Roads and Trade:

Evidence from the US

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Objective:

Estimate the effects of US interstate highways on the level and composition of trade between cities

Main results: Highways within cities promote trade in tons but not in dollar

Why this matters:

- Trade and specialisation matter for growth
- Large resources are devoted to building and maintaining roads
- Trading cities are an important network

What we do:

1. Build a simple model of cities and trade
2. Design a two-step empirical strategy

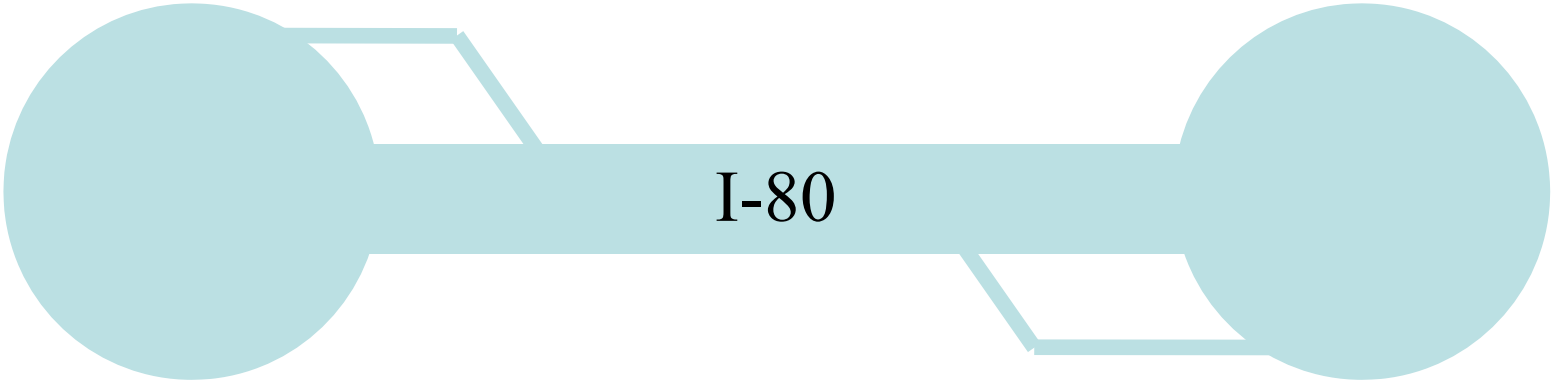
   Step 1: Estimate the propensity of cities to trade from bilateral trade flows

   Step 2: Estimate the elasticity of highways within cities on trade
3. Implement this strategy on high quality and rich data

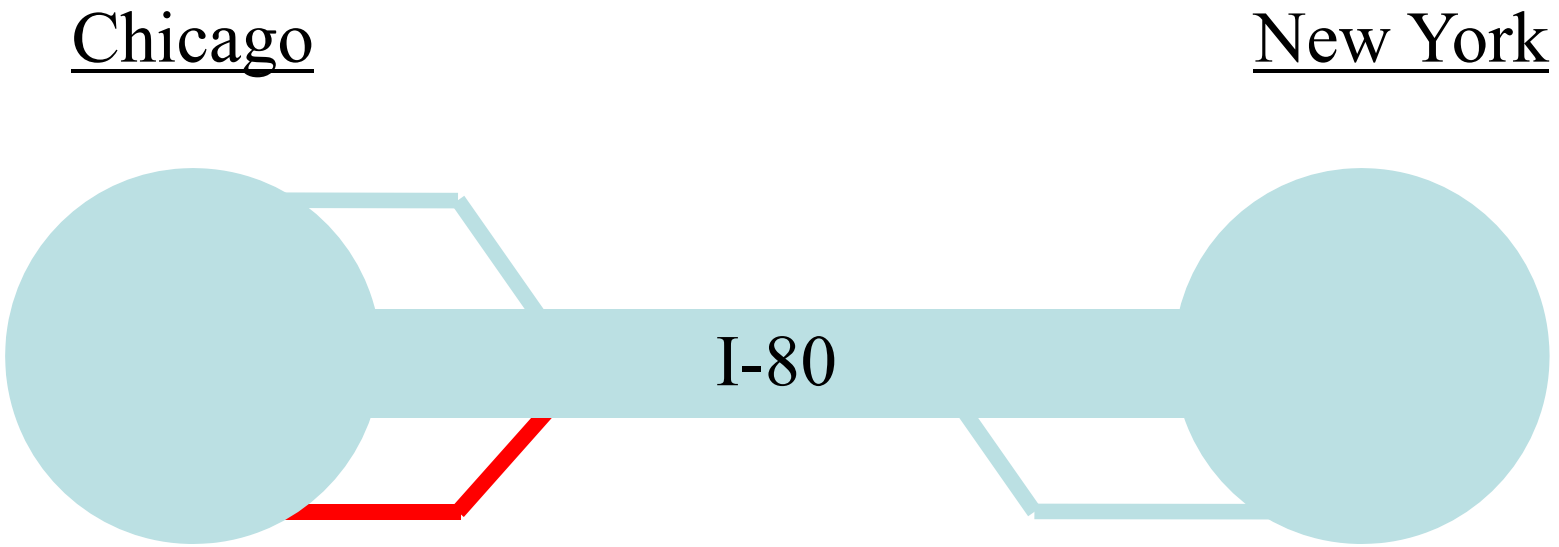
Our thought experiment

Chicago

New York



Our thought experiment



Main identification issue

- Highway construction can be more prevalent in cities that trade more or, alternatively, in cities that trade less

- We exploit exogenous variation in exploration routes between 1528 and 1850, in railroad routes circa 1898, and in a 1947 plan of the interstate highway network

Related literature

- Greater infrastructure facilitates trade: Limao and Venables (2001), Clark et al. (2004), Michaels (2008), Feyrer (2009), Donaldson (2010)

- Transportation costs exist and matter: Hummels (2001,2007), Anderson and Van Wincoop (2004)

- The effect of infrastructure on domestic outcomes: Gramlich (1994), Fernald (1999), Baum-Snow (2007), and Duranton and Turner (2010,2011)

Model

- Estimable gravity model in which importer and exporter fixed effects have a structural interpretation
- A clear exposition of endogeneity concerns
- Comparative advantage/specialisation predictions

Model: Geography, technology and preferences

- Large set of cities
  (exporter i and importer j)
- A continuum of sectors k
- Labour (N): only factor of production paid wage W and immobile across cities
- Each city produces a unique variety in each industry: $Q_i^k = A_i N_i^k$

- Varieties are equally substitutable across industries and producers:

$$U_j = \left[\sum_{i=1}^{i=n} \int_0^1 (q_{ij}^k)^{\frac{\sigma-1}{\sigma}} \, dk \right]^{\frac{\sigma}{\sigma-1}}$$

- Value of shipments of variety k from i to j:

$$X_{ij}^k \equiv P_{ij}^k Q_{ij}^k = \left(\frac{\mathbb{P}_j}{P_{ij}^k} \right)^{\sigma-1} N_j W_j$$

- Constant returns, free entry, and iceberg transportation costs $\Rightarrow$

$$P_{ij}^k = \tau_{ij}^k \frac{W_i}{A_i}$$

- Aggregate value of shipments from i to j:

$$X_{ij} = \left(\frac{A_i}{W_i} \right)^{\sigma-1} \left[\int_0^1 \left(\tau_{ij}^k \right)^{1-\sigma} \, dk \right] \mathbb{P}_j^{\sigma-1} N_j W_j$$

