Estimating Border Effects: The Impact of Spatial Aggregation

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Motivation

By how much borders impede international trade?

- McCallum (1995), Anderson and van Wincoop (2003) and others.
- Gravity equation as the workhorse model.

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By how much borders impede international trade?

- McCallum (1995), Anderson and van Wincoop (2003) and others.
- Gravity equation as the workhorse model.

But, does spatial aggregation matter?

- Idea: Aggregation might increase the relative costs of trading *within* as opposed to *across* borders.

Motivation

Contribution and anticipation of the results:

- Formalization of the idea that standard gravity equations are sensitive to aggregation
- Theoretical results show that empirical estimates of border effects in the literature (domestic and international) are upward biased
- **Spatial Attenuation Effect**. Estimated border effects are smaller for larger aggregates (countries or regions) and larger for smaller ones
- Empirical analysis on trade flows consistent with the theory

Overview

Relation to existing Literature

- **International border effects:**
  McCallum (1995), Anderson and van Wincoop (2003)

- **Domestic border effects:**
  Wolf (2000), Millimet and Osang (2007), Nitsch (2000), Bemrose, Brown and Tweedle (2016).

- **Economic greography:**
  Briant, Combes and Lafourcade (2010)

Gravity Framework

Following Anderson and van Wincoop (2003)

$$x_{ij} = \frac{y_i y_j}{y^W} \left(\frac{t_{ij}}{P_i P_j} \right)^{1-\sigma}$$

$$ln(t_{ij}^{1-\sigma}) = \beta INT_{ij} + \gamma DOM_{ij} + \rho ln(dist_{ij})$$

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Plugging the second equation in, we obtain our **gravity equation**:

The Gravity Equation

$$\begin{aligned} ln(x_{ij}) =& ln(y_i) + ln(y_j) - ln(y^W) + ln(P_i^{\sigma-1}) + ln(P_j^{\sigma-1}) \\ &+ \beta INT_{ij} + \gamma DOM_{ij} + \rho ln(dist_{ij}) \end{aligned}$$

The Model: Domestic Border Effect

The Goal

Understand how the domestic border dummy coefficients are affected when regions are spatially aggregated.

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Understand how the domestic border dummy coefficients are affected when regions are spatially aggregated.

The Assumptions

1. There is an arbitrarily large number of small (S) regions
2. Armington
3. Symmetry $\Rightarrow y_i^S = y^S, P_i^S = P^S \quad \forall i$
4. Frictions at the micro level:
   - Internal trade costs: t_{ii}^S
   - Bilateral trade costs: $t_{ij}^S = t^S$, with $t^S \geq t_{ii}^S \geq 1$.

The Model: Domestic Border Effect

Under the above assumptions, the gravity equation for small region S becomes:

$$x_{ij}^S = \frac{y^S y^S}{y^W} \left(\frac{t_{ij}^S}{P^S P^S} \right)^{1-\sigma}$$

Aggregate $n \geq 2$ regions:

Internal trade costs

$$x_{ii}^L = \frac{y^L y^L}{y^W} \left(\frac{t_{ii}^L}{P^L P^L} \right)^{1-\sigma} \tag{1}$$

The Model: Domestic Border Effect

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Aggregate $n \geq 2$ regions:

Internal trade costs

$$x_{ii}^L = \frac{y^L y^L}{y^W}\left(\frac{t_{ii}^L}{P^L P^L}\right)^{1-\sigma} \quad (1)$$

Note:

$$x_{ii}^L = n x_{ii}^S + n(n-1) x_{ij}^S$$

$$P^L = P^S$$

The Model: Domestic Border Effect

Equation (1) can be simplified to:

$$(t_{ii}^{L})^{1-\sigma} = \frac{1}{n}(t_{ii}^{S})^{1-\sigma} + \frac{n-1}{n}(t^{S})^{1-\sigma} \tag{2}$$

Takeaways:

- Internal trade costs at the macro level grow in the number of aggregated micro regions.
- A frictionless world is the only case where aggregation is irrelevant.

