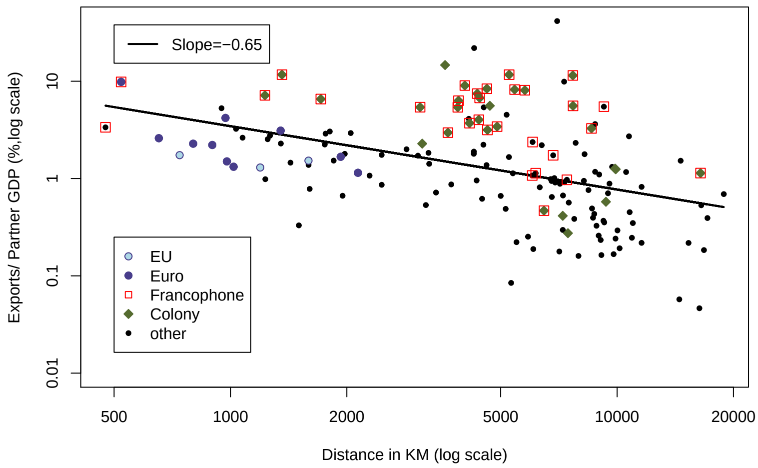
Master EPP, International Macroeconomics
Lecture 3
New trade models for new international macroeconomics

1 The Gravity Equation

Motivation: The Gravity equation is one of the most stable relationship in economics. It shows that trade flows are negatively correlated with the extent of trade barriers, approximated by distance and other cultural and geographical proximity indicators.
This relation is illustrated in Figures 1 and 2 for French data. The figures suggest that both nominal imports and nominal exports are negatively correlated with the distance between France and its partner. Moreover, France tends to trade more with former colonies and French-speaking countries.

Figure 1: France's exports in 2000



This result is generally interpreted as reflecting the impact of trade costs on the volume of trade. Note that this goes beyond the impact of trade barriers as the relation also holds true when considering trade inside a single country (Figure 3).
Historically, the gravity equation has first been a purely empirical result. The development of new trade models following Krugman (1991) has however allowed to rationalize it in a theoretical framework.

Theoretical Framework (Redding & Venables, 2003):
The theoretical framework is based on a standard multi-country new trade theory model. The world consists of $i = 1, ..., R$ countries, and we focus on the manufacturing sector, composed of firms that operate under increasing returns to scale and produce differentiated products. On the demand side, each firm's product is differentiated from that of other firms. There is a constant elasticity of substitution, σ, between pairs of products, so products enter utility through a CES aggregator taking the form:

$$U_j = \left[\sum_{i=1}^{R} \int_{n_i} x_{ij}(z)^{\frac{\sigma-1}{\sigma}} dz \right]^{\frac{\sigma}{\sigma-1}} = \left[\sum_{i=1}^{R} n_i x_{ij}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