Model: more on transportation costs

- Iceberg τ_{ij}^k decomposed as: $\tau_{ij}^k \equiv \tau^k(R_i,R_{ij},R_j) = \tau_x^k(R_i) \times \tau_{xm}(R_{ij}) \times \tau_m(R_j)$ with
  - τ_i^k: exporting costs (city sector)
  - τ_{ij}: cost of distance between i and j
  - τ_j: importing cost
- Depend on roads within and between cities
- Sectors producing heavier goods are more sensitive to roads when exporting
- Issues:
  - Not all parts of the transportation cost are sector specific
  - Everything is multiplicative
  - Heavier sectors may or may not be more sensitive to roads

Implications for trade flows

Proposition:

- A reduction in road distance between two cities increases the value of trade between these two cities but does not affect its composition
- An increase in roads within a city causes an increase in the weight and value of the goods produced in that city
- It also causes a decrease in employment by sectors producing light goods and an increase in employment by sectors producing heavy goods

Implications for estimation

- After simplification, trade flows in value are:

$$\ln X_{ij} = \delta_i^X + (1-\sigma)\ln \tau_{ij} + \delta_j^M$$

- Exporter effect:

$$\delta_i^X = \ln(N_j W_j) - MA_j^M = S(R_i) + \frac{\sigma-1}{\sigma}\ln A_i + \frac{\sigma-1}{\sigma}\ln N_i - \frac{\sigma-1}{\sigma}MA_i^X$$

where: $S(R_i) \equiv \frac{1}{\sigma}\ln \int_0^1 \left(\tau_i^k\right)^{1-\sigma} dk$

and: $MA_i^X = \ln \sum_{j=1}^{j=n} e^{(1-\sigma)\ln \tau_{ij} + \delta_j^M}$

- Importer effect:

$$\delta_j^M = S(R_j) + \frac{\sigma-1}{\sigma}\ln(A_j) + \frac{\sigma-1}{\sigma}\ln(N_j) + \frac{\sigma}{(\sigma-1)^2}MA_j^X - MA_j^M$$

Implications for estimation (2)

- After simplification, trade flows in weight are:

$$\ln T_{ij} = \delta_i^T + (1-\sigma)\ln \tau_{ij} + \delta_j^M$$

- Exporter effect:

$$S^T(R_i) + \ln A_i + \ln N_i - MA_i^X$$

where: $S^T(R_i) \equiv \ln \int_0^1 \left(\tau_i^k\right)^{1-\sigma} V^k \, dk - \ln \int_0^1 \left(\tau_i^k\right)^{1-\sigma} \, dk$

- Analogous expressions when allowing for labour mobility

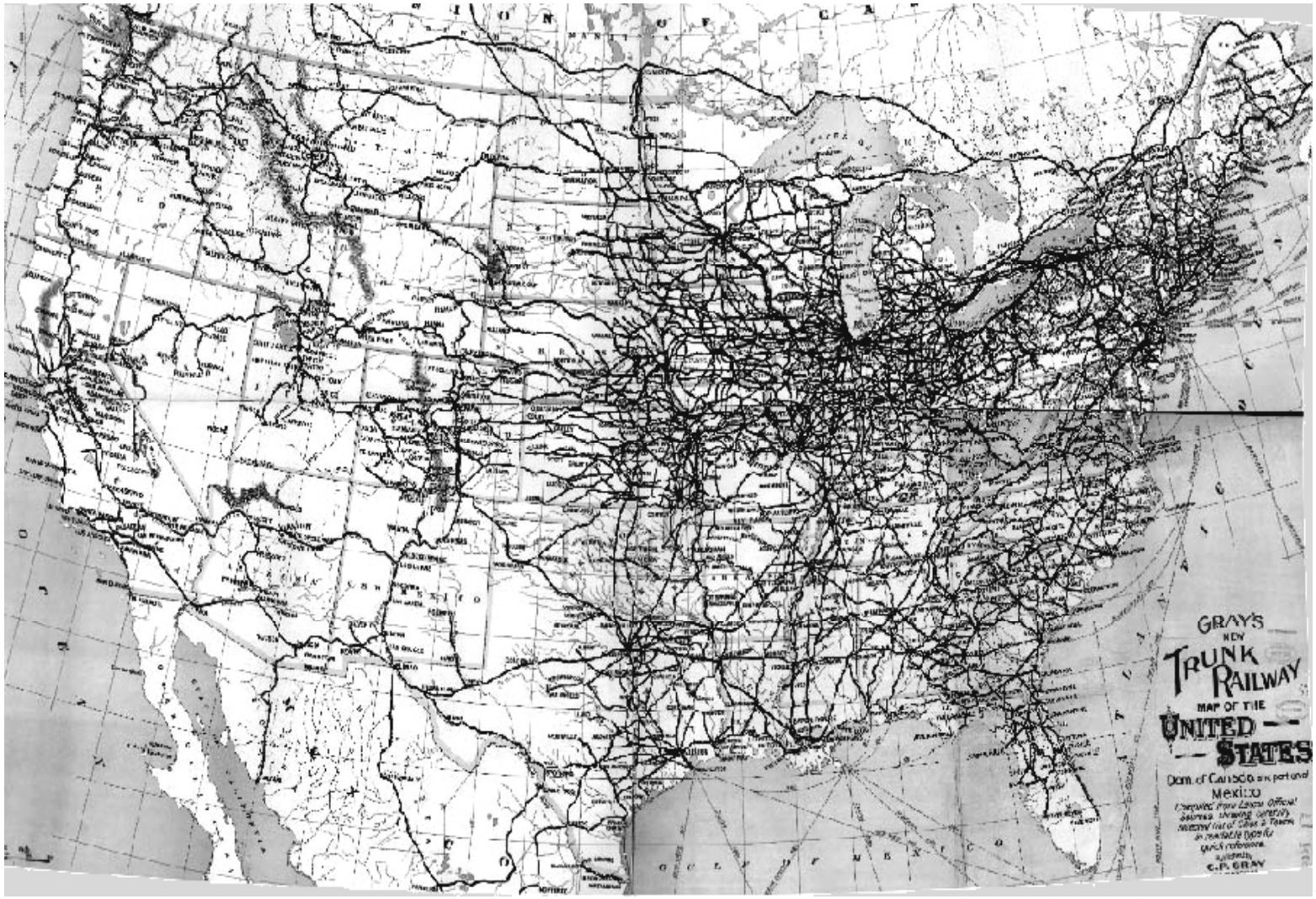
Data

- 2007 Commodity Flow Survey: aggregate trade flows by mode between 66 CFS 'cities'
- 2005 Highway Performance Monitoring Survey: km of highways within and between cities, measures of network shape
- North American Atlas: km of railroads within and between cities
- 1920, 1950, 1990, and 2000 US Census
- County Business Patterns for 1956, 1967, 1977, 1987, 1997, and 2007
- Various measures of geography
- Historical road data: 1898 railroads, 1528-1850 exploration routes, and 1947 highway plan

