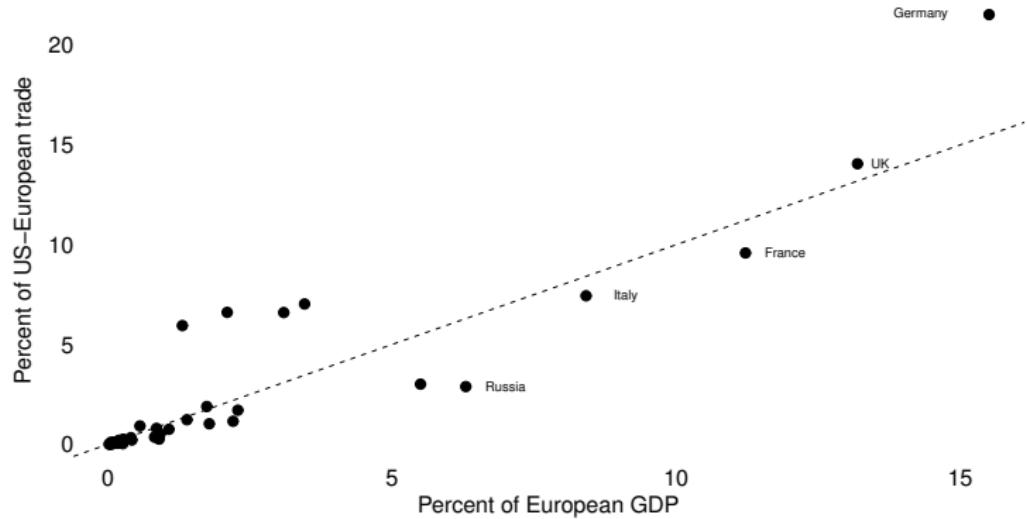


# Gravity model

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Does Ireland export more to Belgium or to China?

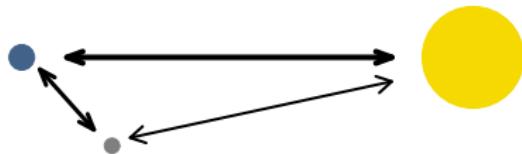


For the US, the three largest European trading partners are also the three largest European economies.

1. Why does U.S. trade more with these countries rather than other European economies?
2. What explains almost linear relationship between GDP and trade flows?

**Size matters:** Jan Tinbergen found out in 1962 that trade volume is directly related to the size of the economy

1. Larger economies produce more and thus have to sell more in export market
2. Larger economies generate more income and are thus able to buy more imports



$$F_{ij} = G \frac{M_1 M_2}{r^2}$$

$M_i$  is the mass of the object

$r$  is the distance between the objects

$G$  is a gravitational constant <sup>1</sup>

<sup>1</sup> $6.67 * 10^{-11} N(m/kg)^2$

Trade between countries is similar to gravitational force between objects

- ▶ Objects with large mass, or those that are close together, have greater gravitational pull between them

This implies that there will be more trade between countries if

1. Countries have large economies
2. Countries are close to each other

In 2015 Ireland exported

- ▶ 12% of total to Belgium
- ▶ 3% of total to China

$$T_{ij} = \alpha \frac{M_i^\beta M_j^\gamma}{D_{ij}^\theta}$$

$T_{ij}$  is trade flow from country  $i$  to  $j$

$M_i$  and  $M_j$  are economic size of the two countries

$D_{ij}$  is the distance between the two countries

$$T_{ij} \propto M_i^\beta M_j^\gamma$$

1. Exports rise proportionally with economic size of destination country
2. Imports increase in proportion to origin's country economic size

The model is short-hand for supply and demand forces

- ▶ For origin country  $i$ 
  - ▶  $M_i$  represents total supply of  $i$
  - ▶  $M_j$  represents total demand of  $j$

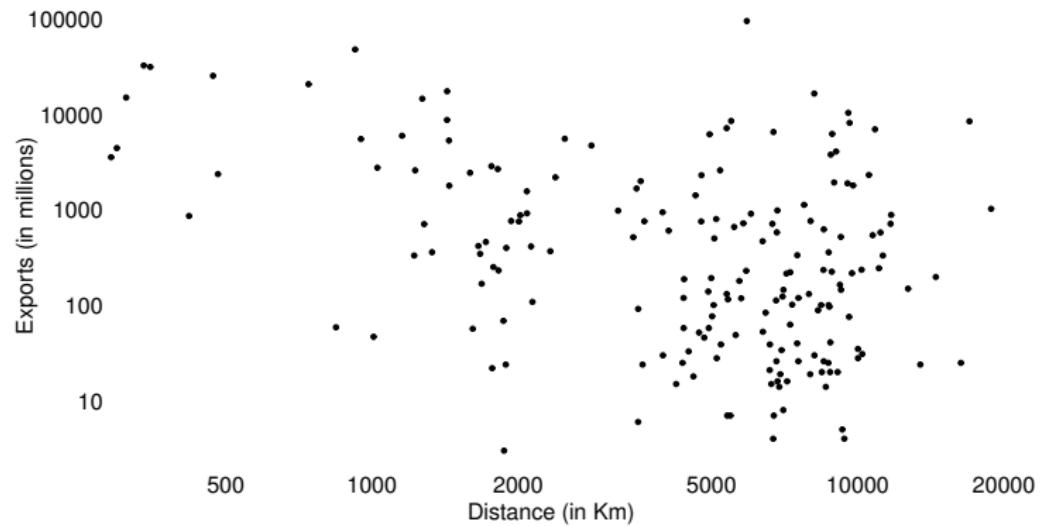
$$T_{ij} \propto \frac{1}{D_{ij}^\theta}$$

1.  $T_{ij}$  is decreasing in distance

Distance basically acts as a tax, imposing trade costs, which results in lower equilibrium trade flows.