Figure 2: France's imports in 2000

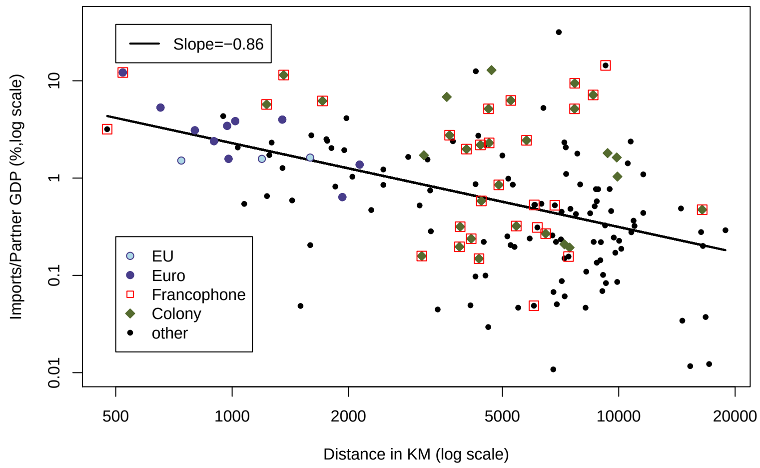
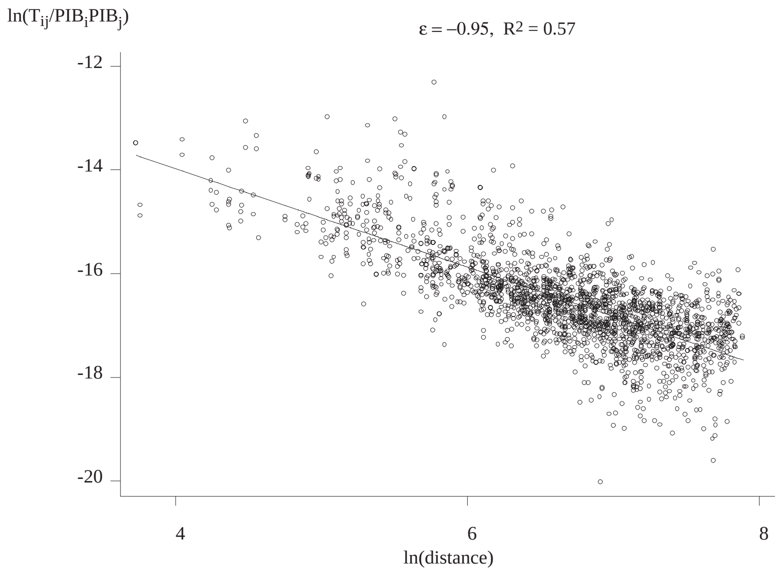


Figure 3: Trade within the USA in 1997



where z denotes manufacturing varieties, n_i is the set of varieties produced in country i, and $x_{ij}(z)$ is the country j demand for the z^{th} product from this set. The second equation makes use of the fact that, in equilibrium, all products produced in each country i are demanded by country j in the same quantity.

1. Derive the price index for manufactures in country j.

The price index for manufactures is obtained by solving the representative consumer's optimization program:

$$\begin{cases} \max_{x_{ij}(z)} \left[\sum_{i=1}^R \int_{n_i} x_{ij}(z)^{\frac{\sigma-1}{\sigma}} dz\right]^{\frac{\sigma}{\sigma-1}} \\ s.t. \quad P_j U_j = \sum_{i=1}^R \int_{n_i} p_{ij}(z) x_{ij}(z) dz \end{cases}$$

where $p_{ij}(z)$ is the price of the variety z in country j.
For any two varieties produced in any two countries, the first-order conditions implies:

$$\frac{x_{ij}(z)}{x_{i'j}(z')} = \left(\frac{p_{ij}(z)}{p_{i'j}(z')}\right)^{-\sigma}$$

Incorporating this in each side of the budget constraint gives:

$$\sum_{i=1}^R \int_{n_i} p_{ij}(z) x_{ij}(z) dz = p_{i'j}(z')^{\sigma} x_{i'j}(z') \left[\sum_{i=1}^R \int_{n_i} p_{ij}(z)^{1-\sigma} dz\right]$$

$$P_j U_j = P_j p_{i'j}(z')^{\sigma} x_{i'j}(z') \left[\sum_{i=1}^R \int_{n_i} p_{ij}(z)^{1-\sigma} dz\right]^{\frac{\sigma}{\sigma-1}}$$

Combining these expressions together gives:

$$P_j = \left[\sum_{i=1}^R \int_{n_i} p_{ij}(z)^{1-\sigma} dz\right]^{\frac{1}{1-\sigma}} = \left[\sum_{i=1}^R n_i p_{ij}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$$

2. In the following, country j's total expenditure on manufactures is denoted E_j. Write the demand function addressed to an individual producer. What is the functional form for real bilateral trade flows ?

