An Overview of Gravity Estimation

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What are Iceberg Trade Costs?

- Iceberg trade costs, τ_{ji}, are a key element in the gravity equation.

- They include all tangible and intangible barriers to trade:
  - Tariffs and non-tariff barriers (quotas etc).
  - Transportation costs.
  - Red tape or administrative barriers.
  - Contractual frictions.
  - Financial impediments (i.e., the need to secure trade finance).

- Some of these barriers can impede within-national trade.
  - τ_{ii} plays a key role in welfare analysis, but is often normalized ($\tau_{ii} = 1$) when estimating the gravity equation.

What are Iceberg Trade Costs?

In the empirical trade literature trade costs are parametrized as follows

$$\tau_{ji} = \mathcal{T} \times \text{Dist}_{ji}^{\beta_d} \times \beta_b^{\text{Border}} \times \beta_a^{\text{FTA}} \times \beta_l^{\text{Lang}} \times \ldots$$

- The justification being that *geo-distance*, *shared border*, *FTAs*, and *common language* can affect all the tangible and intangible barriers to trade, through various channels.

- Distance has a profound effect on trade costs, well beyond its effect on observed transport costs.

Trade Falls with Distance

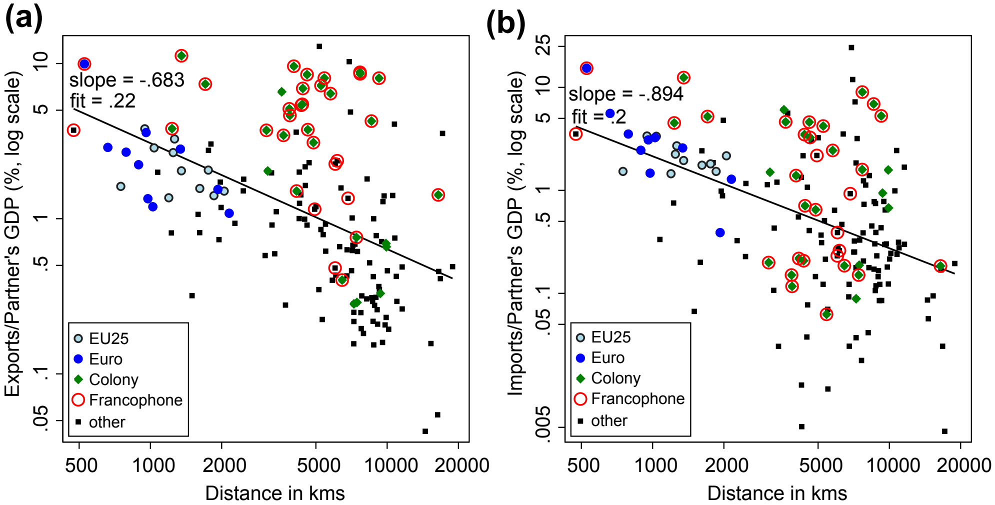
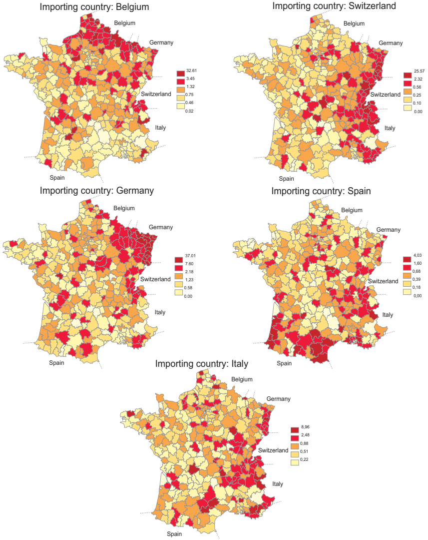


Figure 3.2 Trade is Inversely Proportional to Distance; (a) France's Exports (2006); (b) France's Imports (2006)

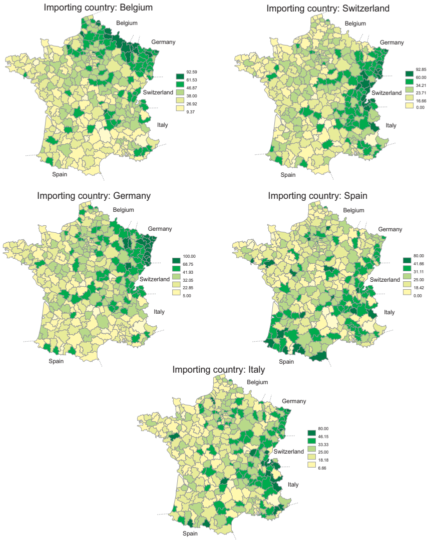
Trade Falls with Distance: *Intensive Margin*