# UK exports in 2015

source: Office for National Statistics



In its simplest form only size and distance are important for trade.  
Also note that

1. Everything enters multiplicatively, including distance
2. No 3rd country effects, except through GDP changes

Despite being a very simple model, the gravity model has produced some of the most robust findings in economic research.

Log-linearisation:

$$\ln(ab) = \ln(a) + \ln(b)$$

$$\ln\left(\frac{a}{b}\right) = \ln(a) - \ln(b)$$

$$\ln(a^b) = b \cdot \ln(a)$$

We can estimate the gravity model using OLS using log-linearisation, so

$$T_{ij} = \alpha \frac{M_i^\beta M_j^\gamma}{D_{ij}^\theta}$$

becomes

$$\ln T_{ij} = \ln \alpha + \beta \ln M_i + \gamma \ln M_j - \theta \ln D_{ij}$$

We can generalise this and add an error term to produce regression model

$$\ln T_{ij} = \theta D_{ij} + \beta \ln M_i + \gamma \ln M_j + \epsilon_{ij}$$

Except distance coefficient  $\theta < 0$  and  $\beta = \gamma = 1$

Economic mass  $M$  often measured by GDP

- ▶ Estimated coefficients close to 1; range from 0.7 to 1.1

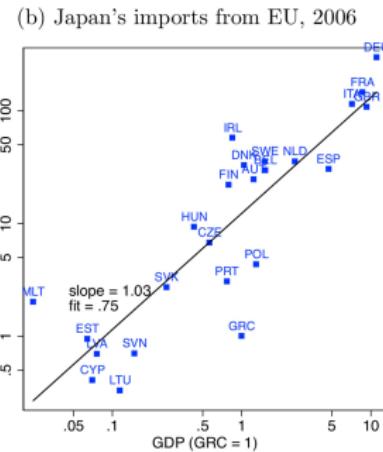
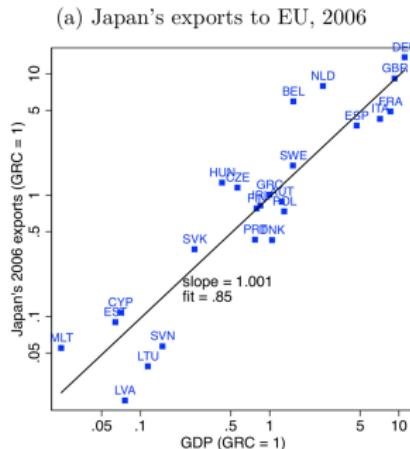
Including  $M_i, M_j$  as regressors leads to inflated  $R^2$  values

1. Large economies will trade more in absolute terms
2. Trade is part of GDP so simultaneity between  $T_{ij}, M_i, M_j$

# Imports and Exports Japan-EU, 2006

Head and Mayer, 2013

Figure 1: Trade is proportional to size



$D$  often based on great circle distance

- ▶ Length of straight line across surface of a sphere
- ▶ Underestimates the true distance

1% increase in distance associated with 0.7-1% loss in trade volume, so doubling the distance could reduce trade by half.

- ▶ Effect could be attributed to substitution elasticity between goods from different countries

The distance associated trade costs seem rather large.

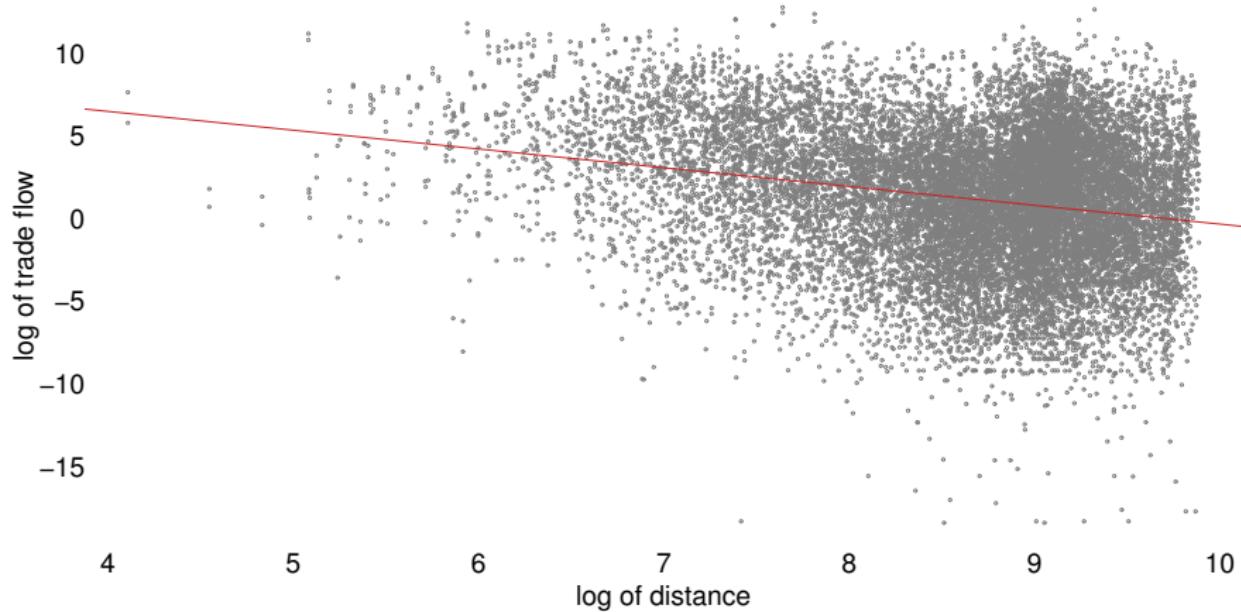
The gravity model has been estimated over a thousand times, so no harm in doing it again.