The first-order conditions derived previously implies the following demand function, at the individual level:

$$x_{ij}(z) = \left(\frac{p_{ij}(z)}{P_j}\right)^{-\sigma} \frac{E_j}{P_j}$$

Summing over all varieties produced in country i implies that the bilateral trade flow is:

$$n_i x_{ij} = n_i \left(\frac{p_{ij}(z)}{P_j}\right)^{-\sigma} \frac{E_j}{P_j}$$

3. Turning to supply, each individual firm has profits $\pi_i(z)$, that depend on aggregate sales and their cost. Technology has increasing returns to scale, represented by a fixed labor requirement $a_i F$ and marginal labor requirement a_i, these technology parameters potentially varying across countries. Last, exporting involves an iceberg trade cost τ_{ij}. What is the optimal price set on each market under these assumptions? Derive the analytical condition under which firms from country i find it profitable to enter export market. Conclude on the equilibrium number of producing firms in each country.

In each country i, an individual firm maximizes the following program:

$$\begin{cases} \max_{p_{ij}(z)} \left[\sum_{i=1}^R p_{ij}(z) x_{ij}(z) - w_i a_i \sum_{j=1}^R \tau_{ij} x_{ij}(z) - w_i a_i F\right] \\ s.t. \quad x_{ij}(z) = \left(\frac{p_{ij}(z)}{P_j}\right)^{-\sigma} \frac{E_j}{P_j} \end{cases}$$

The first term in the definition of profits is revenue earned from sales in all markets and the last two terms represent production costs. The solution is:

$$p_{ij}(z) = \frac{\sigma}{\sigma - 1} w_i a_i \tau_{ij} \equiv p_i \tau_{ij}$$

Profit-maximizing firms set a single f.o.b. price, p_i, and pass the full trade-cost onto local consumers. Given the previous pricing decision, the profit of an individual firm in i writes:

$$\pi_i(z) = \frac{p_i \sum_{j=1}^{R} \tau_{ij} x_{ij}(z)}{\sigma} - w_i a_i F$$

Entry is profitable as long as $\pi_i(z)$ is positive ie:

$$\begin{aligned} & \frac{p_i \sum_{j=1}^{R} \tau_{ij} x_{ij}(z)}{\sigma} \geq w_i a_i F \\ \Leftrightarrow \quad & \sum_{j=1}^{R} \tau_{ij} x_{ij}(z) \geq (\sigma - 1)F \\ \Leftrightarrow \quad & \sum_{j=1}^{R} \tau_{ij}^{1-\sigma} P_j^{\sigma-1} E_j \geq \left(\frac{\sigma}{\sigma - 1} w_i a_i \right)^{\sigma} (\sigma - 1)F \end{aligned}$$

This relationship says that the maximum value of the wage that each firm in country i can afford to pay is a function of the sum of distance weighted “market capacities”. This sum is called “market access” of country i by Redding & Venables.
Finally, one can use the free-entry condition to solve for the equilibrium number of firms per country. Under symmetry, country i's GDP is defined as:

$$Y_i = n_i p_i \bar{y}$$

where $\bar{y}$ is the total production of an individual firm, equal to $(\sigma - 1)F$ under free entry. As a consequence, the equilibrium number of firms is:

$$n_i = \frac{Y_i}{p_i(\sigma - 1)F}$$

4. Finally, conclude on the determinants of bilateral trade.
Using the previous results, bilateral trade flows (in volume) writes:

$$n_i x_{ij} = n_i p_i^{-\sigma} \tau_{ij}^{-\sigma} E_j P_j^{\sigma-1} = \frac{Y_i}{(\sigma - 1)F} p_i^{-\sigma-1} \tau_{ij}^{-\sigma} E_j P_j^{\sigma-1}$$

or in (CIF) value:

$$n_i p_{ij} x_{ij} = n_i p_i^{1-\sigma} \tau_{ij}^{1-\sigma} E_j P_j^{\sigma-1} = \frac{Y_i}{(\sigma - 1)F} p_i^{-\sigma} \tau_{ij}^{1-\sigma} E_j P_j^{\sigma-1}$$

The right-hand side of this equation contains both demand and supply variables. The term $E_j P_j^{\sigma-1}$ is country j market capacity, as defined above. On the supply side, the term $n_i p_i^{1-\sigma}$ measures the “supply capacity” of the exporting country; it is the product of the number of firms and their price competitiveness, such that doubling supply capacity (given market capacities) doubles the value of sales. In addition, the term $\tau_{ij}^{1-\sigma}$ measures bilateral transport costs between countries.