Figure 1: Mean value of individual-firm exports (single-region firms, 1992)



Trade Falls with Distance: *Extensive Margin*

Figure 2: Percentage of firms which export (single-region firms, 1992)



Reduced-Form Gravity Estimation

- We have already reviewed the *structural* gravity estimation.
  - this approach is perhaps more appropriate if our objective is performing counterfactual policy analysis.

- We can also estimate the gravity equation using a *reduced-form* approach, which is quite useful if we are primarily interested in
  1. computing the magnitude of the trade costs;
  2. the determinants of trade costs;
  3. how the role of each cost factor has evolved over time.

- A puzzling finding from reduced-form gravity estimations is that the importance of *distance* has been rising over time!

Two Commonly-Used Reduced-Form Estimators

OLS Estimation:

$$\ln X_{ji} = \underbrace{\beta_d \ln \text{Dist}_{ji} + \text{Controls}_{ji} + M_i + X_j}_{\boldsymbol{\beta} \mathbf{Z}_{ji}} + \varepsilon_{ji}.$$

– Moment condition: $\sum_{ji} \mathbf{Z}_{ji} \cdot \left(\ln X_{ji} - \ln \hat{X}_{ji}\right) = 0$

PPML Estimation:

$$X_{ji} = \exp(\underbrace{\beta_d \ln \text{Dist}_{ji} + \text{Controls}_{ji} + M_i + X_j}_{\boldsymbol{\beta} \mathbf{Z}_{ji}}) + \varepsilon_{ji}.$$

– Moment condition: $\sum_{ji} \mathbf{Z}_{ji} \cdot \left(X_{ji} - \hat{X}_{ji}\right) = 0$

PPML or OLS?

- Advantages of the PPML estimator:
  1. It can naturally account for zeros
  2. The estimated fixed effects, $\hat{M}_i$ and $\hat{X}_i$, are consistent with equilibrium conditions (Fally, 2015).
  3. Provides consistent estimates in the presence of heteroskedasticity.

- Disadvantage of the PPML estimator: it is prone to *small sample bias*.

A Meta-Analysis of Gravity Estimation Results

Table 3.4 Estimates of Typical Gravity Variables

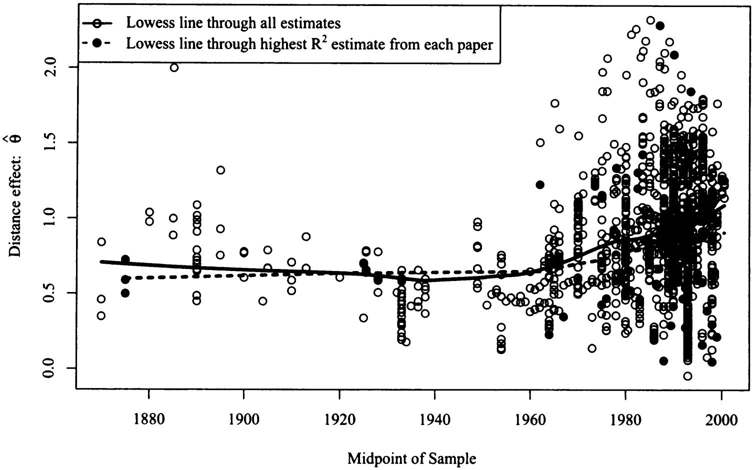
	All Gravity				Structural Gravity			
Estimates:	**Median**	**Mean**	**s.d.**	**#**	**Median**	**Mean**	**s.d.**	**#**
Origin GDP	.97	.98	.42	700	.86	.74	.45	31
Destination GDP	.85	.84	.28	671	.67	.58	.41	29
Distance	−.89	−.93	.4	1835	−1.14	−1.1	.41	328
Contiguity	.49	.53	.57	1066	.52	.66	.65	266
Common language	.49	.54	.44	680	.33	.39	.29	205
Colonial link	.91	.92	.61	147	.84	.75	.49	60
RTA/FTA	.47	.59	.5	257	.28	.36	.42	108
EU	.23	.14	.56	329	.19	.16	.5	26
NAFTA	.39	.43	.67	94	.53	.76	.64	17
Common currency	.87	.79	.48	104	.98	.86	.39	37
Home	1.93	1.96	1.28	279	1.55	1.9	1.68	71

Notes: The number of estimates is 2508, obtained from 159 papers. Structural gravity refers here to some use of country fixed effects or ratio-type method.