- ▶ Using a square gravity dataset for all country-pairs in the world between 1948-2006

Estimate

$$Trade\ flow_{ij} = \beta_1 GDP_i + \beta_2 GDP_j + \beta_3 Distance_{ij}$$

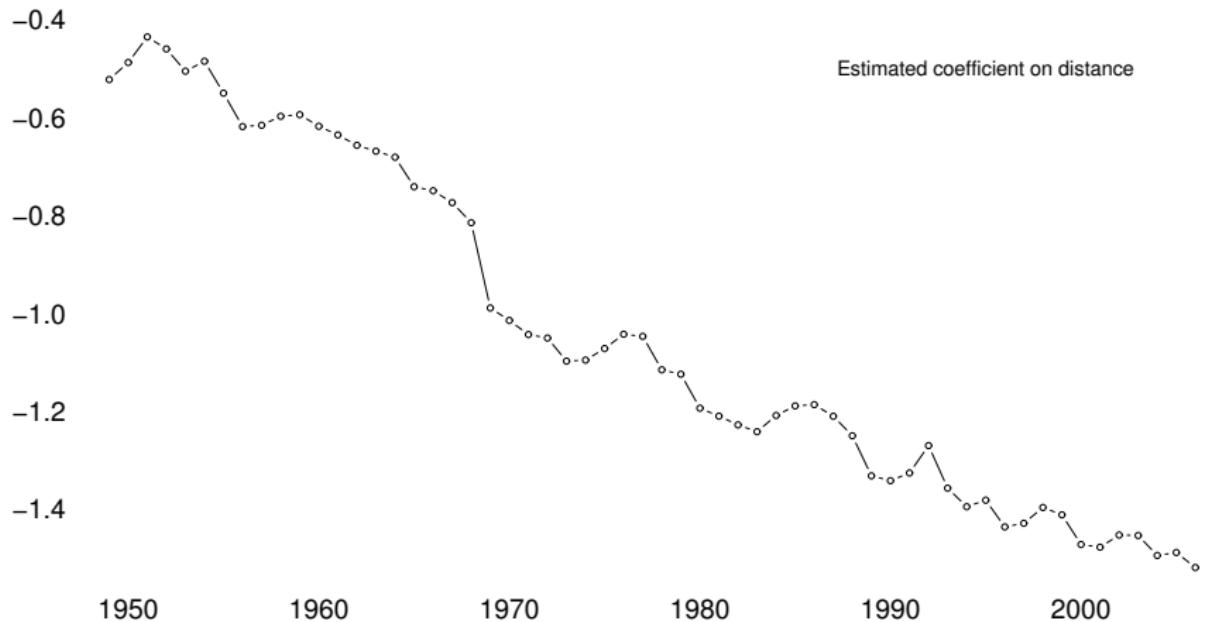
- ▶ Subset data to 2006 and drop zero flows
- ▶ Use natural logs



For 2006 the regression shows that  $\hat{\theta} = -1.52$ ,  $(\pm 0.02)^2$

- ▶ i.e. a 1% increase in distance is associated with a 1.52% decline in trade flows

Can repeat this process looking at the other years to see how the estimated effect changes over time.



# Disdier & Head (2008)

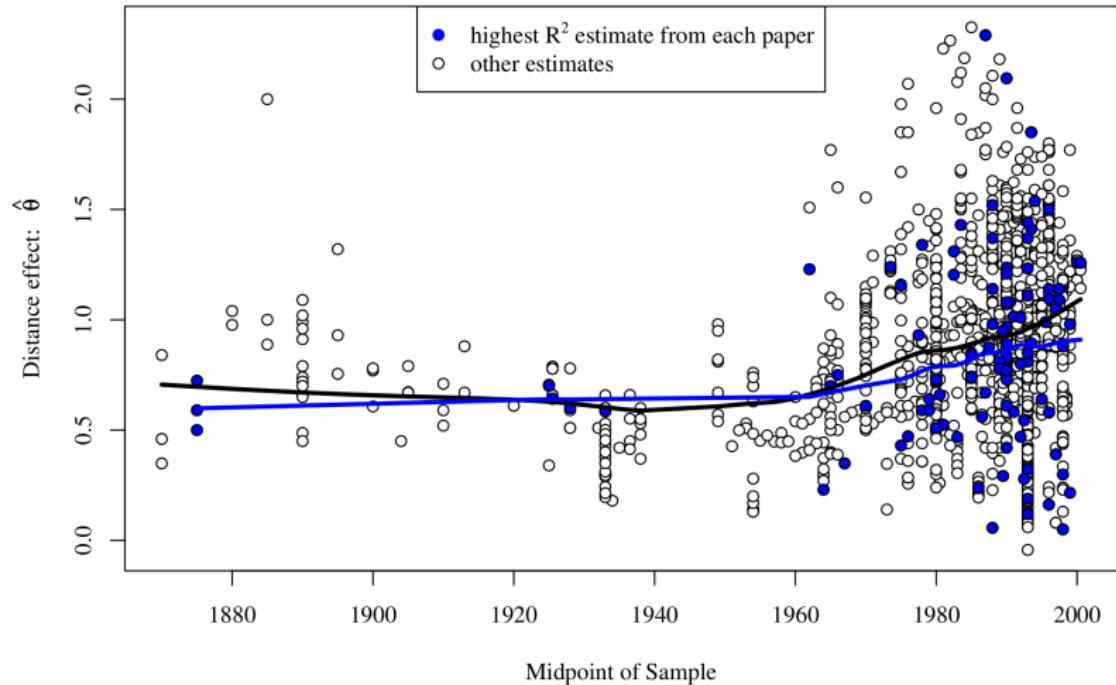


Figure 3: The variation of  $\hat{\theta}$  graphed relative to the mid-period of the data sample.