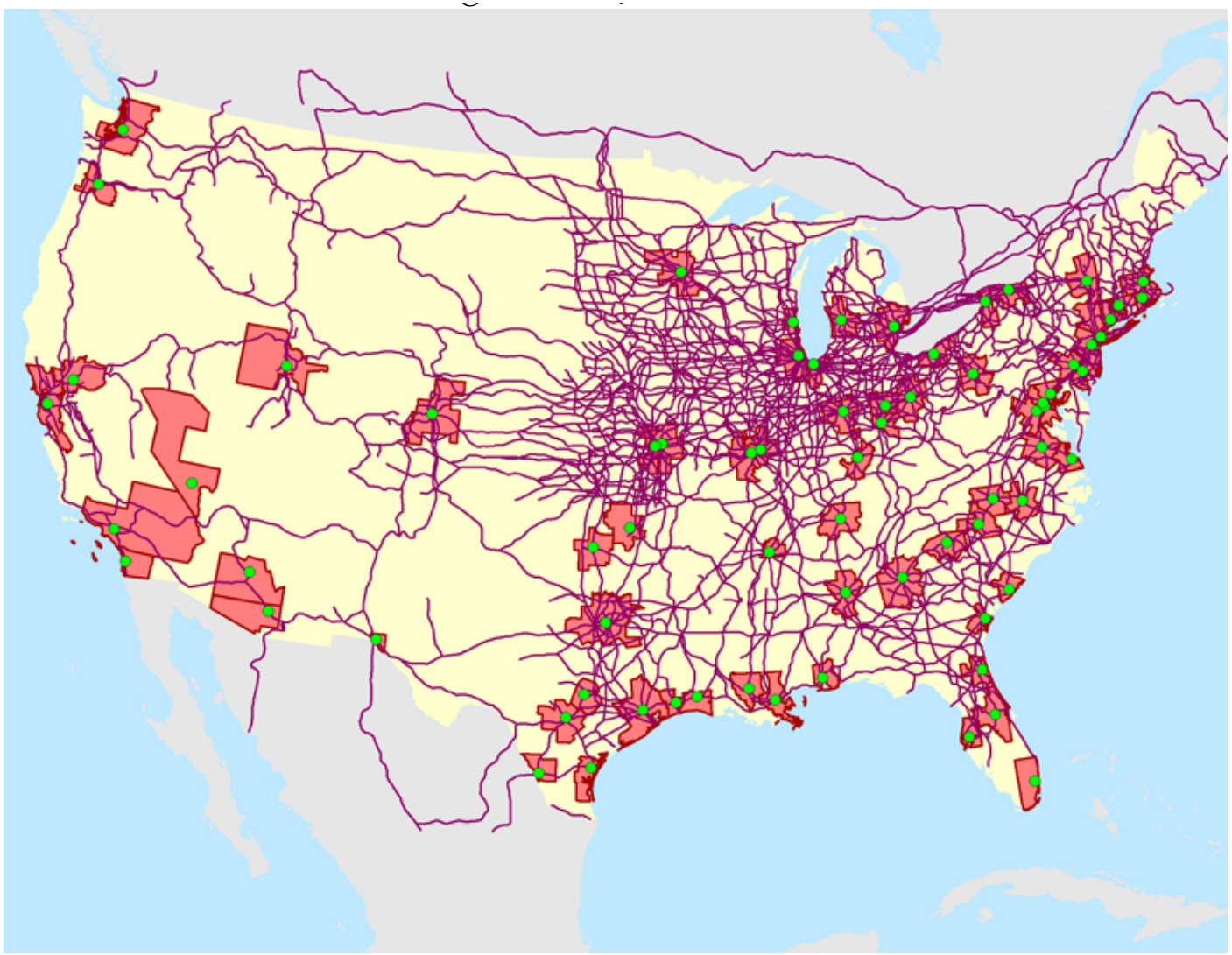
Summary statistics for our main variables

Variable	Mean	Std. Dev.	Minimum	Maximum
Value of exported shipments, road	50,552	62,810	1,295	406,851
(log) Value of exported shipments, road	10.35	0.99	7.17	12.92
Value of imported shipments, road	50,552	57,213	6,182	360,004
(log) Value of imported shipments, road	10.45	0.83	8.73	12.79
(log) Weight of exported shipments, road	10.52	0.89	7.32	12.60
Weight of exported shipments, road	52,615	49,855	1,512	297,702
% Road in exported value	70.7%	14.4%	17.1%	90.1%
% Rail in exported value	1.1%	2.2%	0%	10.0%
% Road in exported weight	86.2%	16.2%	23.5%	100%
% Rail in exported weight	1.5%	2.4%	0%	13.8%
% export in all shipments, value	62.1%	11.3%	40.6%	91.8%
% export in all shipment, weight	31.3%	15.3%	7.3%	78.2%
Employment, 2007	1,129,117	1,180,287	66,006	6,759,481
Section km of interstate highway, 2007	381	247	61	1,661
Railroad km, 2004	335	228	65	1304
Planned highway km, 1947	252	162	56	1,016
Railway km, 1898	619	405	91	2,104
Exploration routes index, 1518-1850	6,329	5,386	225	36,049

