

# Heterogeneity and the Distance Puzzle

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September 2019

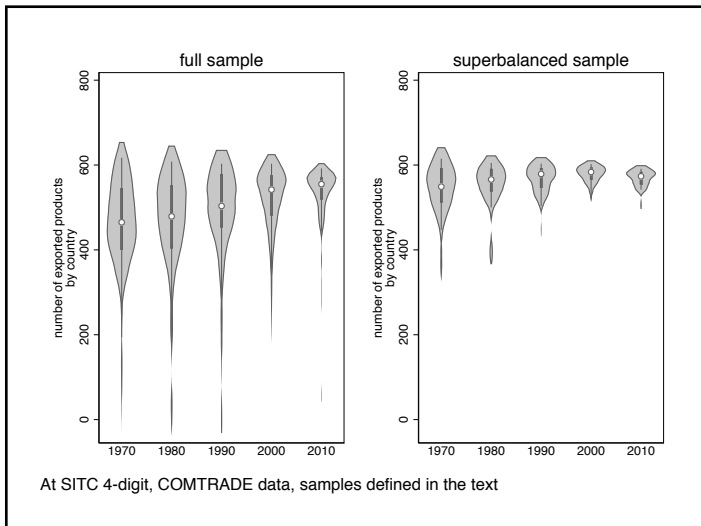
# Introduction: the paradox of distance

- ▶ The distance effect is increasing or stable through time in gravity models: Disdier & Head, (2008), Head & Mayer (2013)...
- ▶ This seems counter-intuitive ("Death of distance")
- ▶ Various answers in the literature (see Head & Mayer (2013)):
  - ▶ Problem with the log-linear estimation strategy?
    - ▶ Not taking zeros into account + heteroskedasticity
    - ▶  $\Rightarrow$  PPML estimates (Santo Silva & Tenreyro (2006), , Bosquet & Boulhol (2015))
  - ▶ Composition effect (Larch et al. (2016))
  - ▶ Relative evolution of short-distance trade costs compared to long-distance trade costs (Buch & al. (2004), Krautheim (2012))
  - ▶ Input-output linkage (Daudin et al. (2011))
  - ▶ Network : the distance coefficient does not depend on trade costs (Chaney (2018))

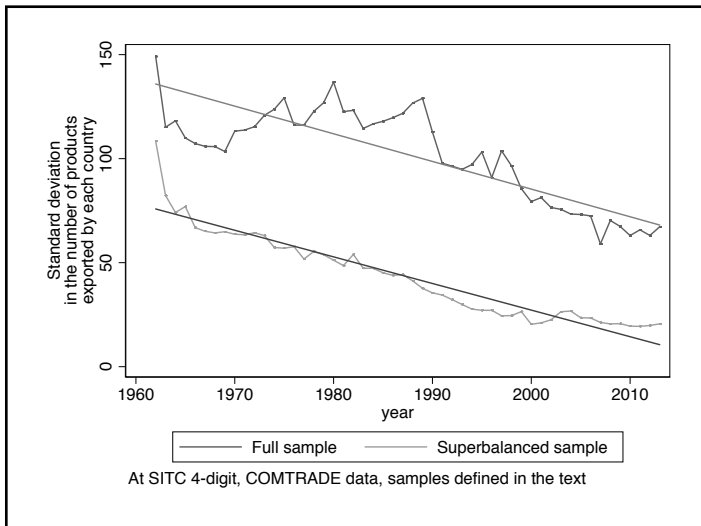
# How do we contribute?

- ▶ Every theoretical foundation of the gravity equation delivers a relationship between the distance elasticity and a degree of structural heterogeneity in some model-specific structural dimension
  - ▶ "Trade elasticity" (Arkolakis et al. (2012))
- ▶ The distance coefficient is the product of:
  1. The elasticity of distance to trade costs
  2. The elasticity of trade to trade costs
- ▶ Empirical evidence on the historical evolution of structural heterogeneity is notoriously scarce
  - ▶ The only other try we know of is Berthelon & Freund (2008) from the late 1980s to early 2000s
- ▶ We document over 1962-2013 how the increasing substitutability of the bundles shipped out by each country (Armington framework) contributes to the paradox

# Dispersion of the number of products exported by each country



# Standard deviation in the number of products exported by each country



# Overview

## The distance puzzle in our data

- Benchmark estimation

- Composition and sample effects

- Summing up: the robustness of the distance puzzle

## Interpreting the distance coefficient

- What does the trade elasticity actually measures?