The Model: Domestic Border Effect

Bilateral trade costs

$$x^L_{n_1,n_2} = \frac{y^L_{n_1} y^L_{n_2}}{y^W} \left(\frac{t^L_{n_1,n_2}}{P^L P^L} \right)^{1-\sigma} \tag{3}$$

Given:

1. $x^L_{n_1,n_2} = n_1 n_2 x^S_{ij}$
2. $P^S = P^L$

$$\Rightarrow t^L_{n_1,n_2} = t^S$$

Result: bilateral trade costs between any two regions are the same regardless of the degree of aggregation.

The Model: Domestic Border Effect. Estimation.

OLS Estimate of Domestic Border Effects

$$\hat{\gamma} = \gamma + \underbrace{\left(\prod_{i=1}^{N} (t_{ii}^{\sigma-1})^{\frac{1}{N}} \right)}_{\text{Bias}} \tag{4}$$

Interpretation:

- Coefficient is upward biased
- Aggregation bias

The Model: Domestic Border Effect. Estimation.

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Implications:

1. Interpretation relative to zero-internal-frictions
2. No direct comparability across samples
3. Systematic composition effects Heterogeneity

The Model: International Border Effect

Sketch of the model

1. World with two countries: Home (H) and Foreign (F)
2. Topography: Country $\equiv$ circle with multiple small micro-regions (S)
3. Armington
4. Symmetry
5. When aggregating, macro regions have no "holes".
6. Trade costs:
   - Internal: t_{ii}^{S}
   - Bilateral: $t_{h}^{S} = \delta^{h}$ with $\delta \geq 1$ with (h =steps between regions)
   - International: $t_{int}^{S} = \delta_{int} exp\left(\frac{\beta}{1-\sigma}\right)$

The Model: International Border Effect

Results:

- Bilateral trade costs at the macro level *within* a country are now sensitive to aggregation Maths
- Bilateral trade costs *between* countries invariant to aggregation
- Implication for estimation: Impact of border is heterogeneous. Spatial Attenuation Effect Maths

The Data

- **Commodity Flow Survey**: Trade flows within US states
- **Origin of Movement series (US Census Bureau)**: Trade flows from US states to 50 largest US export destinations
- Balanced panel for the years 1993, 1997, 2002 and 2007
- For comparability, use of same data as Wolf (2000) and Anderson and van Wincoop (2003)

Empirics. Estimating common border effects

Table 1: Domestic and international border effects

Sample	U.S. only		U.S. and foreign countries	
Year	1993	1993, 1997, 2002, 2007	1993	1993, 1997, 2002, 2007
	(1)	(2)	(3)	(4)
$\ln(dist_{ij})$	-1.07***	-1.08***	-1.19***	-1.21***
	(0.03)	(0.03)	(0.02)	(0.02)
DOM_{ij} (domestic border dummy)	-1.47***	-1.48***		
	(0.20)	(0.19)		
INT_{ij} (international border dummy)			-1.25***	-1.21***
			(0.08)	(0.06)
Internal trade (within U.S. states)	yes	yes	no	no
Domestic trade (between U.S. states)	yes	yes	yes	yes
International trade (with foreign countries)	no	no	yes	yes
Observations	1,726	6,904	6,249	24,996
Clusters	--	1,726	--	6,249
Fixed effects	yes	yes	yes	yes
R-squared	0.90	0.90	0.81	0.82

Notes: The dependent variable is $\ln(x_{ij})$. OLS estimation. Robust standard errors are reported in parentheses, clustered around bilateral pairs ij in columns 2 and 4. Exporter and importer fixed effects in columns 1 and 2; state and country fixed effects in columns 3 and 4; those fixed effects are time-varying in columns 2 and 4. ** significant at 1% level.