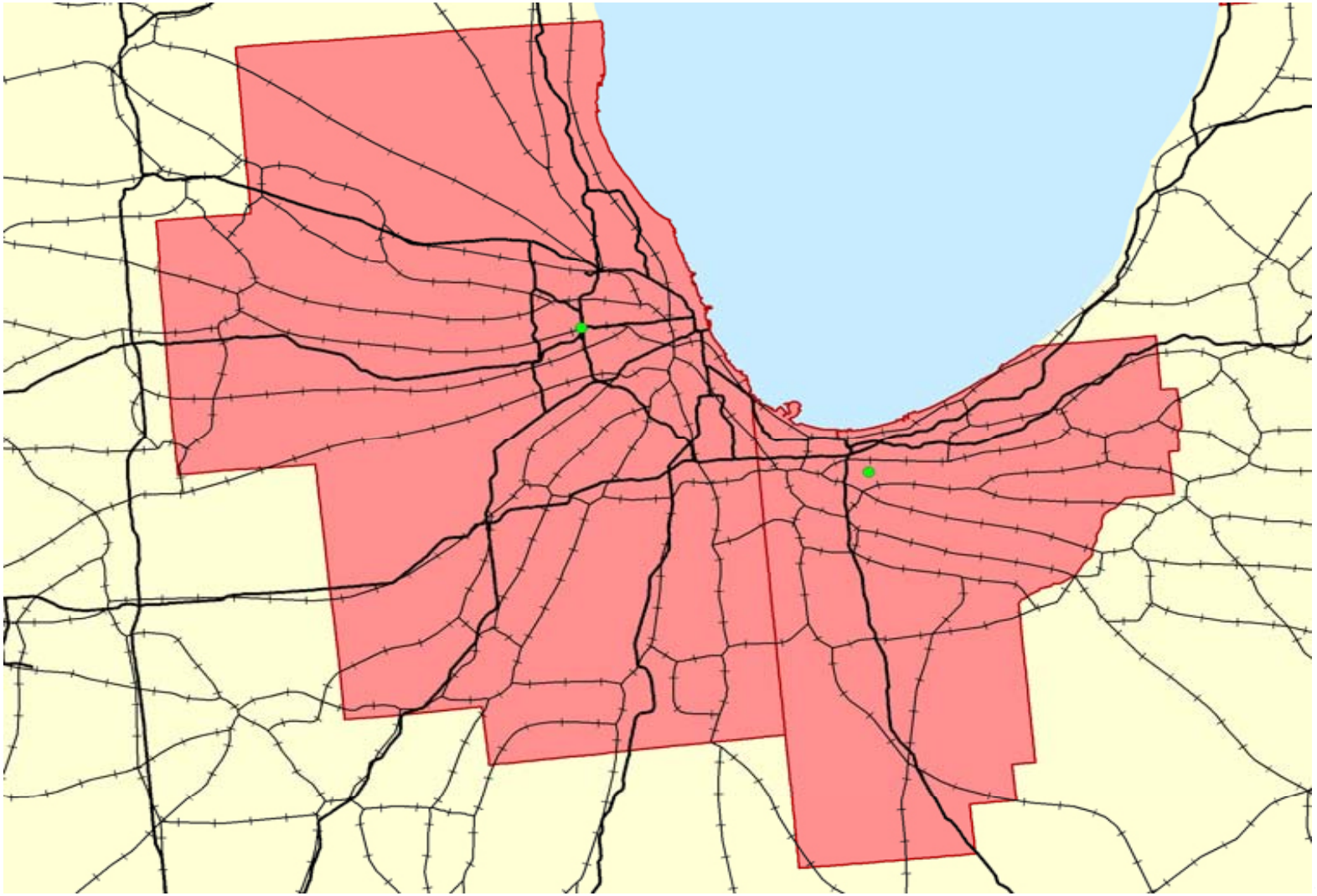
1898 railroads



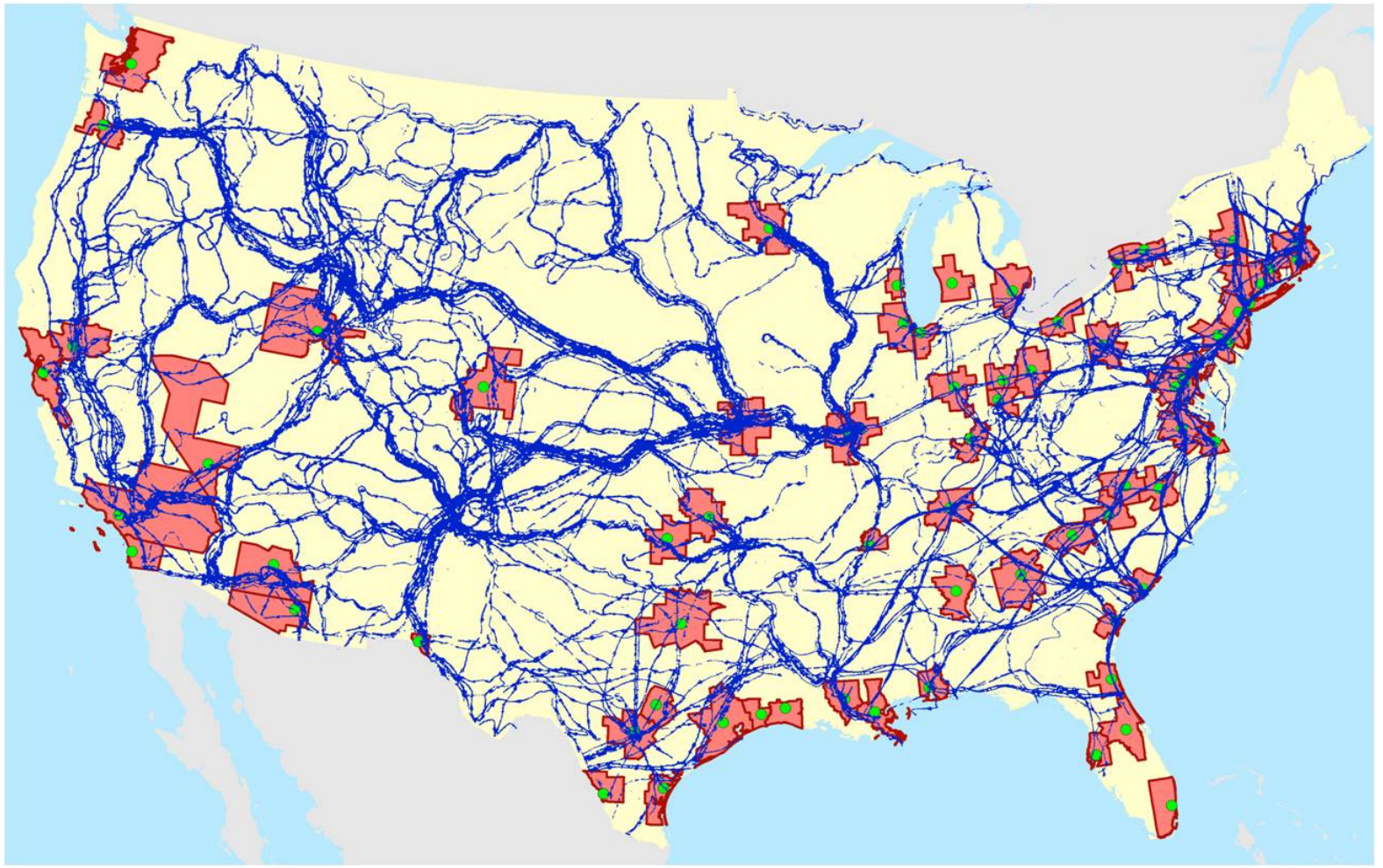
1898 railroads



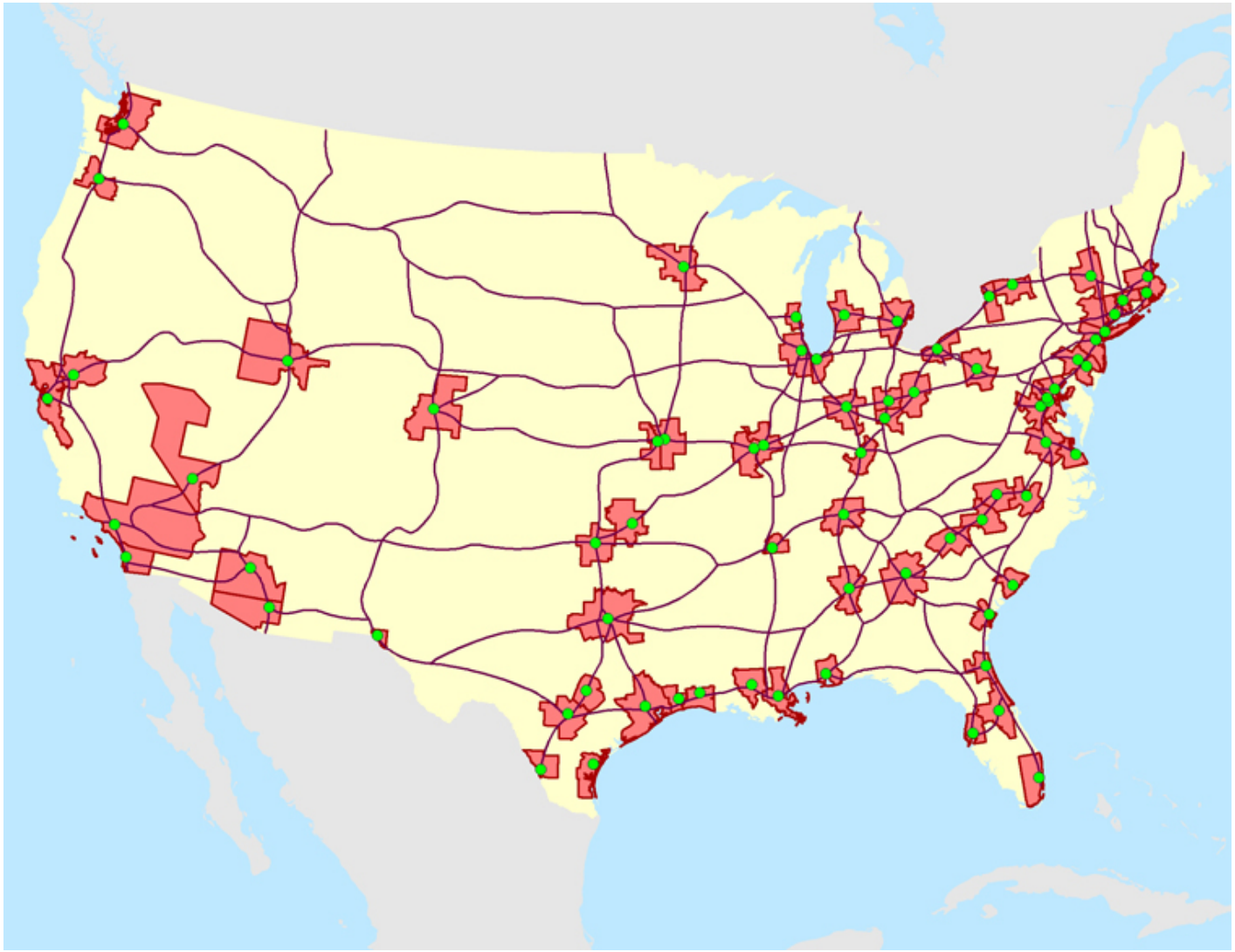
1898 railroads, close up on Chicago



1528-1850 exploration routes



1947 highway plan



Estimation strategy

- Step 1: gravity with fixed effects

$$\ln X_{ij} = \delta_i^X + D_{ij}\alpha + \delta_j^M + \epsilon_{ij}$$

- Step 2: Estimate the effect of city highways

$$\hat{\delta}_i^X = \beta_0 + \rho_R^X \ln R_i + \beta' C_i + \mu_i$$

- Main issue: city productivity should appear as a control but is not observed
  (alternatively and equivalently, city roads are endogenous)