Finally, note that the price index in country j can be written as:

$$P_j = \left[\sum_{i=1}^{R} n_i (p_i \tau_{ij})^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

The term in square brackets is a sum of supply capacities, weighted by transport costs, so measures what we shall term the "supplier access" of country j. It is important because an increase in this supplier access reduces the price index in country j thus increasing real aggregate demand. Supplier access thus summarizes the benefit of proximity to suppliers of final goods.

Empirical Implementation:

1. Use the previous theoretical framework to derive a testable equation explaining bilaterla trade flows.

Log-linearizing the previous equation for bilateral trade gives the following testable equation:

$$\ln Trade_{ij} = \ln \left(n_i p_i^{1-\sigma} \right) + \ln \tau_{ij}^{1-\sigma} + \ln \left(E_j P_j^{\sigma-1} \right)$$

where $Trade_{ij}$ is the value of the bilateral trade flow, $(n_i p_i^{1-\sigma}$ is country i's "supplier capacity", $\tau_{ij}^{1-\sigma}$ is a measure of trade frictions (called "freeness of trade" by Baldwin et al.) that increases between 0 and 1 when trade frictions are reduced, $(E_j P_j^{\sigma-1}$ is country j's "market capacity".

In the following, you are asked to run different gravity estimations and compare results together. The data are stored in a Stata table called col_regfile.dta. It contains the following variables: year, country codes for the exporter (iso_o, iso2_o) and the importing country (iso_d, iso2_d), distance between partners (distw=population-weighted average of the distance from the main cities to the main exit points+average distance between exit points), time difference between partners (tdiff in hours), different dummies for contiguity (contig), the fact a country is landlocked (landlocked_o, landlocked_d), the fact they share the same language (comlang_off, comlang_ethno), the fact they have been in a colonial relationship (col_hist, comcol, col45, col_cur, indepdate), the fact they are in war (conflict), different dummies for trade agreements (rta, custrict, gatt_o, gatt_d), size of their population (pop_o, pop_d in millions), GDPs (gdp_o, gdp_d), GDP per capita (gdpcap_o, gdpcap_d), area (area_o, area_d in square kms), and the value of bilateral trade flows (flow in current US dollars, taken from the IMF-Dots).

2. The first generation of gravity models used GDPs to approximate supplier and market capacities. Run estimations and comment.

Table 1 presents results of the GDP-estimation run on the whole period. In column (1), both GDPs and distance coefficients are highly significant and of the expected sign. Moreover, these three variables alone are able to explain more than 50% of the variability in trade flows. The comparison of columns (1) and (2) shows that the impact of GDPs captures a wealth and a size effects. Several indicators of trade frictions beyond distance significantly affect bilateral trade: the fact that both countries share a border, the same language or a past colonial relationship, the fact one is landlocked, or the fact they are involved in trade or monetary agreements. Regressions of Table 2 suggest that the gravity equation is not stable across time. The impact of distance seems to increase over time, which is somewhat surprising. This is probably due to colinearity in 1960 data. In column (2), both the common language and the contiguity dummies are weakly significant which may suggest that their impact is captured in the distance coefficient. Indeed, the 1960 sample is much smaller, in part because trade relations were less developed in 1960 and mainly occurred between closed countries.