Effect of distance increases over time. Some possible explanations for this include

- ▶ Omitted variable bias
- ▶ Trade costs have increased (unlikely)
- ▶ Regional trade agreements divert trade
- ▶ People have become more responsive to price differences

Recall this guy



Gravity increasing possibly due to vertical disintegration

- ▶ When the production of a product crosses multiple national borders

If a product is shipped multiple time during production, it could lead to being counted in trade data more than once

Economists have offered six explanations for why distance matters so much.

1. Proxy for transport costs
  - ▶ e.g. freights charges, insurance
2. Indication of time elapsed during shipment
  - ▶ Damage or loss of shipment
  - ▶ Decomposition/spoiling of organic goods
  - ▶ Loss of market

3. Synchronisation costs
  - ▶ Sourcing inputs from nearby lowers synchronisation costs
4. Communication costs
  - ▶ Exchange of information via less formal methods
5. Transaction costs
  - ▶ Search for trade opportunities
  - ▶ Establishment of trust between trade partners
6. Cultural distance

# Percentage of firms that export

Croezen and Koenig, 2010

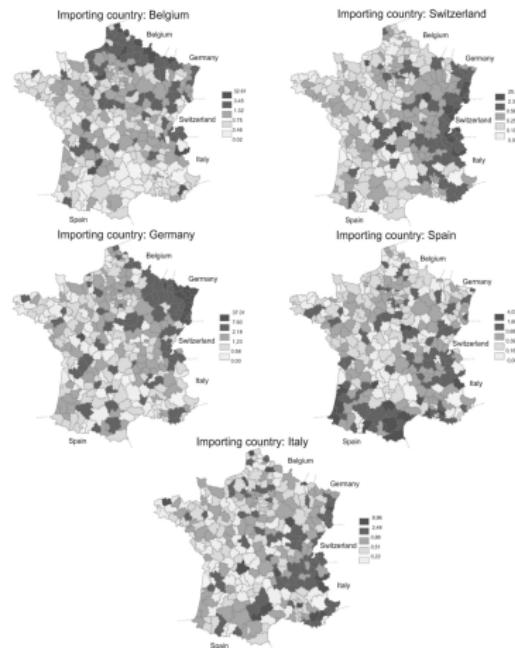


FIGURE 1 Mean value of individual-firm exports (single-region firms, 1992)

# Mean value of individual firm exports

Croezen and Koenig, 2010

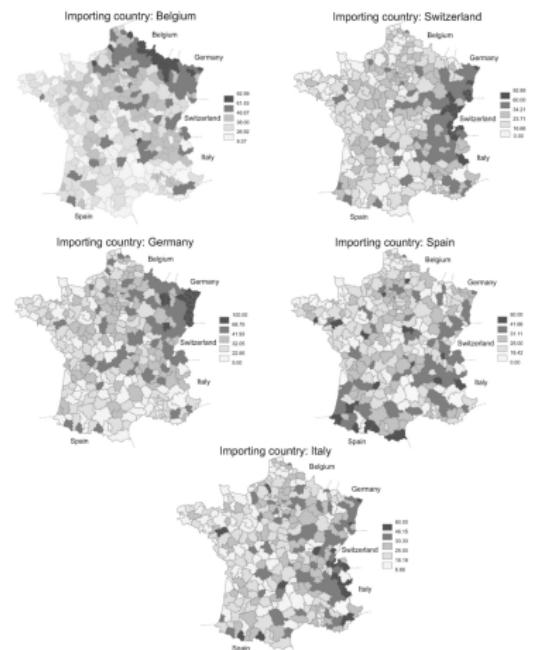


FIGURE 2 Percentage of firms that export (single-region firms, 1992)