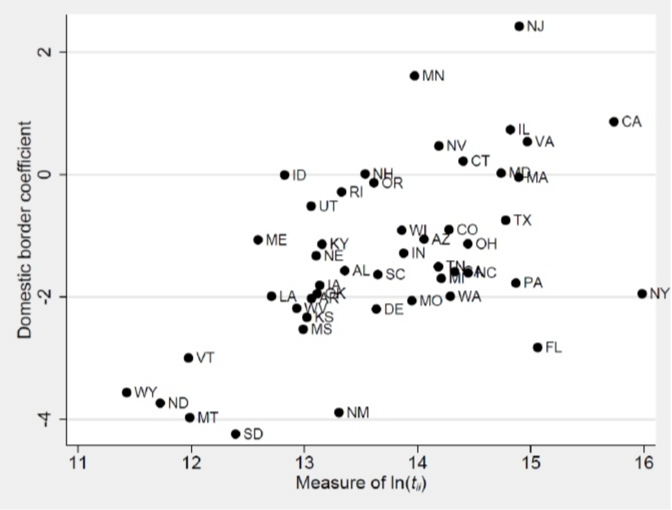

Figure
Heterogeneity in domestic border effects

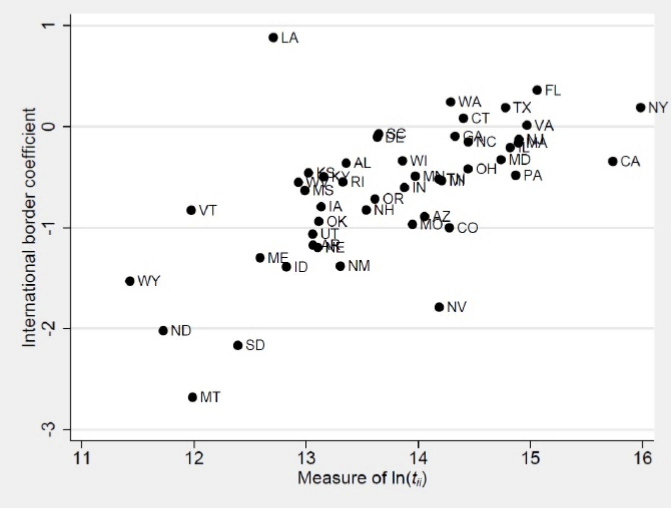

Figure
Heterogeneity in international border effects

Robustness Checks:

- Sample composition effects Go
- Aggregating to US Census Divisions Go
- Multilateral resistance effects in GE Go

Conclusions

- The parameters γ and β **(domestic and international border effects) cannot be identified empirically** in gravity regressions based on aggregate data.
- **Aggregation leads to border effect heterogeneity**. In particular, larger regions or countries are associated with border effects closer to zero. The opposite holds for smaller countries.
- **Theoretical predictions seem to hold in the data**, i.e. larger US states (e.g. California) have significantly lower border effects (domestic and international) than smaller ones (e.g. Wyoming).

Thanks for your attention!

Appendix: heterogeneity in trade costs

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Problem with domestic border effect approach

In reality, $t_{ii} \neq t_{jj}$ $\forall i, j$, in general.

Solution. Let trade cost function account for heterogeneity:

$$ln(t_{ij}^{1-\sigma}) = \gamma DOM_{ij} + \psi(1 - DOM_{ij}) ln(t_{ii}^{1-\sigma} t_{jj}^{1-\sigma})^{\frac{1}{2}}$$

Estimates

$$\hat{\gamma} = \gamma + \underbrace{\psi ln(t_{ii}^{1-\sigma} t_{jj}^{1-\sigma})^{\frac{1}{2}}}_{\text{Spatial Attenuation Effect}}$$

Appendix: heterogeneity in trade costs (1)

Trade costs at the macro level

$$t^{L}_{n_1,n_2,h} = \underbrace{\delta^h}_{\text{bilateral distance}} \underbrace{\left(\frac{1}{n_1}\sum_{v=1}^{n_1}(\delta^{v-1})^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}_{\alpha_{n_1}} \underbrace{\left(\frac{1}{n_2}\sum_{w=1}^{n_2}(\delta^{w-1})^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}_{\alpha_{n_2}}$$

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Appendix: heterogeneity in trade costs (2)

Heterogeneity in trade costs

$$\frac{dln(x_{ij})}{dINT_{ij}} = \beta + \underbrace{\{ln(\alpha_i^{\sigma-1}) + ln(\alpha_j^{\sigma-1})\}}_{\text{Spatial Attenuation Effect}}$$

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Appendix: Sample composition effects (1)