Table 1: Gravity equation, old fashion, Whole period

	(1)	(2)	(3)	(4)	(5)	(6)
ln gdp, origin	0.780[a]		0.780[a]	0.777[a]	0.783[a]	0.775[a]
	(587.29)		(587.86)	(582.50)	(588.86)	(571.04)
ln gdp, dest	0.672[a]		0.672[a]	0.661[a]	0.673[a]	0.667[a]
	(534.03)		(534.47)	(524.43)	(534.31)	(515.73)
ln distance	-1.061[a]	-1.064[a]	-0.999[a]	-1.019[a]	-0.977[a]	- 0.920[a]
	(-304.58)	(-304.92)	(-264.26)	(-271.35)	(-260.56)	(-234.47)
ln gdp cap, origin		0.764[a]				
		(413.58)				
ln gdp cap, dest		0.626[a]				
		(340.79)				
ln pop, dest		0.713[a]				
		(441.59)				
ln pop, origin		0.803[a]				
		(469.75)				
Contiguity			0.721[a]	0.793[a]	0.552[a]	0.526[a]
			(41.08)	(45.51)	(31.64)	(30.20)
Landlocked dest				-0.710[a]		
				(-81.41)		
Landlocked origin				-0.423[a]		
				(-47.99)		
Common language					0.367[a]	0.343[a]
					(46.29)	(43.05)
Colonial relationship					1.661[a]	1.699[a]
					(91.04)	(93.24)
Regional trade agreement						0.880[a]
						(46.40)
Currency Unions						0.619[a]
						(16.20)
Gatt/WTO members						-0.015[a]
						(-2.59)
Constant	-3.911[a]	-3.561[a]	-4.451[a]	-4.007[a]	-4.789[a]	-5.166[a]
	(-118.95)	(-103.57)	(-125.87)	(-113.23)	(-133.58)	(-140.82)
Observations	529,387	526,753	529,387	529,387	529,387	529,387
R^2	0.524	0.526	0.525	0.533	0.536	0.539

t statistics in parentheses

[c] p<0.1, [b] p<0.05, [a] p<0.01

Table 2: Gravity equation, old fashion, Comparison across time

	Whole	1960	2003
ln gdp, origin	0.775^a	0.712^a	1.054^a
	(571.04)	(45.75)	(146.04)
ln gdp, dest	0.667^a	0.653^a	0.832^a
	(515.73)	(43.58)	(120.63)
ln distance	-0.920^a	-0.585^a	-1.181^a
	(-234.47)	(-18.77)	(-56.34)
Contiguity	0.526^a	0.303^b	1.085^a
	(30.20)	(2.35)	(11.00)
Common language	0.343^a	0.018	0.796^a
	(43.05)	(0.24)	(18.38)
Colonial relationship	1.699^a	0.904^a	0.874^a
	(93.24)	(6.85)	(7.97)
Regional trade agreement	0.880^a	0.869^a	0.271^a
	(46.40)	(4.25)	(3.15)
Currency Unions	0.619^a	1.164^a	0.160
	(16.20)	(3.42)	(1.01)
Gatt/WTO members	-0.015^a	0.680^a	0.268^a
	(-2.59)	(11.84)	(8.06)
Constant	-5.166^a	-5.999^a	-8.545^a
	(-140.82)	(-18.27)	(-43.34)
Observations	529387	3557	17917
R^2	0.539	0.564	0.657

t statistics in parentheses

^{c} p<0.1, ^{b} p<0.05, ^{a} p<0.01

Table 3: Gravity equation, hold fashion, Comparison across countries

	(1)	(2)	(3)	(4)	(5)
ln gdp, origin	0.775^{a}	0.716^{a}	0.697^{a}	0.795^{a}	0.726^{a}
	(571.04)	(182.87)	(243.12)	(236.03)	(304.51)
ln gdp, dest	0.667^{a}	0.616^{a}	0.756^{a}	0.563^{a}	0.571^{a}
	(515.73)	(158.13)	(292.04)	(158.63)	(253.45)
ln distance	-0.920^{a}	-0.767^{a}	-0.905^{a}	-0.594^{a}	-0.969^{a}
	(-234.47)	(-100.56)	(-117.00)	(-60.86)	(-164.19)
Contiguity	0.526^{a}	0.341^{a}	0.191^{a}	0.649^{a}	0.699^{a}
	(30.20)	(10.74)	(3.45)	(9.60)	(32.18)
Common language	0.343^{a}	1.074^{a}	0.541^{a}	0.383^{a}	0.406^{a}
	(43.05)	(41.32)	(34.01)	(18.80)	(36.16)
Colonial relationship	1.699^{a}	0.456^{a}	1.328^{a}	1.600^{a}	2.233^{a}
	(93.24)	(12.60)	(48.97)	(47.91)	(54.89)
Regional trade agreement	0.880^{a}	0.141^{a}	0.393^{a}	0.809^{a}	0.899^{a}
	(46.40)	(7.12)	(7.13)	(11.97)	(26.47)
Currency Unions	0.619^{a}	0.380^{a}	2.010^{a}	0.493	0.345^{a}
	(16.20)	(4.72)	(24.94)	(1.02)	(7.39)
Gatt/WTO Members	-0.015^{a}	0.294^{a}	-0.222^{a}	-0.038^{a}	-0.186^{a}
	(-2.59)	(15.36)	(-22.14)	(-2.97)	(-20.28)
Constant	-5.166^{a}	-4.374^{a}	-4.820^{a}	-6.733^{a}	-3.737^{a}
	(-140.82)	(-64.66)	(-63.89)	(-70.67)	(-69.37)
Observations	529387	34906	131314	117987	245180
R^2	0.539	0.804	0.594	0.465	0.406
Origin	Whole	OECD	OECD	NonOECD	NonOECD
Destination	Whole	OECD	Non OECD	OECD	NonOECD

