Trade and the Spatial Distribution of Transport Infrastructure

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Revisiting the Border Effect

- Data on inter- and intranational trade for 21 continental EU countries, year 2012, from WIOD project
- Bilateral distance: population weighted distances between major cities (Head and Mayer, 2014)
- PPML gravity model with appropriate fixed effects (Head and Mayer, 2014)

$$X_{ij} = \exp\left(\delta \ln DIST_{ij} + \beta BORDER_{ij} + \gamma Z_{ij} + ex_i + im_j + \varepsilon_{ij}\right)$$

- $\hat{\beta} = 0.804\ (0.17)$: ceteris paribus, international trade is 55% lower than intranational trade

Contribution and Research Questions

A conceptual framework for understanding the distribution of transport infrastructure and the pattern of transportation costs:

1. How does the optimal distribution of transport infrastructure look like (with or without trade)?
2. Can the border effect be due to systematic underinvestment in infrastructure in border regions?
3. What is the quantitative bite of such a mechanism?
4. Can we find supporting empirical evidence?

Main Mechanism

A link between transport costs and the spatial *endogenous* distribution of transport infrastructure.

- A *GE* model of intra- and interregional trade...
- ... in which transportation costs depend on cumulative transport infrastructure...
- ... whose spatial distribution (in a continuous space) is decided upon by regional planners...
- ... who interact in a non-cooperative way.

The Key Findings

- National governments do not internalize the benefits from infrastructure that accrue to foreign consumers $\implies$ too little infrastructure investment
- Underinvestment in infrastructure has a spatial dimension:
  - trade across national borders entails higher transportation costs than trade within countries, holding bilateral distances and market sizes constant $\implies$ **the border effect!**
- A quantitative exercise:
  - about 20% of the border effect (as usually measured) is due to infrastructure
- Supporting empirical evidence on European cities:
  - transport cost proxies accounting for infrastructure shrink the border effect

Outline

- Modeling transportation costs and transport infrastructure
- Optimal investment, autarky
- Global economics, local policies
- A quantitative exercise
- Empirical evidence

Space: Continuos, Unidimensional

- **Linear** world, $S = [0, \bar{s}]$ (with a "natural periphery")
- $x \in S$ ... address of consumer, $z \in S$ ... address of producer
- $i : S \longrightarrow R^+$ ... spatial distribution of transport infrastructure
- $m : S \longrightarrow R^+$, $m(s) > 0$ ... labor endowment/population size (exogenous)
- $q : S \longrightarrow R^+$, $q(s) > 0$ ... investment costs (exogenous)
- Infrastructure stock available over interval $[x, z] \in S$

$$I(x,z) = \left| \int_x^z i(s)^{1-\delta} ds \right|^{1/(1-\delta)}, \delta > 1$$

with $1/\delta$ being the elasticity substitution between infrastructure investment at different locations

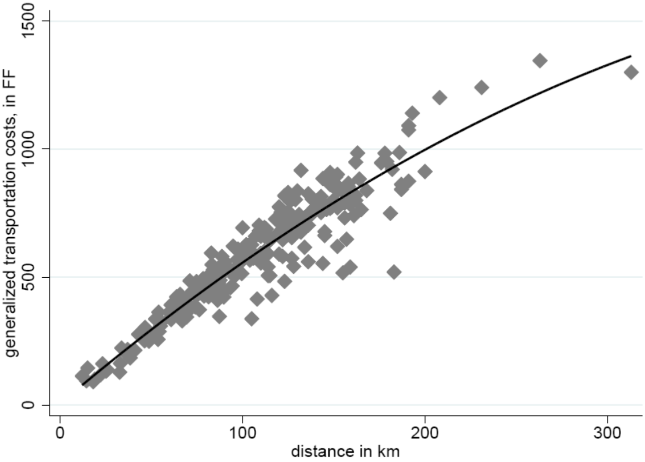
Iceberg Transport Costs

"Standard" approach to modeling iceberg transport costs:

- Krugman (1991): $T(x,z) = e^{a|x-z|}$, $a > 0$
  - analytically tractable
  - unrealistic: $T(x,z)$ depends only on distance and **convex** in distance

Concavity of Transport Costs

Average generalized transit costs, French departments, 1993:



Transportation Costs and Infrastructure

Transportation costs:

$$T(x,z) = \left[1 + \frac{1}{\delta - 1} I(x,z)^{1-\delta}\right]^{\gamma} = \left[1 + \frac{1}{\delta - 1} \left| \int_x^z i(s)^{1-\delta} ds \right| \right]^{\gamma}.$$

- $T(x,z) \geq 1$ with $T(x,x) = 1$; $T(x,y)T(y,z) \geq T(x,z)$
- $T(x,z) = \infty$ if $i(s) = 0$ on some subset (with a positive measure) of $[x,z]$
- $T(x,z)$ can be concave in distance

Armingtonian Supply Side

- At each $z \in S$, two industries with output quantities $y^i(z)$, $i \in \{A, I\}$
  - homogenous good $y^A(z) = bl^A(z)$, freely trade
  - spatially differentiated good $y^I(z) = l^I(z)$, subject to iceberg trade costs $T(x, z)$
- Perfect competition: $p^A(z) = w(z)/b$, $p^I(z) = w(z)$
- Normalization: $p^A(z) = 1 \implies w(z) = b$ for all z
- c.i.f. price at x:

$$p^I(x, z) = p^I(z)T(x, z) = bT(x, z).$$

Consumption

- Household of size $m(x)$ at location x
- Labor income $w(x)m(x) = bm(x)$ taxed at rate $t \geq 0$
- Preferences at x:

$$U(x) = \left[c^A(x)\right]^{\alpha(\sigma-1)/(1-\alpha)} \left[u(x)\right]^{\sigma-1}$$

with

$$u(x) = \left(\int_{z \in S} c^I(x,z)^{(\sigma-1)/\sigma} dz\right)^{\sigma/(\sigma-1)}$$

and $\alpha < 1$, $\sigma > 1$.

- The budget constraint is

$$c^A(x) + \int_{z \in S} p^I(x,z) c^I(x,z)\, dz = bm(x)(1-t).$$

Planner's Problem

- The indirect utility (up to a constant):

$$V(x) = (1-t)^{(\sigma-1)/(1-\alpha)}\tilde{m}(x)\left[\int_{z\in S} T(x,z)^{1-\sigma}\,dz\right], \text{ where}$$
$$\tilde{m}(x) = m(x)^{(\sigma-1)/(1-\alpha)}.$$

- The social planner maximizes the aggregate welfare:

$$\left\{i^a(x), t^a\right\}_{x\in S} = \arg\max\left\{\int_{x\in S} V(x)\,dx \,\middle|\, \int_{x\in S} q(x)\,i(x)\,dx \le btL\right\}$$

with L being the total population size.

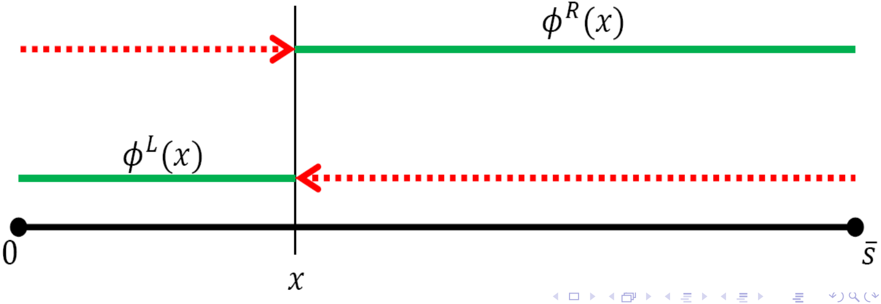
- The objective function is concave if $\gamma(\sigma-1)(\delta-1) < 1$ and $\sigma > 2-\alpha$.
- Without the loss of generality: restrict the solution path $i^a(x)$ to be in the class of continuous functions on $[0, \bar{s}]$.