Source: Head and Mayer (2014, Handbook Chapter)

The Distance Elasticity Puzzle

FIGURE 3.—THE VARIATION OF $\hat{\theta}$ GRAPHED RELATIVE TO THE MIDPERIOD OF THE DATA SAMPLE



Source: Disdier and Head (2008, ReStat)

The Distance Elasticity Puzzle

Why has the elasticity of trade w.r.t. distance been rising?

- *The rise of vertical specialization*: input-output linkages multiply the effect of trade costs.

- *The rise of FDI*: it is more cost-efficient to perform FDI than to perform direct trade with distant partners.

- Other reasons?

The Residual Approach to Estimating Trade Costs

– If we are only interested in determining the magnitude of τ_{ji}, we can use the residual approach developed by Head and Ries (2001).

– This approach builds on a typical gravity equation,

$$X_{ji} = \frac{a_j \left(w_j \tau_{ji}\right)^{-\epsilon}}{\sum_{\ell=1}^{N} a_\ell \left(w_j \tau_{ji}\right)^{-\epsilon}},$$

which can be produced using the *Armington*, *EK*, *Krugman*, or *Melitz-Pareto* models.

– Recall that, even though these models yield the same representation, a_j and ϵ assume different economic interpretations in each model.

The Residual Approach to Estimating Trade Costs

– Assume that $\tau_{ii} = 1$, then the gravity equation implies

$$\frac{X_{ji}}{X_{ii}} = \left(\frac{w_j}{w_i}\right)^{-\epsilon} \tau_{ji}^{-\epsilon}$$

– Assume that $\tau_{ji} = \tau_{ij}$, then we can calculate Head-Ries index for trade costs as follows:

$$\tau_{ji}^{-\epsilon} = \sqrt{\frac{X_{ji}X_{ij}}{X_{ii}X_{jj}}}$$

– Computing the above index can be challenging because it requires data on internal trade (X_{ii} and X_{ji}).

An Application of The Residual Approach

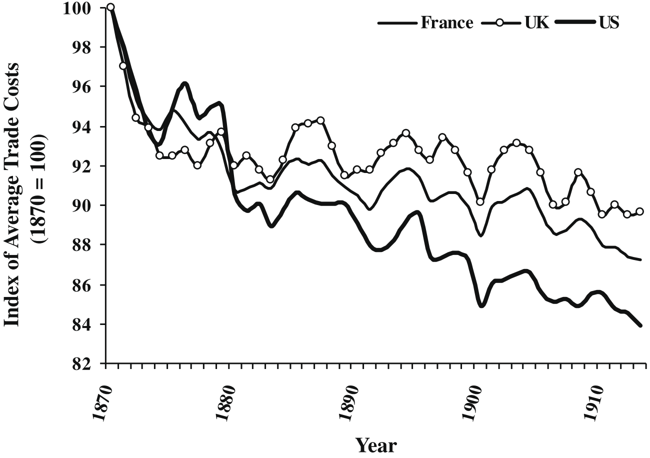


Fig. 2. Index of average trade costs for France, the UK, and the US, 1870–1913.

Source: Jacks, Meissner, and Novy (2010)

Interpreting the Decline in Trade Costs Indexes

Two ways to interpret the decline (over time) in the Head-Ries index

1. Trade costs, τ_{ji}'s, are falling due to tariff liberalization, containerization, etc.
2. The trade elasticity, ϵ, is declining because of the changing composition of traded goods or changes to international technology dispersion.

How Large are Trade Costs After-all?

- How large are the trade costs estimated using these different approaches?

How Large are Trade Costs After-all?

- How large are the trade costs estimated using these different approaches?
  - *Answer*: puzzlingly large.

- Transport costs and tariffs can explain a small fraction of the estimated trade costs.