t statistics in parentheses

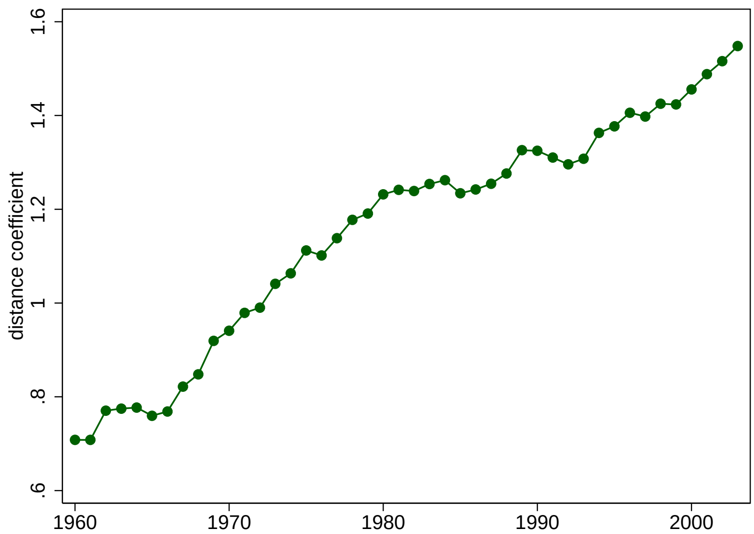
^{c} p<0.1, ^{b} p<0.05, ^{a} p<0.01

Table 3 asks whether results are stable in the spatial dimension. As the new trade model from which the estimated equation is derived assumes intra-industry trade between countries specialized in the same type of goods, it is likely that it is better suited to describe trade between industrialized countries than trade between developing countries. Results however suggest that results are roughly similar whatever the sample of countries considered.

3. In the previous "old fashion" regressions, estimations can suffer from an omitted variable bias as price levels in the origin and destination country are not controlled for. As a consequence, all variables entering $\tau_{ij}^{1-\sigma}$ that affect trade positively will tend to be biased downwards if they are negatively correlated with remoteness, and vice-versa. Since Harrigan (1996) practice has thus been moving towards using fixed effects for these terms instead. Run fixed effects estimations and discuss results.
Caution: With panels, importer and exporter fixed effects should be time-varying as well. The same is true if the data pooled over several industries.

Table 4 provides us with the results of the fixed effects estimation. It shows that previous results are roughly robust to the way the supplier and market capacities are controlled for. However, several coefficients drop in the fixed effect regression, as already noticed in the literature (see question **5**.

Figure 4: FE Estimation of distance coefficient



Figures 4-6 illustrate the dynamics behaviour of various gravity coefficients (namely, the absolute value of the elasticity of trade with respect to distance, colonial link and common language coefficients). It shows that the impact of distance and common language tend to increase over time, whereas the impact of having a past colonial relationship tends to decrease. The reason for this is that during the last 40 years, the growth of international trade is mainly driven by the development of intra-regional trade, which typically takes place between closed countries (in terms of distance and culture).