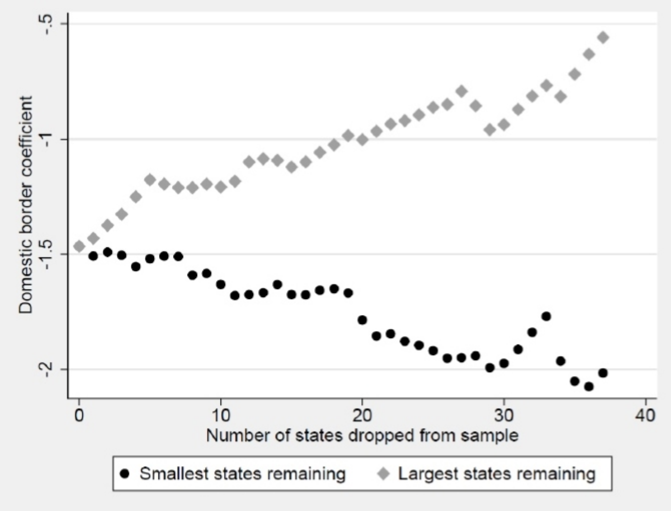

Figure
Illustration of sample composition effects - domestic border

Appendix: Sample composition effects (2)

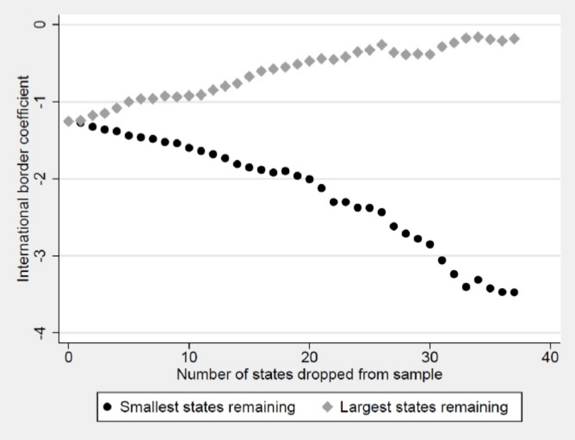

Figure
Illustration of sample composition effects - international border

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Appendix: Aggregation to US Census Divisions (1)

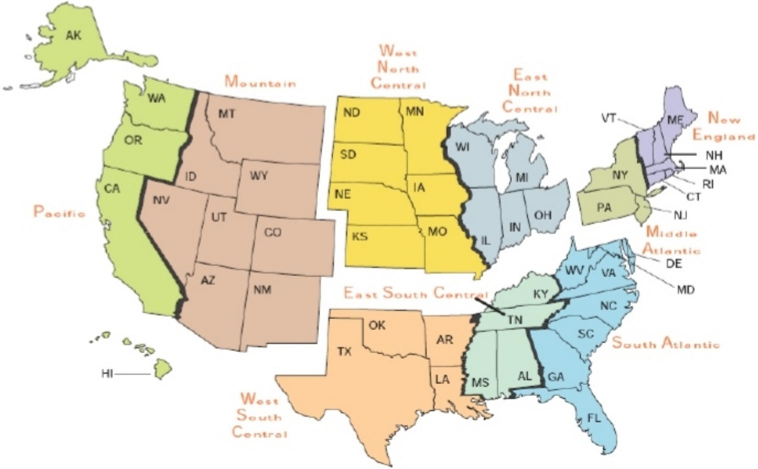

Figure 6: A map of the nine U.S. Census divisions (source: U.S. Department of Energy).

Appendix: Aggregation to US Census Divisions (2)

Table 2: Border effects based on U.S. Census divisions

Sample	U.S. only		U.S. and foreign countries	
Year	1993	1993, 1997, 2002, 2007	1993	1993, 1997, 2002, 2007
	(1)	(2)	(3)	(4)
$\ln(dist_{ij})$	-1.07***	-1.04***	-1.17***	-1.21***
	(0.10)	(0.08)	(0.03)	(0.03)
DOM_{ij} (domestic border dummy)	-1.17***	-1.25***		
	(0.18)	(0.17)		
INT_{ij} (international border dummy)			-0.36***	-0.39***
			(0.11)	(0.10)
Internal trade (within Census divisions)	yes	yes	no	no
Domestic trade (between Census divisions)	yes	yes	yes	yes
International trade (with foreign countries)	no	no	yes	yes
Observations	81	324	2,746	10,984
Clusters	--	81	--	2,746
Fixed effects	yes	yes	yes	yes
R-squared	0.95	0.96	0.78	0.79