- What do we know about the evolution of the trade elasticity?

## Estimation strategy and results

- Benchmark estimation

- Robustness checks

## Conclusion

# Summary of results

- ▶ Robustness of distance puzzle in 1962-2013: increase in distance coefficient
  - ▶ +5% controlling for estimation strategy
  - ▶ +31% controlling for composition and sample effects
- ▶ Evolution of heterogeneity parameter:
  - ▶ ??% increase in 1963-2013 (??% in 1970-2013)
  - ▶ this estimate is likely to be a lower bound
- ▶ Elasticity of trade costs to distance has not increased
  - ▶ ???% decrease in 1963-2013
  - ▶ ??% decrease in 1970-2013
- ▶ Which dimension of increased country similarity?
  - ▶ Result obtained within the Armington framework
  - ▶ Increased substitutability of traded product bundles

# Roadmap

## The distance puzzle in our data

- Benchmark estimation

- Composition and sample effects

- Summing up: the robustness of the distance puzzle

## Interpreting the distance coefficient

- What does the trade elasticity actually measures?

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# Estimation procedure (1)

- ▶ run gravity equations (obviously)
  - ▶ COMTRADE data, 1962-2009 STIC 4 digits (1962-2009 )
  - ▶ cross section, no panel
  - ▶ focus on evolution of distance elasticity overtime
  - ▶ using the PPML estimator (consistency & efficiency)
- ▶ Microfounded gravity equation (Anderson & Wincoop (2003)):

$$X_{ij,t} = \left( \frac{Y_{i,t} Y_{j,t}}{Y_t} \right) \left( \frac{\tau_{ij,t}}{\Pi_{i,t} P_{j,t}} \right)^{\epsilon_t}$$

- ▶ heterogeneity parameter:  $\epsilon_t$ :  $1 - \sigma_t$  in Armington (sector or firm productivity heterogeneity in the framework respectively of Eaton & Kortum and Melitz)

## Estimation procedure (2)

- ▶ Trade costs:

- ▶ distance parameter:  $\bar{\theta}_{ij}$
- ▶ time-invariant cost vector of controls (adjacency,...):  $Z_{ij}$
- ▶ time-varying cost vector of controls (policy: FTAs,...):  $S_{ijt}$
- ▶ unobserved bilateral trade cost component assumed to have mean zero conditional on the observables:  $\nu_{ijt}$

$$\tau_{ijt} = \exp \{ \rho_t \ln \bar{\theta}_{ij} + Z_{ij} \zeta_t + S_{ijt} \varsigma_t + \nu_{ijt} \}$$

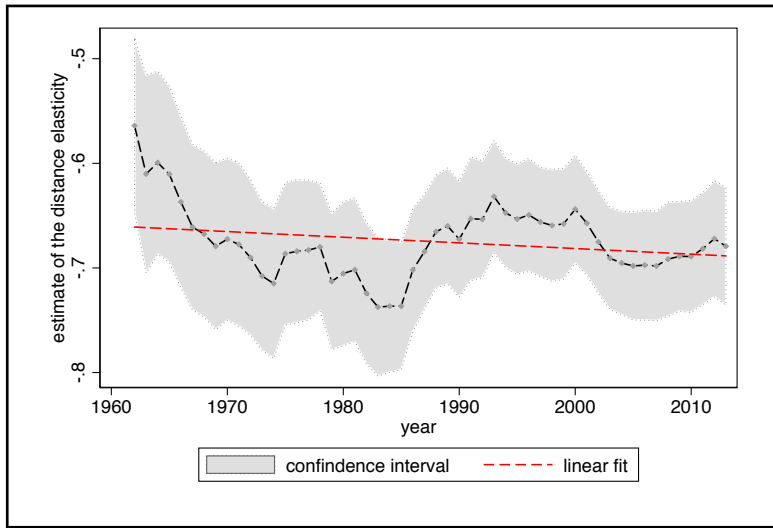
- ▶  $\rho_t$  is the 'world shrinkage' parameter  
i.e. elasticity of trade costs to distance