Instrumentation

- 3 historical transportation measures predicting contemporaneous roads (relevance condition)
- 1898 highways are plausibly unrelated to trade flows today
  (built for local traffic or for grain, livestock, lumber, and migrants)
  But controls are needed to preclude alternative channels
  (exogeneity condition)
- Same type of arguments for old exploration routes and the 1947 highway map
- But different reasons for why our IV may fail (eg, exploration routes are less linked to productivity and more to geography): meaningful over-identification tests

Other estimation issues

- Functional forms
- Use of an estimate as dependent variable
- Rail?
- Endogeneity of market access
- Logistics platform
- Higher quality (as opposed to 'just' lighter goods)
- Direct effect on productivity

First step results: weight

	(1) OLS	(2) TSLS	(3) OLS	(4) TSLS	(5) OLS	(6) TSLS	(7) OLS	(8) OLS
Distance	2005 hwy	2005 hwy	2005 hwy	2005 hwy	2005 hwy	2005 hwy	Eucl.	Eucl.
Panel A. Dependent variable: Weight of bilateral trade flows, road trade.								
log distance	-1.90***	-1.90***	-2.86***	-2.87***	-3.72	0.32	-1.91***	-1.01
	(0.023)	(0.022)	(0.17)	(0.16)	(6.95)	(5.89)	(0.024)	(6.94)
log distance^2			0.077***	0.078***	0.76	-0.25		0.079
			(0.013)	(0.013)	(1.77)	(1.50)		(1.80)
log distance^3					-0.13	-0.018		-0.055
					(0.19)	(0.17)		(0.20)
log distance^4					0.0071	0.0028		0.0046
					(0.0078)	(0.0067)		(0.0083)
log(distance ratio)								-1.54***
								(0.21)
Mean effect	-1.90	-1.90	-1.74	-1.74	-1.63	-1.63	-1.91	-
Median effect	-1.90	-1.90	-1.72	-1.72	-1.73	-1.70	-1.91	-
R^2	0.86	-	0.87	-	0.87	-	0.86	0.87
First-stage Stat.		153,426		20,514		2,211		

First step results: value

Panel B. Dependent variable: Value of bilateral trade flows, road trade.

log distance	-1.41***	-1.41***	-2.18***	-2.19***	-1.82	-0.95	-1.41***	-0.52
	(0.019)	(0.019)	(0.14)	(0.14)	(5.96)	(5.79)	(0.020)	(6.12)
log distance^2			0.062***	0.062***	0.44	0.24		0.11
			(0.011)	(0.011)	(1.52)	(1.48)		(1.59)
log distance^3					-0.092	-0.073		-0.060
					(0.17)	(0.16)		(0.18)
log distance^4					0.0057	0.0051		0.0047
					(0.0068)	(0.0067)		(0.0074)
log(distance ratio)								-1.08***
								(0.17)
Mean effect	-1.41	-1.41	-1.28	-1.28	-1.18	-1.17	-1.41	-
Median effect	-1.41	-1.41	-1.27	-1.27	-1.26	-1.25	-1.41	-
R^2	0.83	-	0.83	-	0.84	-	0.83	0.84
First-stage Stat.		161,034		20,163		2,192		

First-step results: summary and conclusions

- High coefficient on distance
- Strong correlation of fixed effects across estimations
  $\Rightarrow$ the exact first-step specification does not matter for the second step
- Similarity between OLS and TSLS
  $\Rightarrow$ no endogeneity of roads between cities
- Suggestions that it is road distance that matters
- Little room for improvement given the high correlation between road and Euclidian distance

Second-step results, OLS for exporter fixed effects

Exporter fixed effect	(1) weight	(2) weight	(3) weight	(4) weight	(5) value	(6) value	(7) value	(8) value
log highway km	1.17***	0.53***	0.38**	0.27**	1.26***	0.24	0.094	-0.037
Robust s.e.	(0.14)	(0.18)	(0.14)	(0.13)	(0.16)	(0.19)	(0.15)	(0.15)
Non-robust s.e.	(0.12)	(0.16)	(0.16)	(0.14)	(0.14)	(0.17)	(0.16)	(0.13)
Corrected s.e.	(0.12)	(0.18)	(0.16)	(0.16)	(0.14)	(0.17)	(0.16)	(0.16)
log employment		0.55***	0.73*	0.49		0.88***	1.19*	0.90*
		(0.12)	(0.41)	(0.36)		(0.11)	(0.64)	(0.46)
Market access (export)		-0.45***	-0.66***	-0.65***		-0.18	-0.38**	-0.36***
		(0.14)	(0.15)	(0.12)		(0.12)	(0.15)	(0.11)
log 1920 population			-0.38	-0.29			-0.35	-0.23
			(0.27)	(0.25)			(0.32)	(0.33)
log 1950 population			1.02**	0.65			0.95*	0.49
			(0.43)	(0.42)			(0.52)	(0.55)
log 2000 population			-0.74	-0.17			-0.85	-0.13
			(0.51)	(0.49)			(0.79)	(0.64)
log % manuf. emp.				0.66***				0.83***
				(0.13)				(0.17)
R^2	0.59	0.73	0.79	0.84	0.56	0.77	0.81	0.88

Second-step results, OLS for importer fixed effects

Importer fixed effect	(1) weight	(2) weight	(3) weight	(4) weight	(5) value	(6) value	(7) value	(8) value
log highway km	0.92***	0.12	0.13	0.16	0.90***	0.041	0.032	0.067
Robust s.e.	(0.25)	(0.23)	(0.16)	(0.15)	(0.23)	(0.21)	(0.15)	(0.14)
Non-robust s.e.	(0.15)	(0.17)	(0.17)	(0.17)	(0.14)	(0.16)	(0.16)	(0.17)
Corrected s.e.	(0.15)	(0.22)	(0.17)	(0.17)	(0.14)	(0.20)	(0.16)	(0.16)
log employment		0.70***	-0.50	-0.42		0.74***	-0.23	-0.16
		(0.11)	(0.56)	(0.49)		(0.099)	(0.54)	(0.48)
Market access (export)		-0.30	-0.49	-0.58		-0.52	-0.66*	-0.74*
		(0.37)	(0.39)	(0.45)		(0.36)	(0.38)	(0.44)
Market access (import)		-0.52	-0.32	-0.24		-0.18	-0.055	0.025
		(0.34)	(0.35)	(0.39)		(0.34)	(0.37)	(0.41)
log 1920 population			0.061	0.027			-0.020	-0.053
			(0.30)	(0.30)			(0.29)	(0.30)
log 1950 population			-0.22	-0.10			-0.046	0.070
			(0.47)	(0.48)			(0.40)	(0.42)
log 2000 population			1.43**	1.25**			1.10*	0.92*
			(0.67)	(0.56)			(0.61)	(0.53)
log % manuf. emp.				-0.23				-0.22
				(0.41)				(0.38)
R^2	0.37	0.72	0.75	0.75	0.39	0.72	0.75	0.75

Second-step results, summary of OLS results

- Robust positive association between exported tons and roads
- No significant association between exported dollars and roads
- No significant association between imports (in tons or dollars) and roads
- Results consistent with the bulk of the effects going through specialisation across sectors within manufacturing rather than more overall manufacturing