Notes: The dependent variable is $\ln(x_{ij})$. OLS estimation. Robust standard errors are reported in parentheses, clustered around bilateral pairs ij in columns 2 and 4. Exporter and importer fixed effects in columns 1 and 2; division and country fixed effects in columns 3 and 4; those fixed effects are time-varying in columns 2 and 4. *** significant at 1% level.

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Appendix: Multilateral resistance effects in GE (1)

The intuition

Small and large countries react differently to changes in international barriers. After removing a border, relative reallocation to international trade is larger for smaller countries.

Appendix: Multilateral resistance effects in GE (2)

Table 3: General equilibrium effects in response to removing the U.S. international border

	Panel 1: Common border effect							Panel 2: Heterogeneous border effects						
	Total effect		Direct effect		Indirect GE effects			Total effect		Direct effect		Indirect GE effects		
U.S. state	$\Delta \ln(x_{ij})$	=	$(1-\sigma)\,\Delta \ln(t_{ij})$	+	$(\sigma-1)\,\Delta \ln(P_iP_j)$	+	$\Delta \ln(y_iy_j/y^W)$	$\Delta \ln(x_{ij})$	=	$(1-\sigma)\,\Delta \ln(t_{ij})$	+	$(\sigma-1)\,\Delta \ln(P_iP_j)$	+	$\Delta \ln(y_iy_j/y^W)$
	(1a)		(1b)		(1c)		(1d)	(2a)		(2b)		(2c)		(2d)
Average	**0.23**	=	**0.31**	+	**-0.10**	+	**0.02**	**0.24**	=	**0.33**	+	**-0.11**	+	**0.02**
AL	0.24	=	0.31	+	-0.08	+	0.01	0.11	=	0.18	+	-0.10	+	0.02
AR	0.22	=	0.31	+	-0.10	+	0.02	0.45	=	0.60	+	-0.19	+	0.04
AZ	0.21	=	0.31	+	-0.12	+	0.02	0.32	=	0.45	+	-0.17	+	0.03
CA	0.24	=	0.31	+	-0.08	+	0.01	0.13	=	0.18	+	-0.06	+	0.01
CO	0.23	=	0.31	+	-0.10	+	0.02	0.40	=	0.51	+	-0.14	+	0.03
CT	0.25	=	0.31	+	-0.06	+	0.01	-0.07	=	-0.04	+	-0.03	+	0.00
DE	0.25	=	0.31	+	-0.06	+	0.01	0.01	=	0.05	+	-0.05	+	0.01
FL	0.21	=	0.31	+	-0.12	+	0.02	-0.13	=	-0.18	+	0.08	+	-0.02
GA	0.23	=	0.31	+	-0.09	+	0.01	0.01	=	0.05	+	-0.05	+	0.01
IA	0.22	=	0.31	+	-0.10	+	0.02	0.30	=	0.40	+	-0.13	+	0.03
ID	0.23	=	0.31	+	-0.09	+	0.01	0.58	=	0.71	+	-0.16	+	0.03
IL	0.25	=	0.31	+	-0.07	+	0.01	0.07	=	0.11	+	-0.04	+	0.01
IN	0.24	=	0.31	+	-0.09	+	0.01	0.23	=	0.31	+	-0.10	+	0.02
KS	0.22	=	0.31	+	-0.10	+	0.02	0.16	=	0.23	+	-0.09	+	0.02
KY	0.24	=	0.31	+	-0.08	+	0.01	0.18	=	0.25	+	-0.09	+	0.02
LA	0.22	=	0.31	+	-0.10	+	0.02	-0.27	=	-0.45	+	0.23	+	-0.05
MA	0.23	=	0.31	+	-0.09	+	0.01	0.03	=	0.08	+	-0.06	+	0.01

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