An important problem arising with the fixed-effect model is that the number of coefficients to be estimated can become huge when working on panel data.

4. An alternative to fixed-effect models is to use the model in relative terms (Head & Mayer, 2000). Show how the use of trade flows in relative terms allows to get rid of the market and supplier capacities terms. Conclude.

Table 4: Gravity equation, Fixed Effects, 2003 data

	(1)	(2)	(3)	(4)	(5)
ln distance	-1.721^a	-1.629^a	-1.629^a	-1.554^a	-1.552^a
	(-91.26)	(-79.10)	(-79.10)	(-73.91)	(-69.59)
Contiguity		1.003^a	1.003^a	0.857^a	0.841^a
		(10.96)	(10.96)	(9.43)	(9.22)
Landlocked, dest			-2.378^a		
			(-6.50)		
Landlocked, origin			7.554^a		
			(16.61)		
Common language				0.658^a	0.653^a
				(14.65)	(14.53)
Colonial relationship				1.075^a	1.070^a
				(10.39)	(10.32)
Regional trade agreement					-0.035
					(-0.42)
Currency Unions					0.112
					(0.76)
Gatt/WTO Members					0.617^a
					(6.73)
Observations	19833	19833	19833	19833	19833
R^2	0.744	0.746	0.746	0.751	0.752

t statistics in parentheses

^{c} p<0.1, ^{b} p<0.05, ^{a} p<0.01

Figure 5: FE estimation of colonial link coefficient

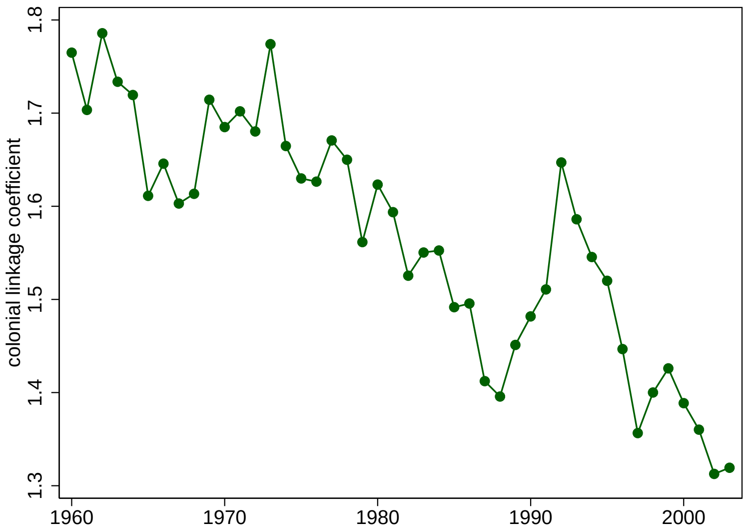
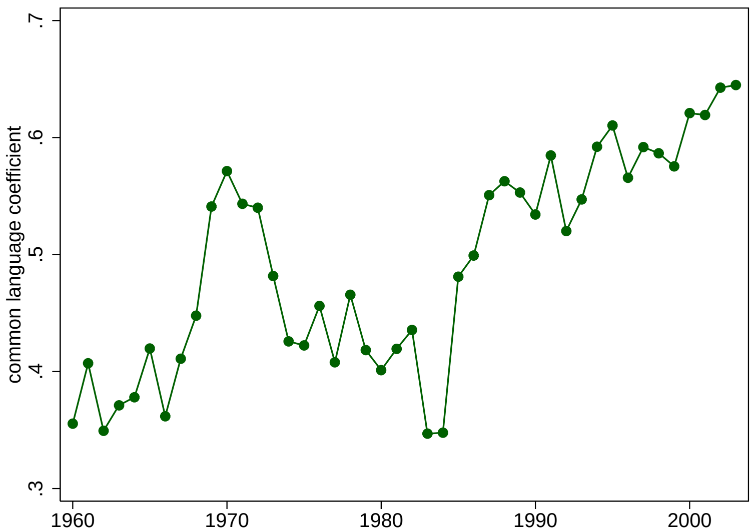