TABLE 7
TARIFF EQUIVALENT OF TRADE COSTS

	method	data	reported by authors	$\sigma=5$	$\sigma=8$	$\sigma=10$
all trade barriers						
Head and Ries (2001) U.S.-Canada, 1990-1995	new	disaggr.	48 ($\sigma=7.9$)	97	47	35
Anderson and van Wincoop (2003) U.S.-Canada, 1993	new	aggr		91	46	35
Eaton and Kortum (2002) 19 OECD countries, 1990 750-1500 miles apart	new	aggr.	48–63 ($\sigma=9.28$)	123–174	58–78	43–57
national border barriers						
Wei (1996) 19 OECD countries, 1982-1994	trad.	aggr.	5 ($\sigma=20$)	26–76	14–38	11–29
Evans (2003a) 8 OECD countries, 1990	trad.	disaggr.	45 ($\sigma=5$)	45	30	23
Anderson and van Wincoop (2003) U.S.-Canada, 1993	new	aggr.	48 ($\sigma=5$)	48	26	19
Eaton and Kortum (2002) 19 OECD countries, 1990	new	aggr.	32–45 ($\sigma=9.28$)	77–116	39–55	29–41
language barrier						
Eaton and Kortum (2002) 19 OECD countries, 1990	new	aggr.	6 ($\sigma=9.28$)	12	7	5
Hummels (1999) 160 countries, 1994	new	disaggr.	11 ($\sigma=6.3$)	12	8	6
currency barrier						
Rose and van Wincoop (2001) 143 countries, 1980 and 1990	new	aggr.	26 ($\sigma=5$)	26	14	11

Source: Anderson and Van Wincoop (2004, JEL)

Limitations of Existing Transport Cost Estimates

- Existing estimates of transport costs are subject to two limitations
  1. they depend crucially on the chosen trade elasticity value.
  2. in gravity models, trade costs are empirically indistinguishable from taste (i.e., higher trade costs can be interpreted as consumers having more taste for local product varieties)

- One way to address the above limitation is to infer trade costs from regional price dispersion (Atkin and Donaldson, 2015).
  - The no arbitrage condition implies that for good ω

$$\ln p_{ji}(\omega) - \ln p_{ii}(\omega) = \ln \tau_{ji}(\omega)$$

  - With good-specific data on regional prices, we can back out $\tau_{ji}(\omega)$.

Gravity Estimation with Unobserved Heterogeneity

- Trade data is often reported at the industry-level, which is the sum of trade over many different types of goods

$$X_{ji} = \sum_{\omega} X_{ji,\omega}$$

- We may suspect that different types of goods are subject to different trade elasticities:

$$X_{ji,\omega} = \frac{a_j \left(w_j \tau_{ji}\right)^{-\epsilon_\omega}}{\sum_{\ell=1}^{N} a_\ell \left(w_j \tau_{ji}\right)^{-\epsilon_\omega}}, \quad \omega \in \{1, ..., M\}$$

$\Longrightarrow$ applying standard techniques to aggregated trade data, $\{X_{ji}\}$, will lead to *aggregation bias* when estimating the effect of Dist or RTAs on trade.

Alternative Approach (*Fieler, 2010 & Lashkaripour, 2019*)

- Assume a standard parmaterization for τ_{ji}

$$\tau_{ji} = \mathcal{T} \times \text{Dist}_{ji}^{\beta_d} \times \beta_b^{\text{Border}} \times \beta_a^{\text{FTA}} \times \beta_l^{\text{Lang}}$$

- Jointly estimate the trade costs parameters, $\boldsymbol{\beta}$, the exporter FE, $\boldsymbol{\alpha}$, and the type-specific trade elasticities, $\boldsymbol{\epsilon} \equiv \{\epsilon_\omega\}$, by solving

$$\min_{\boldsymbol{\alpha},\boldsymbol{\beta},\boldsymbol{\epsilon}} \sum_{j,i} \left(\sum_{\omega} \hat{X}_{ji,\omega}(\boldsymbol{w}; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\epsilon}) - X_{ji} \right)^2$$

$$\text{s.t.} \;\; w_i L_i = \sum_{j,i} \sum_{\omega} \hat{X}_{ji,\omega}(\boldsymbol{w}; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\epsilon}).$$

  - The above problem can be tackled using the MPEC method.
  - To identify the ϵ, we need to assume that $\tau_{ji} = \tau_{ij}$.

Fit of the Gravity Model

In-Sample Fit

- Not great if we assume balanced trade and symmetric trade costs
- Good if we allow for unbalanced trade or asymmetric trade costs.

Out-of-Sample Fit

- Poor: the gravity model does a poor job at predicting changes in X_{ji} in response to observed changes in tariffs (Lai and Trefler, 2002)
- How can we improve the out-of-sample fit?