Second-step results, TSLS for exporter fixed effects

Exporter fixed effect	(1) weight	(2) weight	(3) weight	(4) weight	(5) value	(6) value	(7) value	(8) value
log highway km	1.13***	0.57***	0.47***	0.39***	1.10***	0.17	0.070	-0.028
	(0.14)	(0.16)	(0.14)	(0.12)	(0.17)	(0.16)	(0.14)	(0.12)
log employment		0.52***	0.69*	0.46		0.91***	1.20**	0.89**
		(0.11)	(0.39)	(0.34)		(0.091)	(0.59)	(0.43)
Market access (export)		-0.45***	-0.65***	-0.63***		-0.19	-0.38***	-0.36***
		(0.14)	(0.14)	(0.11)		(0.12)	(0.14)	(0.11)
log 1920 population			-0.38	-0.29			-0.35	-0.23
			(0.25)	(0.23)			(0.31)	(0.30)
log 1950 population			1.00**	0.64*			0.95*	0.49
			(0.40)	(0.38)			(0.49)	(0.52)
log 2000 population			-0.74	-0.18			-0.85	-0.13
				(0.49)				(0.74)
log % manuf. emp.				0.64***				0.83***
				(0.12)				(0.16)
Overid. p-value	0.100	0.043	0.15	0.30	0.081	0.071	0.28	0.55
First-stage Stat.	97.5	90.3	80.4	85.2	97.5	90.3	80.4	85.2

Second-step results, summary of TSLS results

- Confirm OLS results for tons and dollar exported
- Also confirm OLS results for tons and dollar imported
- Preferred elasticity of 0.47
- Consider Milwaukee and Indianapolis (same population around 1.7/1.8 m)
  Indianapolis has 151% more highways
  Our estimates predict that Indianapolis should export $2.51^{0.47} = 1.54$ or +54% more tons
  Real difference: +56%
  But roughly same amount exported in value
- Going from the second to the ninth decile of kilometres of highways is equivalent to reducing distance to other cities by 23%.
  This is equivalent to moving New York close to Chicago with respect to shipments to San Francisco.

Robustness check, instruments and instrumenting method

	(1) TSLS	(2) TSLS	(3) TSLS	(4) TSLS	(5) TSLS	(6) TSLS	(7) LIML	(8) GMM
Panel A. Employment, market access and past populations as controls.								
log highway km	0.50***	0.45***	0.55***	0.49***	0.83***	0.11	0.47***	0.41***
	(0.15)	(0.14)	(0.17)	(0.15)	(0.25)	(0.31)	(0.14)	(0.13)
Instruments								
log 1528-1850 exploration	N	Y	Y	N	N	Y	Y	Y
log 1898 railroad km	Y	N	Y	N	Y	N	Y	Y
log 1947 highway km	Y	Y	N	Y	N	N	Y	Y
Overid. p-value	0.061	0.24	0.089	.	.	.	0.043	0.15
First-stage Stat.	70.1	105	46.1	139	45.4	14.9	80.4	80.4
Panel B. Employment, market access, past populations and manufacturing share of employment as controls.								
log highway km	0.39***	0.38***	0.51***	0.38***	0.64***	0.34*	0.39***	0.36***
	(0.13)	(0.12)	(0.16)	(0.13)	(0.22)	(0.19)	(0.13)	(0.12)
Overid. p-value	0.12	0.83	0.25	.	.	.	0.30	0.30
First-stage Stat.	64.1	113	46.7	128	40.9	23.9	85.2	85.2

Robustness check, one-step OLS estimations

Bilateral trade flows	(1) weight	(2) weight	(3) weight	(4) weight	(5) value	(6) value	(7) value	(8) value
Panel A. OLS estimations.								
log highway km	1.10***	0.43***	0.31**	0.21	1.18***	0.18	0.091	-0.030
for exporter	(0.13)	(0.15)	(0.13)	(0.14)	(0.13)	(0.15)	(0.14)	(0.12)
log highway km	0.83***	0.091	0.054	0.13	0.84***	0.064	0.019	0.052
for importer	(0.23)	(0.15)	(0.14)	(0.13)	(0.19)	(0.13)	(0.12)	(0.11)
log employment		0.64***	-0.66	-0.51		0.69***	-0.36	-0.27
for exporter		(0.10)	(0.35)	(0.32)		(0.10)	(0.48)	(0.37)
log employment		0.51***	0.64***	-0.69		0.58***	0.69***	-0.38
for importer		(0.12)	(0.61)	(0.47)		(0.11)	(0.52)	(0.45)
Market access		-0.47***	-0.82***	-0.75***		-0.12	-0.38*	-0.28*
for exporter		(0.16)	(0.21)	(0.19)		(0.15)	(0.20)	(0.17)
Market access		-1.12***	-1.12***	-1.17***		-0.89***	-0.98***	-1.02***
for importer		(0.19)	(0.19)	(0.22)		(0.17)	(0.17)	(0.20)
log populations 20, 50, 00	N	N	Y	Y	N	N	Y	Y
log % manuf. emp.	N	N	N	Y	N	N	N	Y
R^2	0.70	0.77	0.78	0.80	0.59	0.71	0.72	0.75

Robustness check, one-step TSLS estimations

Bilateral trade flows	(1) weight	(2) weight	(3) weight	(4) weight	(5) value	(6) value	(7) value	(8) value
Panel B. TSLS estimations.								
log highway km	1.08***	0.51***	0.41***	0.35***	1.04***	0.17	0.095	0.026
for exporter	(0.13)	(0.14)	(0.13)	(0.12)	(0.15)	(0.15)	(0.14)	(0.11)
log highway km	0.81***	0.13	0.092	0.14	0.78***	0.058	0.020	0.034
for importer	(0.21)	(0.14)	(0.14)	(0.15)	(0.17)	(0.13)	(0.13)	(0.13)
log employment		0.56***	0.47	0.35		0.89***	0.96**	0.72*
for exporter		(0.095)	(0.36)	(0.33)		(0.096)	(0.48)	(0.38)
log employment		0.62***	-0.67	-0.50		0.69***	-0.36	-0.26
for importer		(0.13)	(0.61)	(0.46)		(0.12)	(0.52)	(0.45)
Market access		-0.46***	-0.79***	-0.72***		-0.13	-0.38*	-0.26
for exporter		(0.16)	(0.21)	(0.19)		(0.15)	(0.21)	(0.16)
Market access		-1.11***	-1.15***	-1.22***		-0.89***	-0.98***	-1.02***
for importer		(0.19)	(0.19)	(0.21)		(0.16)	(0.17)	(0.20)
log populations 20, 50, 00	N	N	Y	Y	N	N	Y	Y
log % manuf. emp.	N	N	N	Y	N	N	N	Y
Overid. p-value	0.24	0.11	0.23	0.37	.	0.18	0.39	.
First-stage Stat.	69.3	47.6	58.6	55.8	70.3	45.4	44.1	53.1

Robustness check, alternative channels of transmission

Added var.	(1) Water	(2) Slope	(3) Census div.	(4) % college	(5) Income p.c.	(6) % wholesale	(7) Traffic	(8) All
Panel A. OLS estimations.								
log highway km	0.30*	0.38**	0.28*	0.26*	0.31**	0.42***	0.37*	0.19
	(0.15)	(0.15)	(0.16)	(0.14)	(0.15)	(0.14)	(0.19)	(0.17)
R^2	0.79	0.79	0.81	0.81	0.80	0.82	0.79	0.90
Panel B. TSLS estimations.								
log highway km	0.37**	0.47***	0.39***	0.36***	0.42***	0.51***	0.49**	0.45***
	(0.16)	(0.14)	(0.15)	(0.13)	(0.14)	(0.13)	(0.19)	(0.17)
Overid. p-value	0.11	0.20	0.13	0.19	0.14	0.36	0.12	0.46
First-stage Stat.	70.9	86.6	65.5	83.9	81.0	78.5	56.9	27.5
Panel C. TSLS estimations with controls for manufacturing employment.								
log highway km	0.34**	0.41***	0.35***	0.33***	0.36***	0.43***	0.42**	0.45***
	(0.15)	(0.13)	(0.13)	(0.12)	(0.13)	(0.11)	(0.16)	(0.17)
Overid. p-value	0.27	0.46	0.10	0.25	0.25	0.49	0.27	0.46
First-stage Stat.	79.9	90.3	70.0	87.0	82.7	83.6	62.3	27.5

