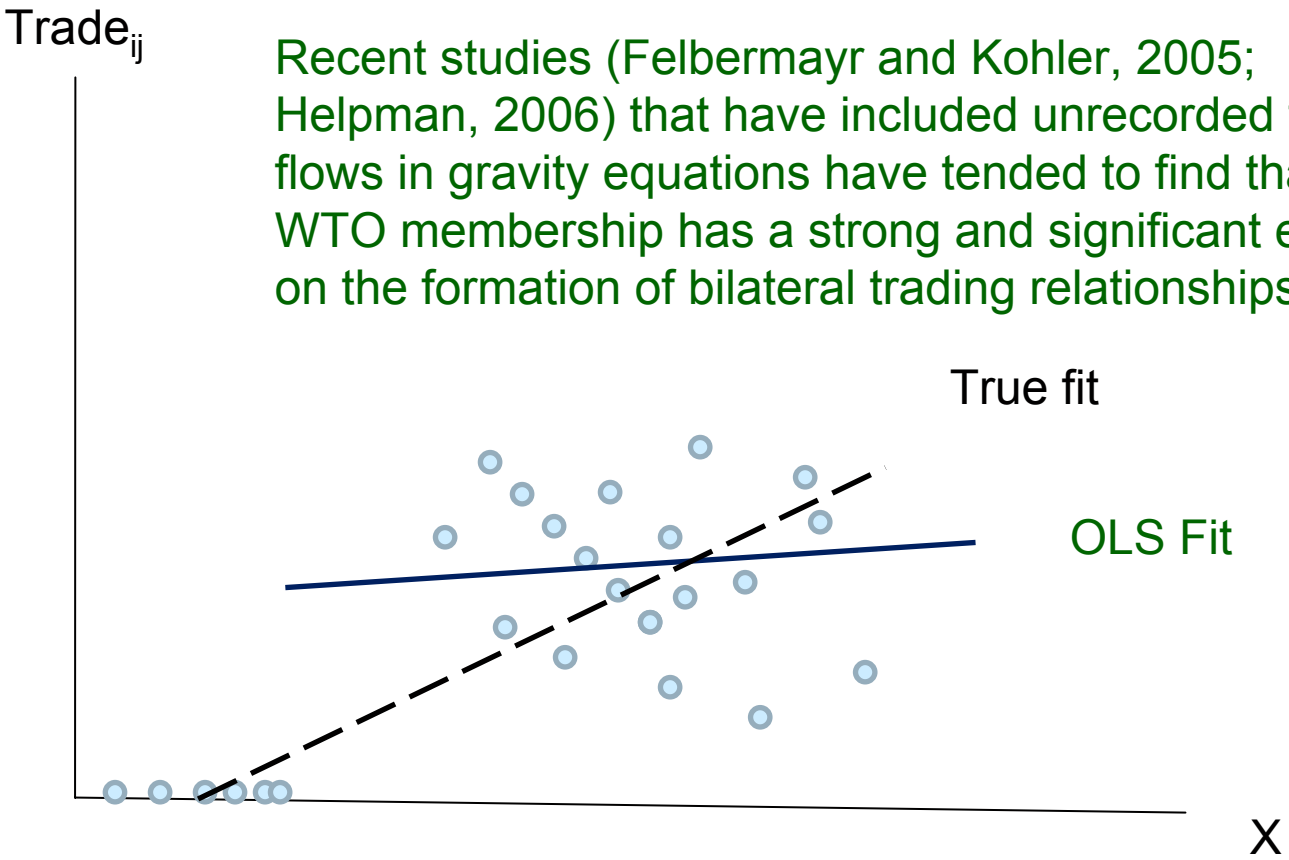
Traditionally,

- When taking logs, zero observations are dropped from the sample. Then, the OLS estimation is run on positive values.

- Take the $\log(1+X_{ij})$, but then use Tobit estimation as the OLS would provide biased results

OLS Bias if zero observations are not used

Recent studies (Felbermayr and Kohler, 2005; Helpman, 2006) that have included unrecorded trade flows in gravity equations have tended to find that WTO membership has a strong and significant effect on the formation of bilateral trading relationships.



How to handle zero-trade data?

More recently,

Helpman et al. (2006) claim: biased results using the standard approach

- In their model, differences in trade costs across countries and firms heterogeneity account for both asymmetric trade flows and zero trade. Zero trade occurs when the productivity of all firms in country i is below the threshold that would make exporting to j profitable.

- Problem: the probability of having positive trade between 2 countries is correlated with unobserved characteristics of that country pair. These characteristics also affect the volume of their bilateral trade, given that they trade.

How to handle zero-trade data?

More recently,

Helpman et al. (2006)provide the following solution:

Use **2 stage estimation**

1. Probit on the likelihood that 2 countries trade
2. Then, estimate the gravity equation, introducing the estimated Mills Ratio to control for sample selection bias (as in the estimation of a selection model a la Heckman) and a variable controlling for firms heterogeneity. Selection bias and omitted variable problem.

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Data sources

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- CEPII Distance and other geography variables http://www.cepii.fr/anglaisgraph/bdd/distances.html