- ▶ Estimated equation:

$$X_{ij,t} = \exp \left( \xi_t - \delta_t \ln \bar{\theta}_{ij} + Z_{ij} \tilde{\zeta}_t + S_{ijt} \tilde{\varsigma}_t + f_{it} + f_{jt} \right) \eta_{ijt}$$

- ▶  $f_{it}$  and  $f_{jt}$  are fixed effects to control for price levels
- ▶  $\xi_{ijt}$  is a multiplicative error term which includes the exponentiated unobserved bilateral trade cost
- ▶ distance elasticity:  $-\delta_t = \epsilon_t \rho_t$

## Baseline regression (PPML)

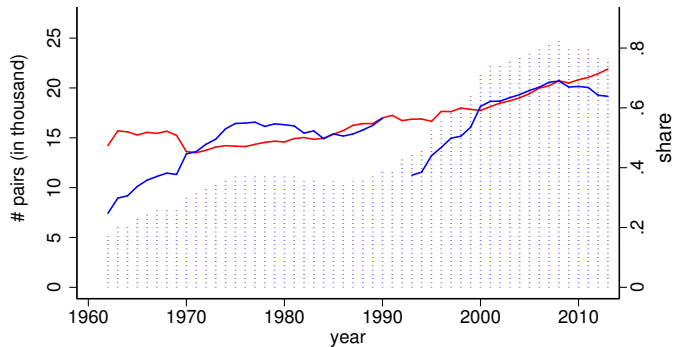


Increase in absolute value of 4.5% : basically stable

# Sample composition effect

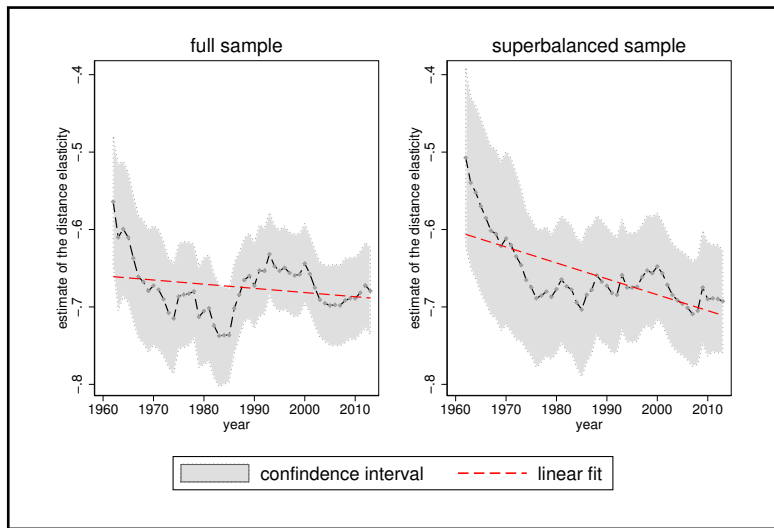
- ▶ We know the country sample potentially matters
  - ▶ Increasing number of new low volume long-distance relationship
  - ▶ Potentially increases the distance elasticity of trade (Mayer et al. (2019), Head & Mayer (2013) )
  - ▶ Though it should be less of an issue with PPML
- ▶ There are big sample issues in the data
- ▶ Test: keep only trading pairs that have reciprocal non-zero trade every year from 1962 to 2009 ("Superbalanced sample")
  - ▶ It deepens the puzzle

# Share of active pairs



- ..... # active pairs
- share of active pairs (out of yearly potential pairs)
- share of active pairs (out of active pairs in subperiod)