Robustness check, alternative measures of highways

Measure of city roads	(1) log highway rays	(2) log highway rays	(3) log highway lane km, 2007	(4) log highway lane km, 2007	(5) log highway urban km, 2007	(6) log highway urban km, 2007	(7) log highway km, 1987	(8) log highway km, 1987
Panel A. OLS estimations.								
Road var.	0.30***	0.33***	0.25**	0.21*	0.25	0.27*	0.11*	0.11**
	(0.11)	(0.094)	(0.12)	(0.11)	(0.16)	(0.15)	(0.057)	(0.050)
% manuf. emp.	N	Y	N	Y	N	Y	N	Y
R^2	0.79	0.86	0.78	0.84	0.77	0.84	0.78	0.84
Panel B. TSLS estimations.								
Road var.	0.41***	0.40***	0.55***	0.44***	0.95***	0.77***	0.41***	0.32***
	(0.15)	(0.12)	(0.17)	(0.15)	(0.34)	(0.29)	(0.13)	(0.12)
% manuf. emp.	N	Y	N	Y	N	Y	N	Y
Overid. p-value	0.63	0.14	0.47	0.68	0.20	0.32	0.18	0.20
First-stage Stat.	74.8	73.5	21.4	20.4	5.09	4.99	19.2	17.7

Robustness check, short and long distance trade

Exporter fixed effect	(1) weight OLS	(2) weight OLS	(3) weight TSLS	(4) weight TSLS	(5) value OLS	(6) value OLS	(7) value TSLS	(8) value TSLS
Panel A. Short distance trade (less than 1,000 km).								
log highway km	0.65***	0.56***	0.81***	0.75***	0.31**	0.20	0.36**	0.29**
	(0.15)	(0.15)	(0.16)	(0.15)	(0.15)	(0.15)	(0.15)	(0.13)
% manuf. emp.	N	Y	N	Y	N	Y	N	Y
R^2	0.75	0.79			0.81	0.87		
Overid. p-value			0.18	0.39			0.29	0.25
First-stage Stat.			80.8	85.5			80.8	85.5
Panel B. Long distance trade (more than 1,000 km)								
log highway km	0.16	0.084	0.23	0.17	-0.098	-0.22	-0.15	-0.24
	(0.16)	(0.16)	(0.16)	(0.15)	(0.19)	(0.19)	(0.17)	(0.16)
R^2	0.73	0.77			0.78	0.84		
Overid. p-value			0.025	0.058			0.12	0.22
First-stage Stat.			83.0	87.9			83.0	87.9
Panel C. Long distance trade (more than 750 km)								
log highway km	0.28	0.21	0.36**	0.31**	-0.017	-0.13	-0.039	-0.12
	(0.16)	(0.16)	(0.16)	(0.15)	(0.19)	(0.19)	(0.17)	(0.16)
R^2	0.76	0.79			0.79	0.85		
Overid. p-value			0.023	0.055			0.16	0.25
First-stage Stat.			86.2	90.6			86.2	90.6

Robustness check, internal trade

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exporter fixed effect	weight	weight	weight	weight	value	value	value	value
Panel A. Dependent variable: log internal trade, OLS.								
log highway km	1.26***	0.38**	0.41**	0.38**	1.45***	0.33***	0.26**	0.20*
	(0.14)	(0.17)	(0.16)	(0.17)	(0.12)	(0.12)	(0.12)	(0.11)
Controls.	0	1	2	3	0	1	2	3
R^2	0.63	0.82	0.82	0.83	0.66	0.90	0.91	0.92
Panel B. Dependent variable: log internal trade, TSLS.								
log highway km	1.22***	0.54***	0.56***	0.54***	1.31***	0.31***	0.27**	0.22*
	(0.13)	(0.15)	(0.16)	(0.16)	(0.13)	(0.12)	(0.12)	(0.11)
Overid. p-value	0.72	0.77	0.67	0.84	0.26	0.21	0.25	0.65
First-stage Stat.	97.5	90.3	80.4	85.2	97.5	90.3	80.4	85.2
Panel C. Dependent variable: log share of internal trade, TSLS								
log highway km	0.043	-0.035	-0.030	-0.024	0.13*	0.064	0.084	0.10
	(0.030)	(0.035)	(0.034)	(0.034)	(0.068)	(0.081)	(0.078)	(0.074)
Overid. p-value	0.13	0.20	0.098	0.14	0.073	0.098	0.28	0.42
First-stage Stat.	97.5	90.3	80.4	85.2	97.5	90.3	80.4	85.2
Panel D. Dependent variable: log internal trade, TSLS controlling for internal distances.								
log highway km	0.95***	0.33	0.33	0.32	1.09***	0.36**	0.16	0.13
	(0.24)	(0.22)	(0.24)	(0.22)	(0.24)	(0.17)	(0.20)	(0.20)
log internal distance	0.61*	0.40	0.40	0.39	0.49	-0.081	0.20	0.16
	(0.35)	(0.26)	(0.30)	(0.28)	(0.40)	(0.22)	(0.29)	(0.26)
Overid. p-value	0.37	0.57	0.54	0.75	0.093	0.21	0.20	0.58
First-stage Stat.	34.9	42.8	31.7	34.9	34.9	42.8	31.7	34.9

Robustness check, comparison with rail

Exporter fixed effect	(1) weight	(2) weight	(3) weight	(4) weight	(5) value	(6) value	(7) value	(8) value
Panel A. OLS estimations.								
log railroad km	0.45	0.83***	0.93***	1.00***	0.13	0.074	-0.072	-0.034
	(0.32)	(0.26)	(0.27)	(0.25)	(0.27)	(0.31)	(0.31)	(0.33)
Controls.	0	1	2	3	0	1	2	3
Observations	40	34	34	34	39	39	39	39
R^2	0.09	0.25	0.28	0.38	0.00	0.02	0.21	0.22
Panel B. TSLS estimations.								
log railroad km	0.070	0.79**	0.74**	1.10***	-0.040	-0.34	-0.34	-0.22
	(0.35)	(0.32)	(0.30)	(0.29)	(0.39)	(0.48)	(0.42)	(0.42)
Controls.	0	1	2	3	0	1	2	3
Observations	40	34	34	34	39	39	39	39
First-stage Stat.	43.7	22.8	17.1	17.4	62.9	36.4	33.6	31.1

Other robustness checks

- Alternative specifications for the first step
  - Weighted least squares
  - Censored trade flows (Heckit)
  - No internal distance correction
  - TSLS fixed effects vs. OLS
  - linear vs. quadratic vs. quartic
  - all trade vs. road trade
- Alternative specifications of market access
  - Including or excluding own city
  - Ad hoc using contemporaneous incomes
  - Instrumented using past populations
- Analogous checks for trade in value and importer effects
- Checks on the appropriate functional form for city roads