# World trade relative to GDP over time

source: World Bank Development Indicators



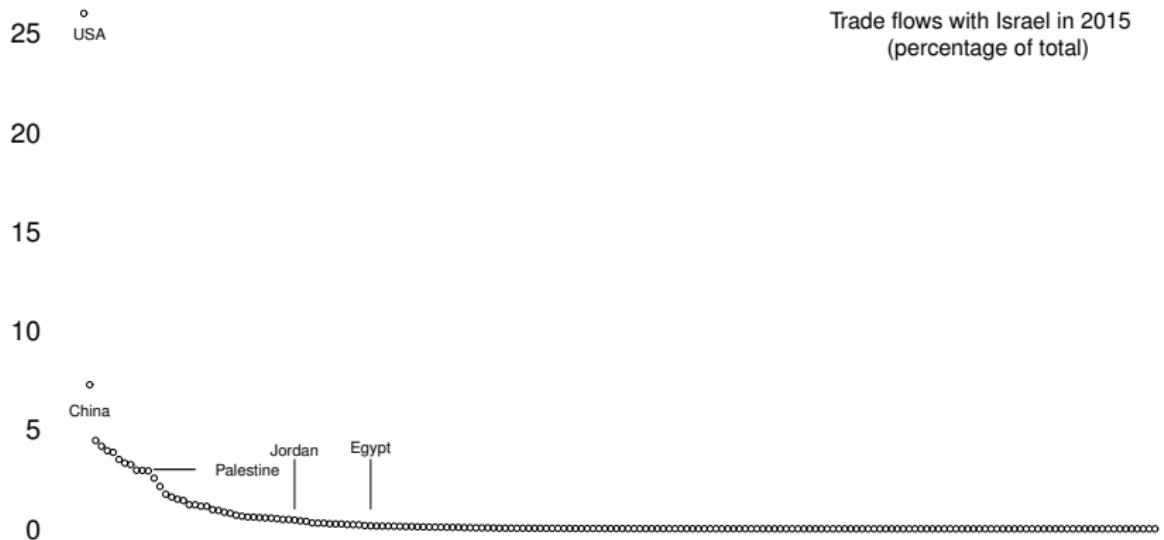
A number of technological improvements have reduced the costs of trade, or relative distance, in the past half-century

- ▶ Containerisation; lowered costs and shipping time of manufactured goods
- ▶ Commercial jet air transport costs fell by 90% between 1955-2004
- ▶ International telephone costs per minute fell by 95% between 1980-2010
- ▶ Internet-based communication increases bandwidth of long-distance information flows

Other factors influencing trade volumes include

- ▶ Geography
  - ▶ Port availability and lack of mountain barriers facilitate transport
- ▶ Cultural distance
  - ▶ Cultural ties often correlated with economic ties
  - ▶ Different cultures could inhibit communication, generate misunderstandings, clashes in negotiation style etc.
- ▶ Multinationals
  - ▶ Imports/exports between company's divisions
  - ▶ Synchronisation costs
- ▶ Borders
  - ▶ Crossing borders involves bureaucracy and possibly tariffs

Trade flows with Israel in 2015  
(percentage of total)



Although distance is accounted for using a simple geographic measure it can proxy for factors such as

1. Similar language
2. Cultural affinity
3. Contiguity

The original formulation of the gravity model simply describes an empirical relationship. Of course economists could not resist to derive the equation formally. Let's assume that  $s_{ij}$  is the share of  $M_j$  that is spent on goods from country  $i$ , we get

$$T_{ij} = s_{ij} M_j$$

We know about  $s$  that

- ▶  $0 \geq s \leq 1$
- ▶ Increase if  $i$  produces wide variety of goods; large  $n_i$ ;
- ▶ Increase if goods from  $i$  are perceived to be of high quality; large  $\mu_i$ ;
- ▶ Decrease due to trade barriers such as distance  $D_{ij}$

$s$  can be written as

$$s_{ij} = \frac{g(n_i, \mu_i, D_{ij})}{\sum_I g(n_I, \mu_I, D_{Ij})}$$

A specific  $g()$  is required and here we will use one that let's both  $n$  and  $\mu$  vary across countries

- ▶ Also assume that different goods are of the same average quality and subject to same transport costs

$$g() = n_i (p_{ij}/\mu_{ij})^{1-\sigma}$$

$\sigma$  is elasticity of substitution

Next step is to link the delivery price to the price in the country of origin and the transportation costs. The following relationship is assumed<sup>3</sup>

$$\frac{p_{ij}}{\mu_{ij}} = \left( \frac{p_i}{\mu_i} \right) D_{ij}^\delta$$

The origin price  $p_i$  is also known as the free-on-board price and in this model it varies according to the quality of the export country's products:  $\frac{p_{ij}}{\mu_{ij}} \approx k$

Since we can't observe  $n_i$  we assume that all firms are the same size  $q$

$$n_i = M_i/q$$

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<sup>3</sup>Note that the delivery price is quality-adjusted.

Finally, defining  $\theta \equiv \delta(\sigma - 1) \geq 0$  we get

$$g() = \frac{M_i D^{-\theta}}{q k^{\sigma-1}}$$

Which implies that the market share for exporter  $i$  in country  $j$  is given by

$$s_{ij} = M_i D_{ij}^{-\theta} R_j$$

Where  $R_j = \frac{1}{\sum_i M_i D_{ij}^\theta}$  and captures remoteness.

We can rewrite this into

$$T_{ij} = R_j \frac{M_i M_j}{D_{ij}^\theta}$$

Note that  $R_j$  replaces the gravitational constant  $\alpha$

Concerning remoteness let's consider two dyads

1. Australia - New Zealand

- ▶ Distance between Sydney - Auckland: 2160 Km
- ▶ Combined GDP: 1.4T USD

2. Spain - Hungary

- ▶ Distance between Madrid - Budapest: 1982 Km
- ▶ Combined GDP: 1.3T USD

What would we expect in terms of trade flow for each dyad?