# Superbalanced sample



Increase in absolute value of 18.2%

## Sector composition

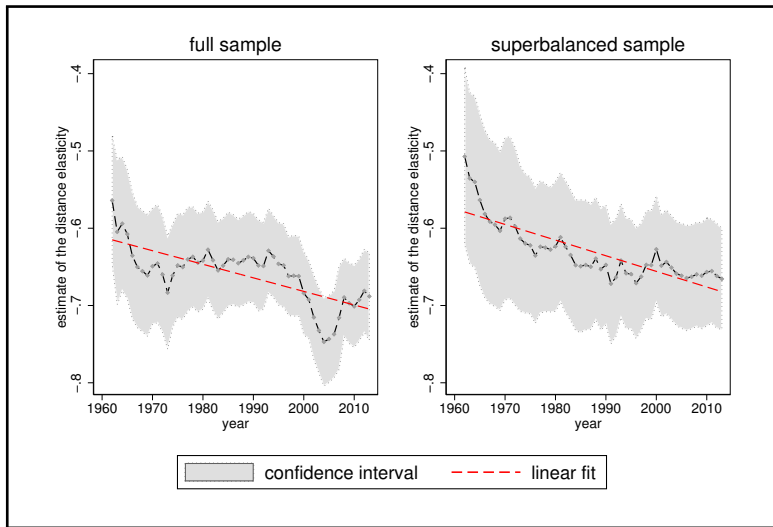
- ▶ We do not expect the elasticity of trade to distance to be constant by sector
  - ▶ Some sectors can only be procured in specific places (oil), other are more mobile (textile)
  - ▶ In the long-term, the decline of the share of oil should increase the absolute value of the elasticity of trade to distance
  - ▶ In the short-term, price variation of primary products change their share in trade and hence the elasticity of trade to distance
- ▶ We use two tests
  1. Fixing the sectoral composition of total trade to 1962. We modify all trade flows by a sector-specific factor.

$$\tilde{X}_{ijt}^k = X_{ijt}^k * \frac{S_{w,1962}^k}{S_{w,t}^k}$$

2. Fixing the sectoral composition of each country's export to 1962. We modify all trade flows by a sector and country-specific factor

$$\tilde{X}_{ijt}^k = X_{ijt}^k * \frac{S_{i,1962}^k}{S_{i,t}^k}$$

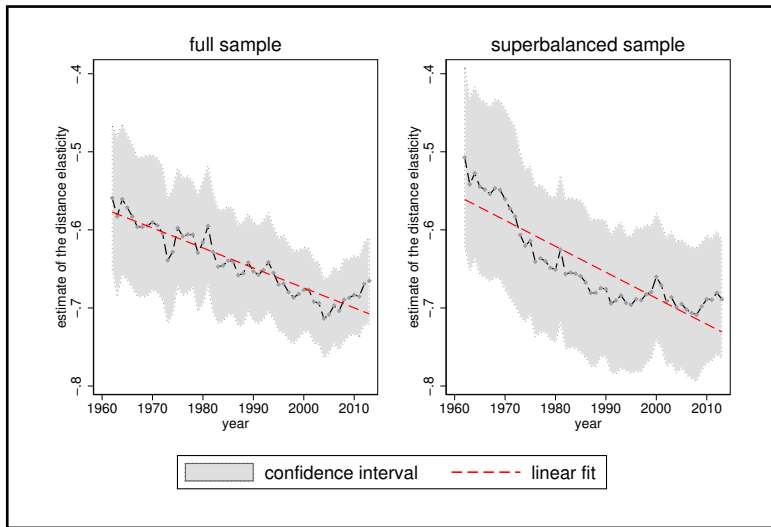
## Product composition effect: fixing the world bundle



Increase in absolute value of 14.5 and 18.4%



## Product composition effect: fixing the country bundle



Increase in absolute value of 22.7 and 31.4%

## Summary (PPML)

**Table:** Evolution of  $\delta_t$ : sample and composition effects

	FULL			STABLE		
	rate (%)	R-sq	total change	rate (%)	R-sq	total change
Baseline	.09*	.07	1.045	.33***	.49	1.182
World bundle	.26***	.53	1.145	.33***	.68	1.184
Country bundle	.40***	.87	1.227	.54***	.77	1.314

Note: Estimated annualized growth rates reported in col.2 and col.5 are obtained as a geometric fit on the basis of annual point estimates of the distance coefficient in 1962-2013. Col.3 and col.6 report the share of time variation in the point estimate explained with the annualized growth rate.