Specialisation: looking at weight per unit value

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) TSLS	(6) TSLS	(7) TSLS	(8) TSLS
Panel A. Dependent variable: exporter effect, weight per unit value.								
log highway km	-0.10	0.29**	0.29**	0.33**	0.029	0.43***	0.43***	0.46***
	(0.092)	(0.13)	(0.14)	(0.15)	(0.099)	(0.12)	(0.13)	(0.12)
Controls.	0	1	2	3	0	1	2	3
R^2	0.02	0.35	0.36	0.39	0.01	0.34	0.34	0.37
Overid. p-value					0.89	0.97	0.77	0.53
First-stage Stat.					97.5	90.3	80.4	85.2
Panel B. Dependent variable: importer effect, weight per unit value.								
log highway km	0.0071	0.060	0.082	0.086	0.028	0.080	0.095*	0.097*
	(0.030)	(0.048)	(0.055)	(0.057)	(0.031)	(0.053)	(0.057)	(0.058)
R^2	0.00	0.15	0.20	0.21				
Overid. p-value					0.26	0.17	0.26	0.17
First-stage Stat.					97.5	90.3	80.4	85.2

More on specialisation

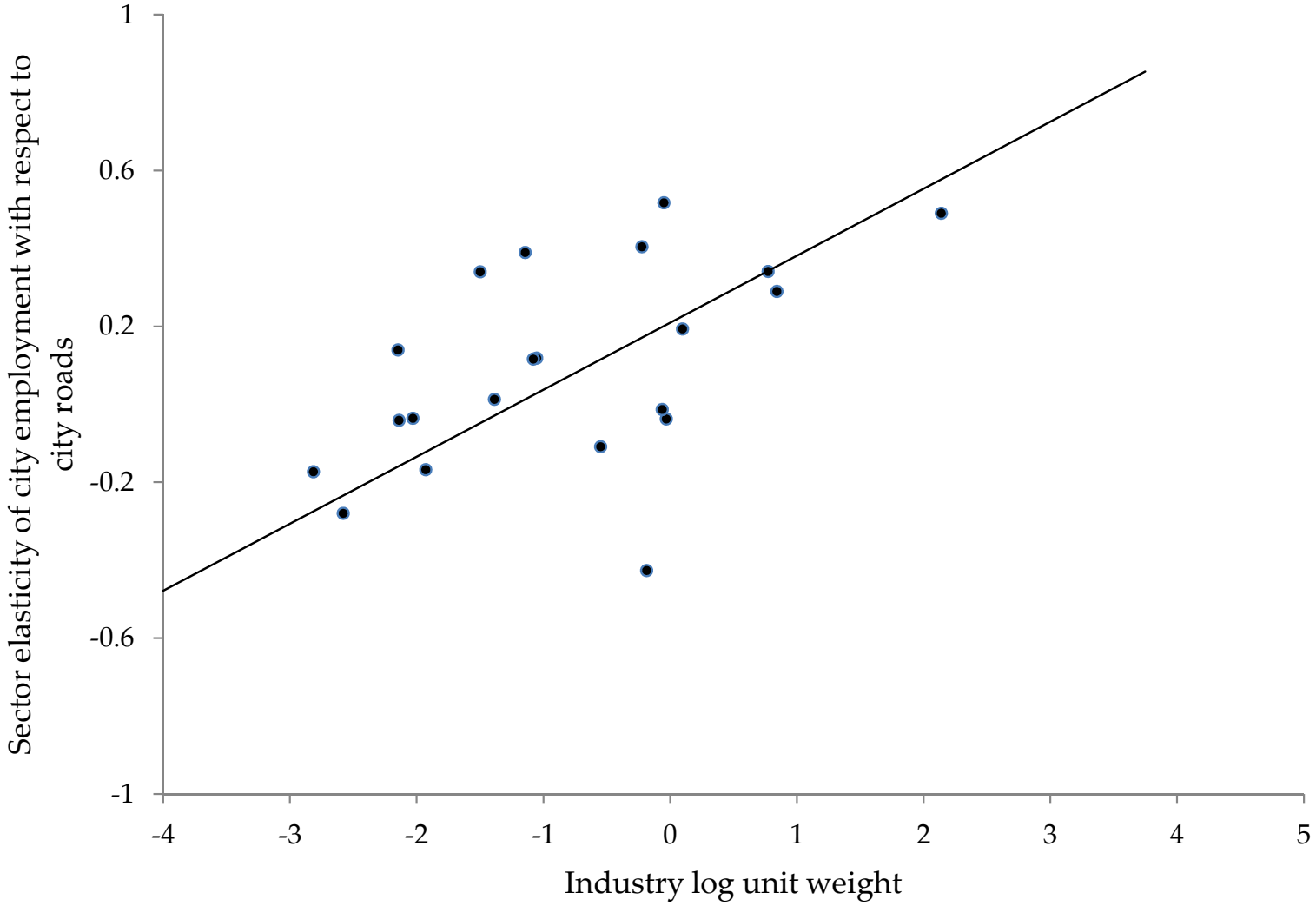
- First, measure elasticity of employment with respect to roads for each sector:

$$\ln N_i^k = \beta_0^k + \rho_R^{N,k} \ln R_i + \beta^{k\prime} C_i + \epsilon_i^k$$

- Second, regress on weight per unit value:

$$\hat{\rho}_R^{N,k} = \gamma_0 + \gamma_1 \ln UW^k + u^k$$

Specialisation plot



Main specialisation results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable: industry specific coefficient on interstate highways								
estimated with:	OLS	TSLS	TSLS	TSLS	TSLS	TSLS	TSLS	TSLS
using additional controls:	-	-	Water & Slope	Census Div.	% College	Mining	Income pc.	Wholesale
Panel A: Baseline								
log weight per unit value	0.13**	0.16***	0.22**	0.12**	0.16***	0.14**	0.17***	0.16***
	(0.047)	(0.051)	(0.082)	(0.055)	(0.048)	(0.049)	(0.053)	(0.050)
R^2	0.28	0.33	0.26	0.18	0.34	0.29	0.34	0.32
Panel B: With 2007 manufacturing employment								
log weight per unit value	0.16***	0.18***	0.22**	0.13**	0.16***	0.16***	0.18***	0.17***
	(0.038)	(0.044)	(0.079)	(0.050)	(0.045)	(0.043)	(0.048)	(0.043)
R^2	0.46	0.44	0.28	0.24	0.39	0.40	0.41	0.45
Panel C: With 1956 sectoral employment								
log weight per unit value	0.12**	0.16***	0.11**	0.10**	0.18***	0.17***	0.19***	0.16***
	(0.045)	(0.042)	(0.043)	(0.044)	(0.037)	(0.048)	(0.039)	(0.043)
R^2	0.26	0.42	0.26	0.22	0.54	0.39	0.54	0.42
Panel D: With 1956 sectoral and 2007 manufacturing employment								
log weight per unit value	0.14***	0.17***	0.13***	0.12**	0.13***	0.18***	0.17***	0.17***
	(0.041)	(0.041)	(0.039)	(0.047)	(0.033)	(0.043)	(0.040)	(0.041)
R^2	0.37	0.47	0.35	0.23	0.45	0.47	0.49	0.47

Summary of specialisation results

- Complementarity between roads and production in heavy sectors
- Confirmed by a one step estimation
- Robust to controls for sectoral employment at earlier dates (but effect become smaller)

Results about the dynamics of specialisation

	(1) 1956-1967	(2) 1956-1977	(3) 1956-1987	(4) 1956-1997	(5) 1956-2007
Panel A. Dependent variable: industry specific coefficient on interstate highways in first-difference, OLS					
log weight per unit value	0.0057 (0.038)	-0.0082 (0.026)	0.093** (0.042)	0.15*** (0.036)	0.15*** (0.045)
R^2	0.00	0.01	0.19	0.46	0.36
Panel B. Dependent variable: industry specific coefficient on interstate highways in first-difference, TSLS					
log weight per unit value	0.096* (0.050)	0.037 (0.031)	0.15*** (0.044)	0.21*** (0.040)	0.20*** (0.045)
R^2	0.16	0.07	0.37	0.57	0.50

Conclusions

- More highways in a city cause more exports in volume
- But only weak evidence about exports in value
- Consistent with strong patterns of increased specialisation in heavier sectors
- No evidence about imports