Trade flows per dyad in 2015

1. Australia - New Zealand: 10.9B USD
2. Spain - Hungary: 4.2B USD

## The US economy

- ▶ Exports about 2.1T USD per year, accounting for 13.8% of GDP
- ▶ Exports support about 6.8 million jobs

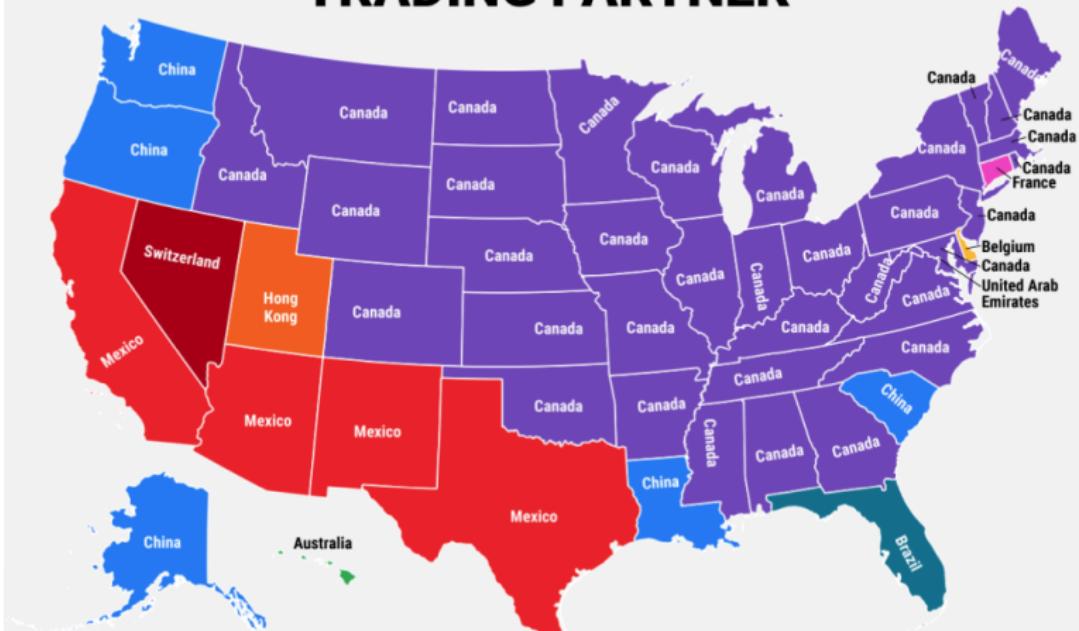
What percentage of US firms exports?

Of 30 million US companies, less than 1 % exports, according to US sources

- ▶ Of these companies, 58% exports to only one country

OECD figures show that about 4.5% of US firms export, in the EU the average is 6%.

# EACH STATE'S BIGGEST EXPORT TRADING PARTNER



SOURCE: US Census Bureau

BUSINESS INSIDER

# EACH STATE'S BIGGEST IMPORT TRADING PARTNER



SOURCE: US Census Bureau

BUSINESS INSIDER

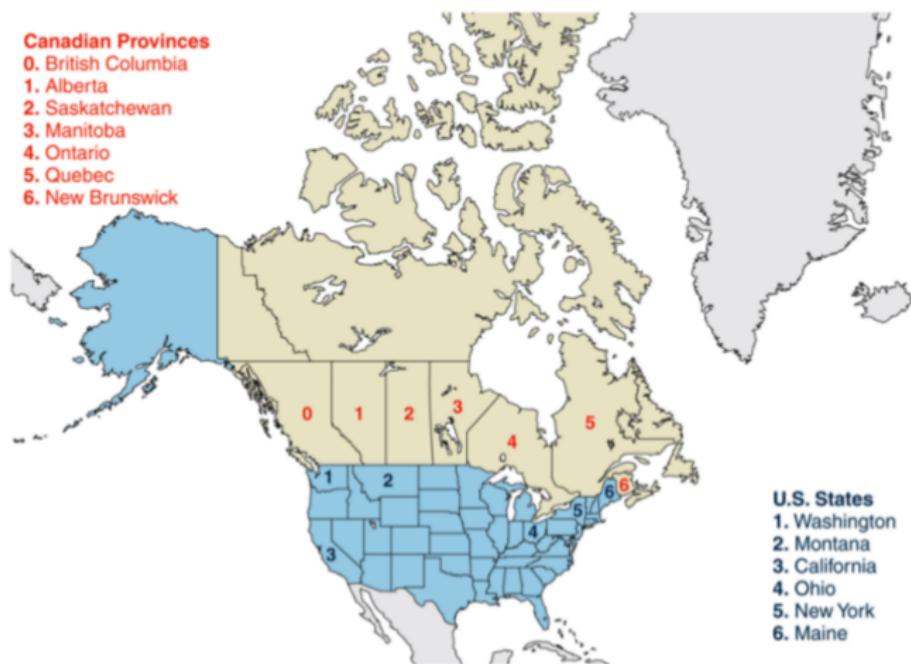
USA is Canada's main trade partner: 67.7% of total trade in 2015.  
This is probably due to

- ▶ Similarities in terms of language, culture, history
- ▶ As well as small distance between countries

Border are associated with trade reduction as trade between countries is harder than within countries: this is called the Border Effect

- ▶ Within-country region-pairs are 10-20 times more likely to trade than identical pairs across countries

# Canadian provinces and US states that trade with British Columbia



## Canadian provinces and US states that trade with British Columbia

Canadian Province	Trade as Percent of GDP	Trade as Percent of GDP	U.S. State at Similar Distance from British Columbia
Alberta	6.9	2.6	Washington
Saskatchewan	2.4	1.0	Montana
Manitoba	2.0	0.3	California
Ontario	1.9	0.2	Ohio
Quebec	1.4	0.1	New York
New Brunswick	2.3	0.2	Maine

**Source:** Howard J. Wall, "Gravity Model Specification and the Effects of the U.S.-Canadian Border," Federal Reserve Bank of St. Louis Working Paper 2000-024A, 2000.