Solution and Its Properties

- The solution of the planner's problem:

$$i^a(x)^\delta = \frac{bL\gamma(1-\alpha)(1-t^a)}{q(x)}\left[\phi^L(x) + \phi^R(x)\right]$$

where $\phi^L(x)$ and $\phi^R(x)$ represent the aggregate marginal welfare gains to the left and the right of location x.



Solution and Its Properties

- Zero infrastructure investment at borders: $i^a(0) = i^a(\bar{s}) = 0$.
- $\left(i^a(x)\right)'_{x=0} = \infty$ and $\left(i^a(x)\right)'_{x=\bar{s}} = -\infty$.
- If $q(x) = q$ and $m(x) = m$ for any $x \in S$, then $i^a(x)$ is symmetric around $x = \bar{s}/2$ and has a hump shape with maximum at $x = \bar{s}/2$.

2 Country Infrastructure Game

- The world economy: $[0, 2\bar{s}]$-interval $\implies$ border at $s = \bar{s}$
  - locations from $[0, \bar{s}]$ and $(\bar{s}, 2\bar{s}]$ represent the home and foreign country (the countries are symmetric)
- **Global markets, regional politics':**
  - consumers demand goods produced all over the world
  - the government of each country decides on infrastructure investment in a non-cooperative way
- No variation in the costs of infrastructure and the household sizes across locations: i.e., $q(x) = q$ and $m(x) = m$ for all $x \in [0, 2\bar{s}]$
  - to isolate a pure border effect on the equilibrium infrastructure profile

The Social Planner Problem (Home)

- The social planner maximizes the aggregate welfare:

$$\left\{ i^H(x), t^H \right\}_{x \in [0,\bar{s}]} = \arg\max \left\{ \int_0^{\bar{s}} V(x)\, dx \,\middle|\, q \int_0^{\bar{s}} i(x)\, dx \leq btL \right\}$$

- BUT! The indirect utility at x

$$V(x) = (1-t)^{(\sigma-1)/(1-\alpha)} \tilde{m}(x) \left[\int_0^{2\bar{s}} \tau^{ind(x,z)} T(x,z)^{1-\sigma} dz \right],$$

where $ind(x,z)$ is equal to 1 if x and z are in different countries, 0 otherwise.

- The infrastructure profile and tax rate at Foreign are taken as given.

The Nash Solution

- The solution in the symmetric equilibrium:

$$i^H(x)^\delta = \frac{bL\gamma(1-\alpha)(1-t^H)}{q}\left[\phi^{L,H}(x) + \phi^{R,H}(x) + \phi^{L,F}(x)\right],$$

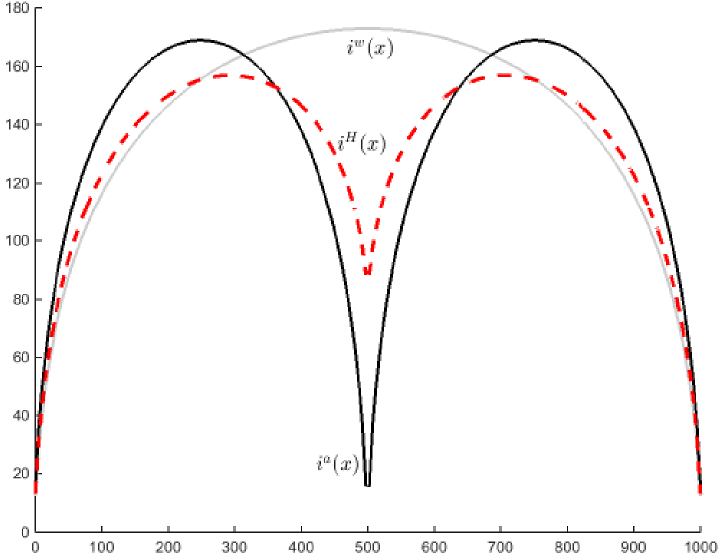
  where $\phi^{L,F}(x)$ is additional welfare gains caused by the presence of Foreign.