# Ingredients of the puzzle

- ▶ The distance coefficient is the elasticity of trade to distance
  - ▶ Trivial: the whole point of log-linear equations
  - ▶ Still the case in the Poisson specification
- ▶ It is a product of two coefficients:
  - ▶ Elasticity of trade flows to trade costs  $\epsilon$
  - ▶ Elasticity of trade costs to distance  $\rho$
- ▶ The 'death of distance' intuition is really about the elasticity of trade costs to distance (Which should be going down)
- ▶ But it does not tell much about the heterogeneity dimension, i.e. the trade elasticity  $\epsilon$

## Short incursion in microfoundations (1)

- ▶ The gravity equation can be justified by three canonical families of theories: (see Head & Meyer(2014) )
- ▶ Ricardian framework (Eaton & Kortum (2002))  
Homogeneous goods  
Shop around the world for lowest cost supplier (intersectoral productivity heterogeneity)
- ▶ Heterogeneous firms framework: (Melitz (2003), Chaney (2008))  
Trade because all firms produce different varieties  
A subset of firms enters export markets (intrasectoral productivity heterogeneity)
- ▶ Armington framework (Anderson and Wincoop (2003))  
Trade because consumers value variety  
Country-specific goods (heterogeneity: degree of substitutability between bundles)

## Short incursion in microfoundations (2)

- ▶ Ricardian framework:
  - ▶ Distance coefficient:  $\rho\theta$
  - ▶  $\theta$  captures intersectoral productivity dispersion
  - ▶ if sectors have similar productivity
    - small differences in variable costs have a large effect on trade flows
    - high elasticity of trade to trade costs
- ▶ Monopolistic competition between heterogeneous firms:
  - ▶ Distance coefficient:  $\rho\gamma$
  - ▶  $\gamma$  captures productivity dispersion across firms (parameter of Pareto)
  - ▶ if distribution decays swiftly, higher probability that productivity cut-off for exporting is close to the mass of firms
    - small differences in variable costs have large effect on entry
    - high elasticity of trade to trade costs

## Short incursion in microfoundations (3)

- ▶ Armington framework
  - ▶ Distance coefficient:  $\rho(1 - \sigma)$
  - ▶  $\sigma$  captures degree of similarity between country-specific product bundles
  - ▶ if the set of goods produced by different countries is similar
    - high Armington elasticity
    - high elasticity of trade to trade costs
- ▶ In all cases: elasticity of trade flows to trade costs is inversely related to heterogeneity

# Measuring the trade elasticity (1)

- ▶ Evolution on the supply side
  - ▶ Technological dissimilarity in productivity between sectors or firms
  - ▶ Levchenko & Zhang (2016) 1960-2010 in 75 countries: within-country convergence in knowledge shocks between sectors (but not the Eaton & Kortum parameter)
  - ▶ Andrews et al. (2016) 1997-2014 OECD: divergence between firm productivity inside sectors. But there are difficulties in interpreting it in the Meltiz framework
- ▶ Evolution on the demand side
  - ▶ Welsch (2006): among exporters to the French market the lower-tier Armington elasticity peaked in the 1970s and declined thereafter
  - ▶ Broda et al. (2006): compares American imports between 1972-1988 and 1990-2001 they find a decrease
  - ▶ These results would deepen the distance puzzle

## Measuring the trade elasticity (2)

- ▶ Measuring the level of Armington elasticity
  - ▶ A perennial question in trade economics from Feenstra (1994) to the review in Feenstra (2018)
  - ▶ The canonical method assumes that it is constant through time: that is not interesting for us
  - ▶ Feenstra's elasticity parameter determines short-run, marginal, longitudinal effects, whereas we are interested in the parameter that determines long-run, equilibrium, cross-section outcomes
- ▶ Our method
  - ▶ Measure the evolution of Armington elasticities
  - ▶ Its irrelevance in the Melitz and Eaton & Kortum framework is linked to the specific distribution function of productivity
  - ▶ uses CIF unit values and bilateral trade flows to estimate the trade elasticity
  - ▶ we need a measure of the aggregate level: that cannot be generally mimicked by a theoretically grounded weighted average of sector-specific trade elasticities (Imbs & Mjean (2015)). So we assume they are all the same and work on aggregate data