A border increases both the time and costs needed to trade

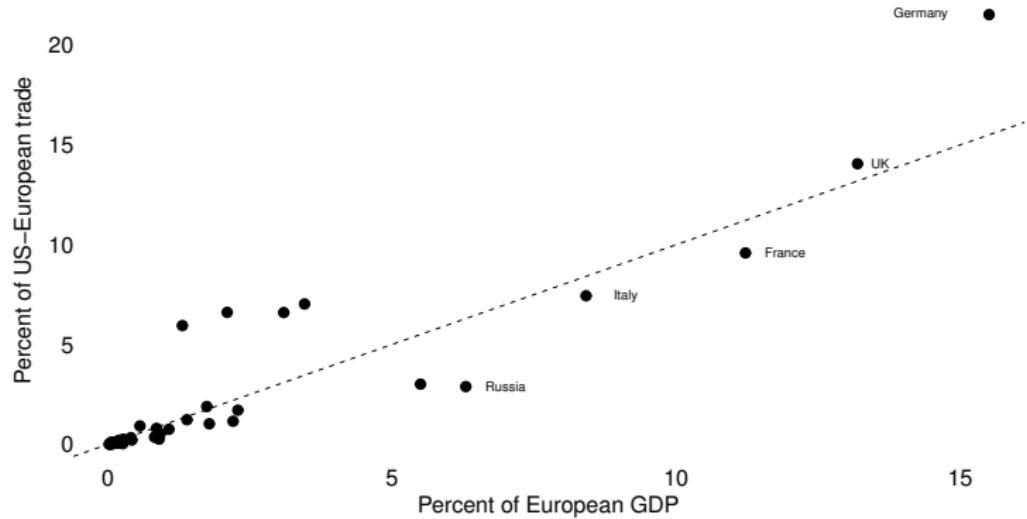
- ▶ Due to bureaucracy mainly

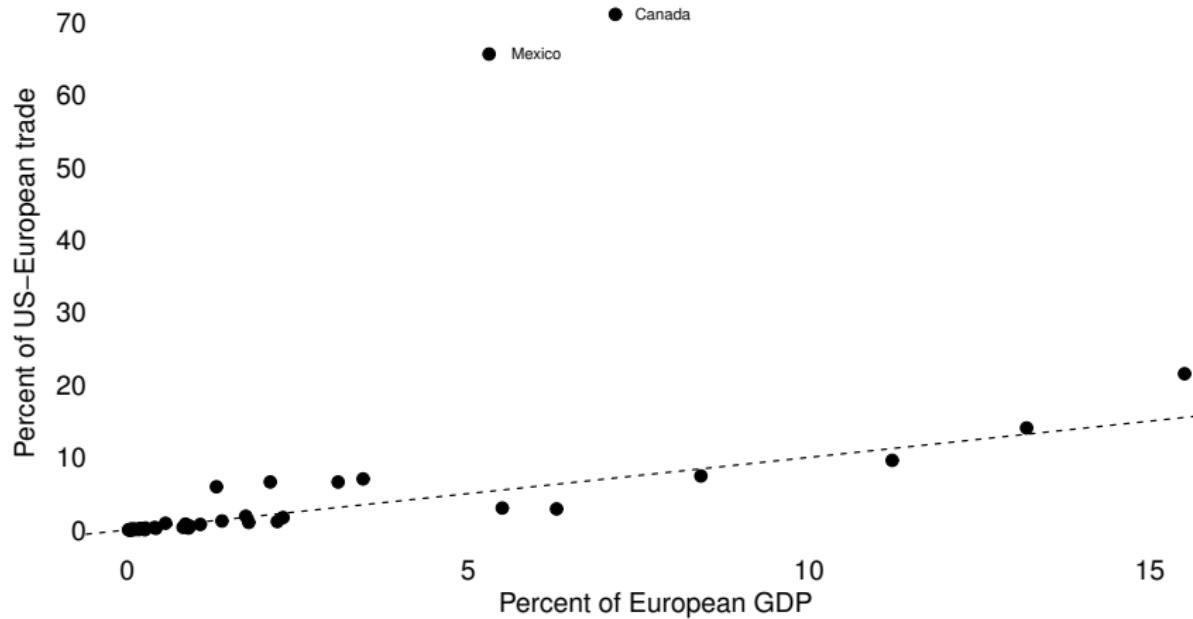
Trade agreements can help to reduce these costs and increase trade. And a gravity model can help assess the effect of the trade agreement

## North American Free Trade Agreement (NAFTA)

- ▶ Aim to eliminate barriers to trade and investments between USA, CAN, MEX
- ▶ Came into force in 1994

Note: CAN economy ranks 10th in the world, MEX 15.





Despite technological progress in transport and communication, distance still is an important factor. Not only on trade but also other flows/transactions

1. FDI
2. Portfolio investment
3. Web browsing
4. Patent citations

Distance is a proxy for lack of information which leads to uncertainty

- ▶ Familiarity declines rapidly with distance

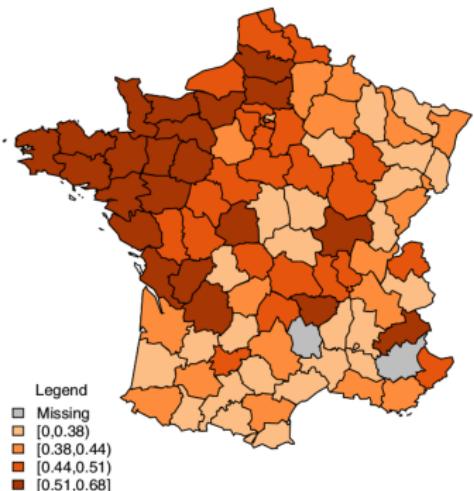
Additionally, distance is associated with localised tastes