- In the symmetric Nash equilibrium:
  - $i^H(0) = 0$, but $i^H(\bar{s}) > 0$
  - $\left(i^H(x)\right)'_{x=0} = \infty$ and $\left(i^H(x)\right)'_{x=\bar{s}}$ is negative, but finite

(a) Normalizations		
Parameter	Value	Explanation
$m(x)$	1000	arbitrary choice
$\bar{s}$	500	arbitrary choice
b	1	symmetry
$q(x)$	1	symmetry
α	0.5	arbitrary choice
(b) Parameters calibrated to match EU data		
Parameter	Value	Moment
γ	0.86	Distance elasticity of transport costs in French data: 0.9
δ	1.65	Distance elasticity μ_1 estimated in EU trade data: -1.1
τ	1.32	Border effect μ_2 estimated in EU trade data: -0.8
σ	2.70	Set to satisfy the inequality given calibrated values of γ, δ, τ

Table:

Illustrations



Border Effect: The Role of Infrastructure

- The following experiment:
  - we set the infrastructure investment $i(x)$ at all locations to its average value under the benchmark parameterization $\bar{\imath}$
  - the distribution of infrastructure is flat and does not affect the size of the border effect
  - all other parameters and variables remain fixed
  - we simulate trade volumes within and between countries and estimate the border effect generated by the model
- We find that the estimate of the border effect drops from 0.80 to 0.65
  - the variation in infrastructure investments explains around 20% of the border effect

Table: The border effect and the role of infrastructure: Poisson models

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dep.var.:	aggregate trade						sectoral trade		
Sample	full		non-contingent pairs				full		
	PPML	PPML	PPML	PGMM	PGMM	PGMM-IV	PPML	PPML	PPML
Border (0,1)	-0.804***	-0.547***	-0.422**	-2.063***	-1.546***	-1.411***	-0.775***	-0.503***	-0.391***
	(0.170)	(0.180)	(0.176)	(0.458)	(0.428)	(0.462)	(0.0915)	(0.101)	(0.101)
ln great-circle distance	-1.112***			-1.204***			-1.142***		
	(0.128)			(0.135)			(0.0674)		
ln road distance		-1.171***						-1.211***	
		(0.123)						(0.0693)	
ln travel time			-1.361***		-1.365***	-1.443***			-1.391***
			(0.124)		(0.139)	(0.163)			(0.0713)
Common language (0,1)	0.761***	0.840***	0.841***	-0.295	-0.145	-0.134	0.763***	0.843**	0.841***
	(0.132)	(0.134)	(0.125)	(0.414)	(0.355)	(0.367)	(0.0803)	(0.0793)	(0.0792)
Contiguity (0,1)	0.326**	0.215	0.134				0.320***	0.200**	0.131
	(0.157)	(0.154)	(0.141)				(0.0845)	(0.0843)	(0.0816)
Constant	14.92***	15.58***	16.07***	17.66***	17.66***	18.03***	12.49***	13.24***	13.63***
	(0.881)	(0.872)	(0.802)	(0.835)	(0.835)	(0.834)	(0.780)	(0.788)	(0.758)
Observations	441	441	441	377	377	377	7,004	7,004	7,004
R-squared	0.989	0.990	0.991	0.977	0.977		0.959	0.961	0.961

Notes: Pseudo Maximum Likelihood (PPML) or Generalized Methods of Moments (PGMMs) estimations of Poisson moels. All models contain complete sets of separate exporter and importer fixed effects (exporter $\times$ sector, importer $\times$ sector effects in case of sectoral trade data). Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Conclusion

- Endogenous distribution of infrastructure investment may lead to systematic ***underinvestment in border regions***, thereby rationalizing (partly) the ***border effect***
- Small border costs ***amplify*** the border effect
- Empirical analysis confirms predictions of the model

Thank you!