## Our equation (1)

- ▶ One-good Armington framework.  $X_{ij}$  is the cif value of the exports from  $i$  to  $j$  are:

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

$P_{ij}$  is the cif price and  $P_j$  is the price index in the destination and  $Y_j$  total import demand in the destination. The exponent  $(1 - \sigma)$  is the trade elasticity

- ▶ Aggregate exports are the sum of imports from each sector  $k$  where a sector corresponds to a SITC 4-digit category:  
 $X_{ij} = \sum_k X_{k,ij}$ . Sectoral demand in country in sector for imported goods is given by:

$$Y_{k,j} = \left( \frac{P_{k,j}}{\beta_k P_j} \right)^{1-\sigma} Y_j$$

Where  $P_{k,j}$  and  $P_j$  are price indexes,  $\beta_k > 0$  is a sector-specific preference parameter,  $Y_j$  is total demand for imported goods,  $\sigma > 1$  is the elasticity of substitution between sectors.

## Our equation (2)

Each country exports a specific national variety. Preferences within each sector  $k$  between national varieties are assumed well represented by a CES utility function with the same  $\sigma$  parameter as the intersectoral CES utility function. Intrasectoral demand for varieties exported by  $i$  in  $j$  in sector  $k$  is:

$$X_{k,ij} = \left( \frac{p_{k,ij}}{\gamma_i P_{k,j}} \right)^{1-\sigma} Y_{k,j}$$

Where  $\gamma_i > 0$  is a origin-country-specific preference parameter and  $P_{k,j}$  is the CES price index:

$$P_{k,j} = \left[ \sum_{i \neq j} \left( \frac{p_{k,ij}}{\gamma_i} \right)^{1-\sigma} \right]^{1/(1-\sigma)}$$

Defining  $\frac{Y_{k,j}}{Y_j} = \omega_{k,j}$ , we get:

$$\frac{X_{k,ij}}{Y_j} = \omega_{k,j} \left( \frac{p_{k,ij}}{\gamma_i P_{k,j}} \right)^{1-\sigma}$$

## Our equation (3)

Summing over all SITC 4-digit sectors:

$$\sum_{k=1}^K \frac{X_{k,ij}}{Y_j} = \frac{X_{ij}}{Y_j} = \gamma_i^{\sigma-1} \sum_{k=1}^K \omega_{k,j} \left[ \frac{p_{k,ij}}{P_{k,j}} \right]^{1-\sigma}$$

Changing notation to  $\kappa_i = \gamma_i^{\sigma-1}$ , the market share becomes, assuming multiplicative errors of measurement:

$$\frac{X_{ij}}{Y_j} = \kappa_i \sum_{k=1}^K \omega_{k,j} \frac{p_{k,ij}^{1-\sigma}}{\sum_{l \neq j} \kappa_l p_{k,lj}^{1-\sigma}} \cdot e^{\varepsilon_{i,j}} \quad (1)$$

We take logs to transform the errors into additive ones and estimate the following equation for each year with a non-linear least square procedure in STATA:

$$\ln \left( \frac{X_{ij}}{Y_j} \right) = \ln \kappa_i + \ln \left( \sum_{k=1}^K \frac{Y_{k,j}}{Y_j} \cdot \frac{p_{k,ij}^{1-\sigma}}{\sum_{l \neq j} \kappa_l p_{k,lj}^{1-\sigma}} \right) + \varepsilon_{i,j} \quad (2)$$

This approach yields annual estimates of  $\kappa_i$  and  $\sigma$ .

## Dealing with missing unit values

- ▶ Trade flow observed, but information on quantities missing
- ▶ On average, this is the case for 14% of total trade
- ▶ Use stepwise price imputation procedure
  - ▶ construct relative prices at highest disaggregation level
  - ▶ construct next level relative price as weighted average of observed relative prices
  - ▶ destination-specific weights at each step
  - ▶ repeat at each aggregation level
- ▶ assumption: missing unit values can be best approximated by observed prices for similar goods