- ▶ Historically determined and change slowly with experience (home bias)

# Localised historical tastes

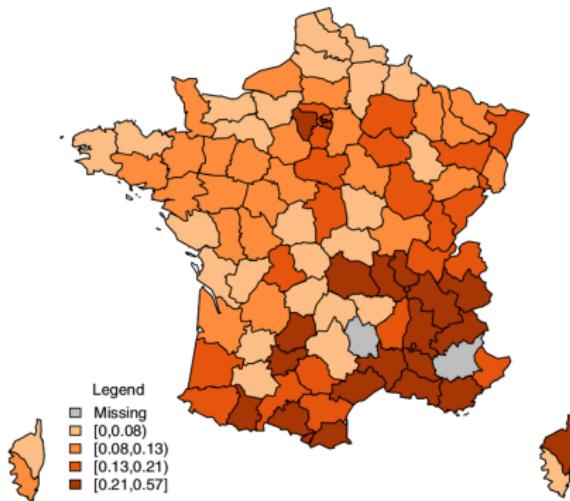
source: Head and Mayer, 2013

(a) Butter



Note: 10 240 households – 2005–06

(b) Olive oil



Note: 10 240 households – 2005–06

FIGURE 8 Expenditure shares (out of all fats and oils) of 10,240 French households, 2005–2006

There is some empirical evidence that suggests there are stronger trade links between metropole and former colonies

- ▶ Quebec and France, Canada and UK

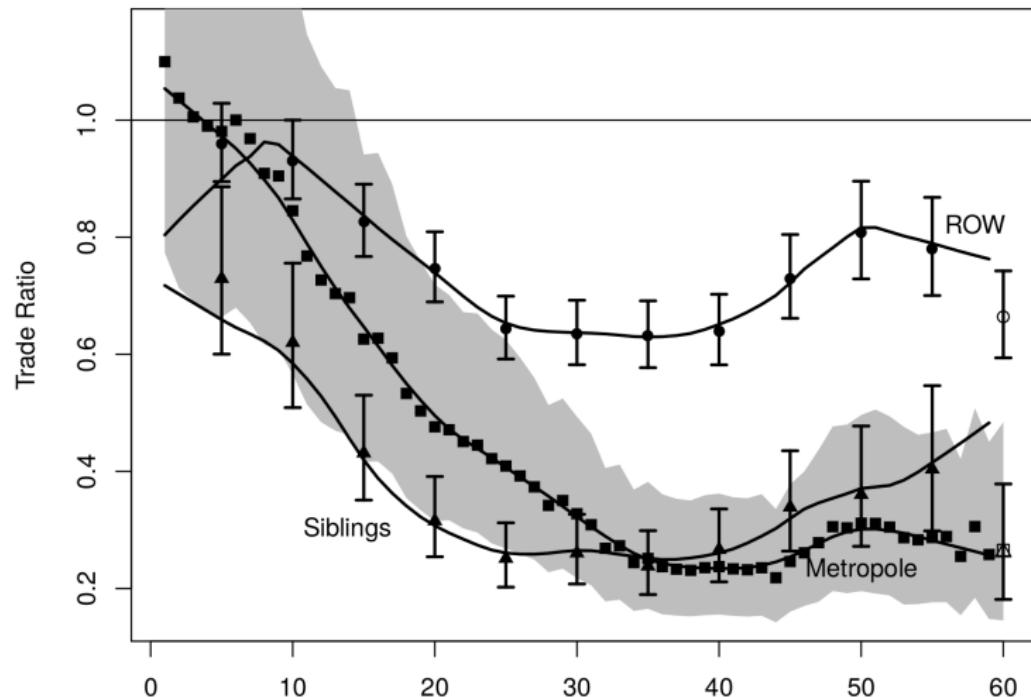
Nonetheless, there is a steady decline in trade

- ▶ between colonial power and colony
- ▶ between colonies of same colonial power

# "The erosion of colonial trade linkages after independence"

Head et al. (2010)

Figure 7: Trade with metropole, "siblings," and rest-of-world after independence



This trade loss between metropole and former colony, and among former colonies of same metropole is somewhat puzzling given

- ▶ Common institutions
- ▶ Same language
- ▶ Substantial bilateral migration

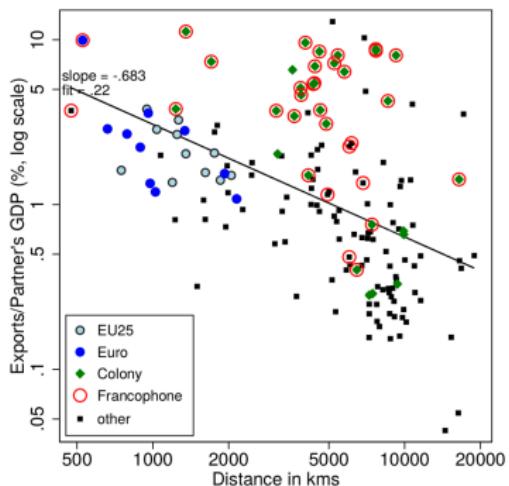
Barriers to trade seem to be low. But despite the decline, trade levels are still higher than predicted by gravity model

# Colonial ties: France

source: Head and Mayer, 2013

Figure 2: Trade is inversely proportional to distance

(a) France's exports (2006)



(b) France's imports (2006)