Figure 6: FE estimation of common language coefficient



Starting from the bilateral trade relation derived in the theoretical part, one can verifies that the relative size of bilateral trade with respect to the importer's internal trade is:

$$\frac{Trade_{ij}}{Trade_{jj}} = \frac{n_i}{n_j} \left(\frac{p_i}{p_j}\right)^{1-\sigma} \left(\frac{\tau_{ij}}{\tau_{jj}}\right)^{1-\sigma}$$

Now, multiply this with the relative size of bilateral trade with respect to country i's internal trade to get:

$$\frac{Trade_{ij}}{Trade_{jj}} Trade_{ji} Trade_{ii} = \left(\frac{\tau_{ij}\tau_{ji}}{\tau_{jj}\tau_{ii}}\right)^{1-\sigma}$$

Assuming that $\tau_{ij} = \tau_{ji}$ and $\tau_{ii} = \tau_{jj} = 1$, one can get an estimate of the "free-ness" of trade using trade and production data:

$$\tau_{ij}^{1-\sigma} = \sqrt{(\frac{Trade_{ij}Trade_{ji}}{Trade_{ii}Trade_{jj}})}$$

2 Gravity within and between Canada and the United States (Feenstra, 2004)

A famous example of the sensitivity of gravity estimations with respect to the methodology concerns the so-called "border-effect". Feenstra provide on his website data allowing to illustrate this point (http://www.econ.ucdavis.edu/faculty/fzfeens/textbook.html).

Table 5 illustrates the results of estimates proposed by Feenstra. Comment.

Table 5: Gravity equation on trade within and between Canada and the United States, 1993 data

	(1)	(2)	(3)	(4)
ln GDP, exporter	1.219^a	1.128^a	1.133^a	
	(.033)	(.020)	(.020)	
ln GDP, importer	.980^a	.982^a	.974^a	
	(.033)	(.020)	(.020)	
ln distance	-1.353^a	-1.082^a	-1.111^a	-1.252^a
	(.069)	(.035)	(.034)	(.037)
Canada dummy	2.802^a		2.752^a	
	(.142)		(.109)	
US dummy		.406^a	.398^a	
		(.058)	(.057)	
Border effect				-1.551^a
				(.059)
Constant	3.743^a	2.660^a	2.912^a	
	(.772)	(.449)	(.427)	
Observations	679	1421	1511	1511
R^2	0.762	0.853	0.852	0.664
Method	OLS	OLS	OLS	M/X FE
Sample	Can-Can	USA-USA	Can-Can	Can-Can
	Can-USA	Usa-Can	USA-USA	USA-USA
			Can-Usa	Can-Usa
			Usa-Can	Usa-Can
Within premium	16.5	1.5	15.7/1.5	4.7

t statistics in parentheses

^{c} p<0.1, ^{b} p<0.05, ^{a} p<0.01

Results in Table 5 show that coefficients on provincial or state GDP are close to unity and the relationship between distance and trade is strongly significant. For Canadian data, the coefficient on cross-provincial is surprisingly high. Taking the exponent, we obtain that the cross-provincial trade is

16 times larger than cross-border trade. This is meant to capture all factors that might impede trade between the United States and Canada, ie the “border-effect”.

Anderson and van Wincoop (2003) suggest that this high border-effect is linked to an asymmetry on countries of different size. To see that, suppose for instance that the USA is 10 times larger than Canada. If trade were frictionless, Canada would export 90% of GFDP to the United States and sell 10% internally. Suppose now the border effect reduced cross-border trade by a factor of one half. Then Canada exports 45% of its GDP to the United States and sells 55% internally. Internal trade went up by 5.5 times and cross-border trade by one-half. Internal trade is thus incerased by 11 times more than cross-border trade. Imagine now that Canada exported 10% of its GDP to the United States in a frictionless world. The border effect implies that exports reduce to 5% of Canada’s GDP while internal trade incerases from 90 to 95%. Cross-state trade has now risen by slightly more than 2 times cross-border trade. This side effect is likely to explain the difference in the extent of the “Within premium” between Canada and the USA.

This size effect is less pronounced when controlling for price differentials as large countries are also more competitive.