## Dealing with zero trade flows

- ▶ Under model assumptions some trade would be observed in every sector between each pair
- ▶ Zero trade flows prevalent: from 86-90% of possible observations at 4-digit level
- ▶ Assumption: statistical, not structural zeros linked to data collection thresholds
- ▶ Same stepwise procedure used for price imputation
- ▶ Corresponds to assumption that unobserved relative price equal to observed
- ▶ Problem: unobserved prices much higher than imputed prices

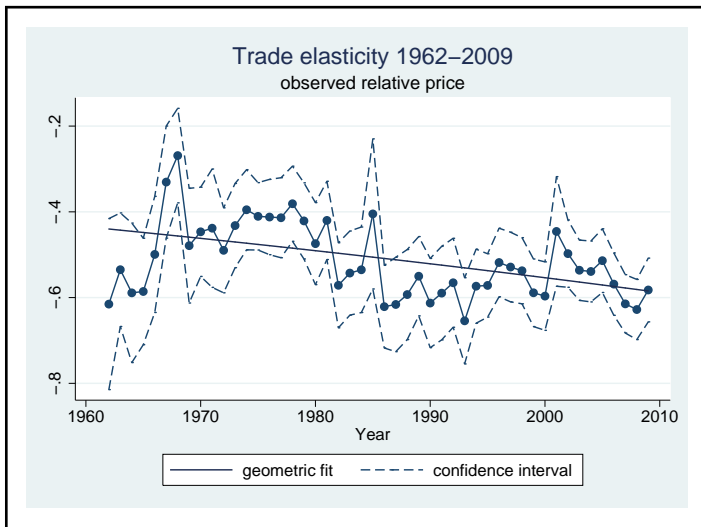
# Proportion of zero trade flows as a function of market share

Share of ZTF		
ms	-0.0427*** (0.0001)	-0.2573*** (0.013)
year	-0.0033*** (0.0000)	-0.0024*** (0.000)
<i>ms * year</i>		0.0001*** (0.000)
constant	6.0976*** (0.0366)	4.2515*** (0.134)
Observations	657001	657001

# Overestimation bias

- ▶ Underestimation factor not constant across exporters
  - ▶ share of ztf decreasing in market share
  - ▶ reduction in share of ztf proceeds at quicker pace for small exporters
- ▶ Relative price underestimated by more for small exporters
- ▶ For given distribution of market shares, true underlying distribution of prices is greater than observed distribution
- ▶ Estimated parameter overestimates the true substitutability parameter
- ▶ But less so overtime
- ▶ If estimated elasticity increases, this is a lower bound on true parameter evolution

# Results



- ▶ 33% increase in parameter 1962–2009
- ▶ corresponds to annual increase of .6% per year



## Changing the dataset: BACI

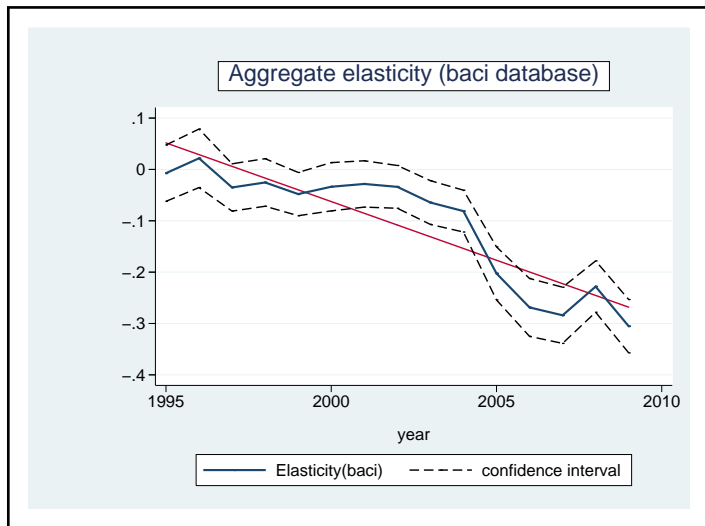


Figure: Estimated  $(1 - \tilde{\sigma})$ , BACI database

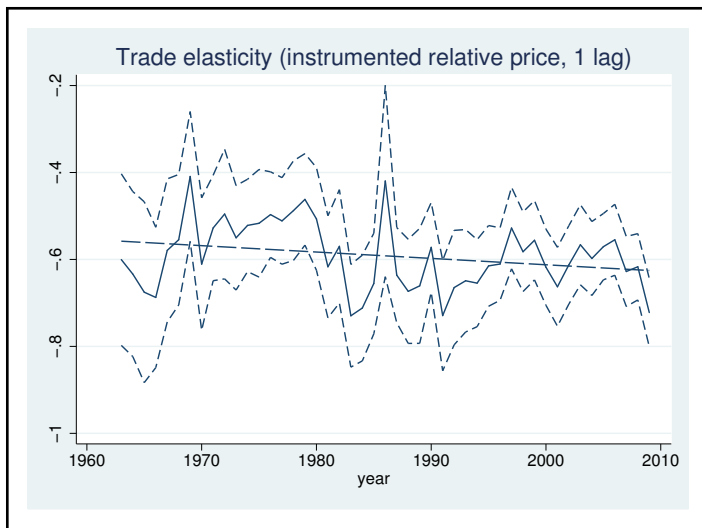
# Instrumenting: motivation

- ▶ Results subject to caution?
  - ▶ attenuation bias (if supply schedules not horizontal)
  - ▶ matters not only for level, but for evolution (Feenstra(1994))
- ▶ Objective: capture exporter-specific shocks to the price of the composite good which are not demand-driven
- ▶ Indicator: GDP price level (Penn World Tables: 189 countries, 1950-2009)

## Instrumenting: procedure

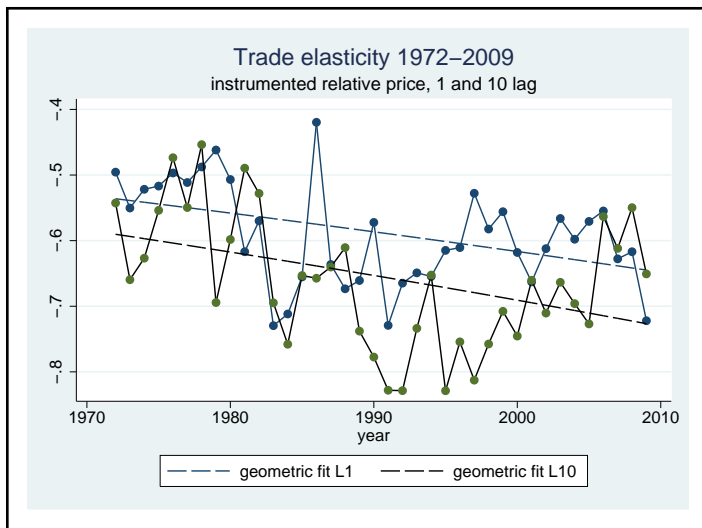
- ▶ compute relative prices for exporter-specific composite goods
- ▶ compute evolution of GDP price levels of trading partners, weighted by market shares (common currency)
- ▶ compute hypothetical relative price in  $t$  for each exporter as:
  - ▶ product of its relative price in  $(t - s)$
  - ▶ evolution of its GDP price level between  $t$  and  $(t - s)$  relatively to all other partners
- ▶ predict relative price of each exporter in  $t$ : regress observed relative price on hypothetical relative price.
- ▶ Idea: get an instrumented relative price which depends on past relative price and relative evolution of GDP price level.
- ▶ Estimate market share equation using instrumented relative prices

## Instrumenting: one lag



- ▶ reassuring: level of parameter increases by 9%
- ▶ results on evolution hold: 13% increase

## Increasing the number of lags



- ▶ level increases with number of lags: 22% for 10 lags
- ▶ results on evolution hold: 23% increase in 1972–2009

## Is there a distance puzzle left?

- ▶ empirical evidence on 13% increase in substitutability parameter
- ▶ this is aggregate trade elasticity in Armington framework
- ▶ combining with 7% increase in distance elasticity
- ▶ provides a direct explanation of the distance puzzle
- ▶ economic interpretation of increased perceived substitutability of product bundles?
  - ▶ increasing similarity in set of traded goods across countries
  - ▶ composition effects (changes in range or shares of traded goods)
- ▶ Not done: separate out net effect of increased perceived similarity
- ▶ Not feasible? parameter estimated on aggregate data is not a weighted average of sectoral parameters