Railroads, Reallocation, and the Rise of American Manufacturing or Railroads, Market Integration, and Aggregate Productivity Growth

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Railroads and American Economic Growth

Did railroads have substantial impact on American economic growth?

- Fogel argued not (social savings as an upper bound)
- Others disagreed (e.g., David)
- Donaldson and Hornbeck: land value and market access

Research Questions

- How much did railroads drive economic growth in the US?
- How does market integration impact aggregate productivity?
- How much can one technology drive economic growth?

Preview of Results

Substantial gains from market integration through railroads

- From 1860 to 1880, 1 s.d. greater increase in market access increased manufacturing productivity by 13%

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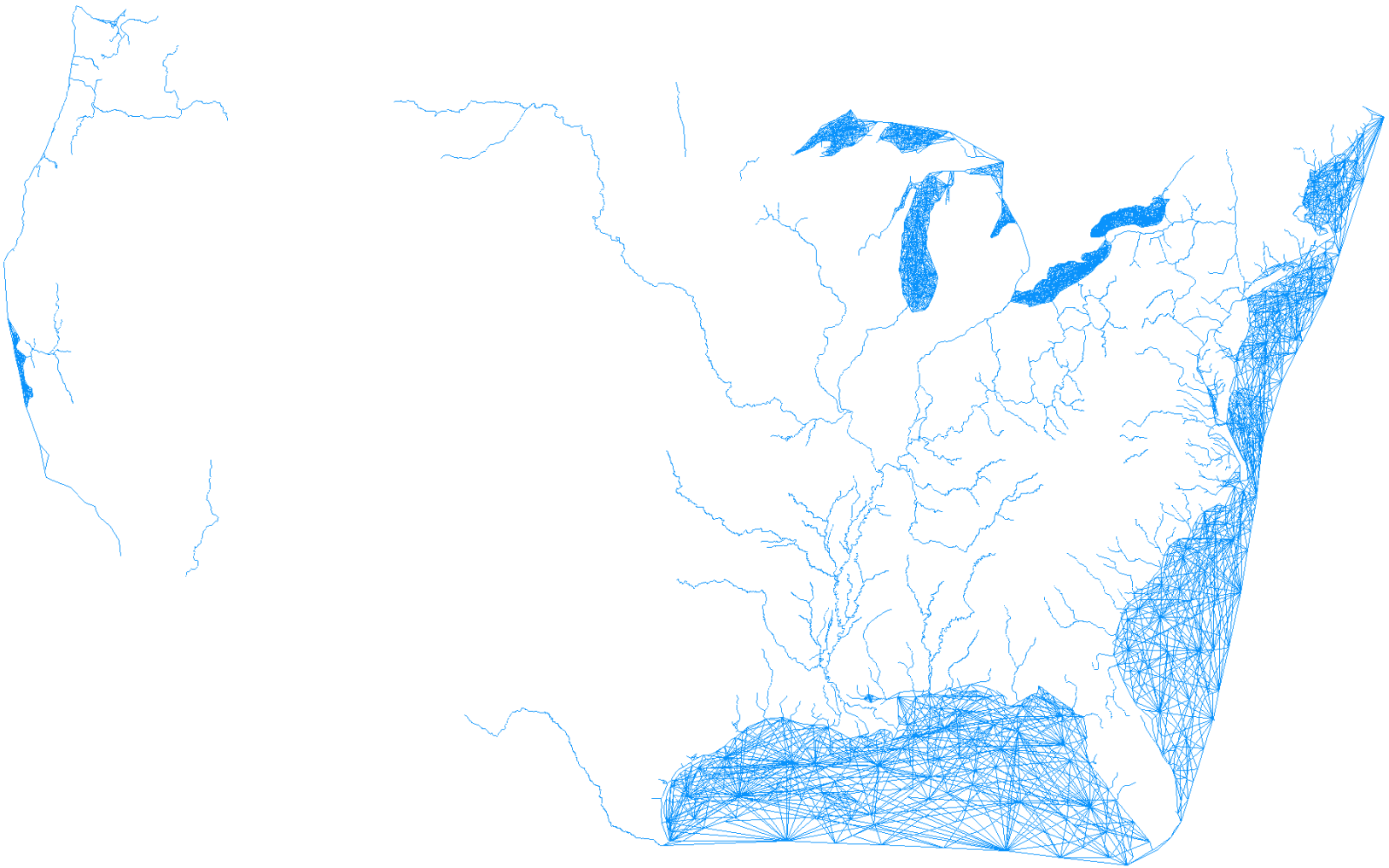
When resources are allocated inefficiently, widely-used infrastructure/technologies have substantially larger economic benefits

Presentation Outline

1. Measuring changes in market integration (RHS)
   - Mapping transportation routes
   - Definition of “market access”
2. Measuring changes in manufacturing productivity (LHS)
   - County productivity
   - Decomposition: county TFPR and county RE
3. Reduced-form results, relative effects
4. Counterfactual results, aggregate effects

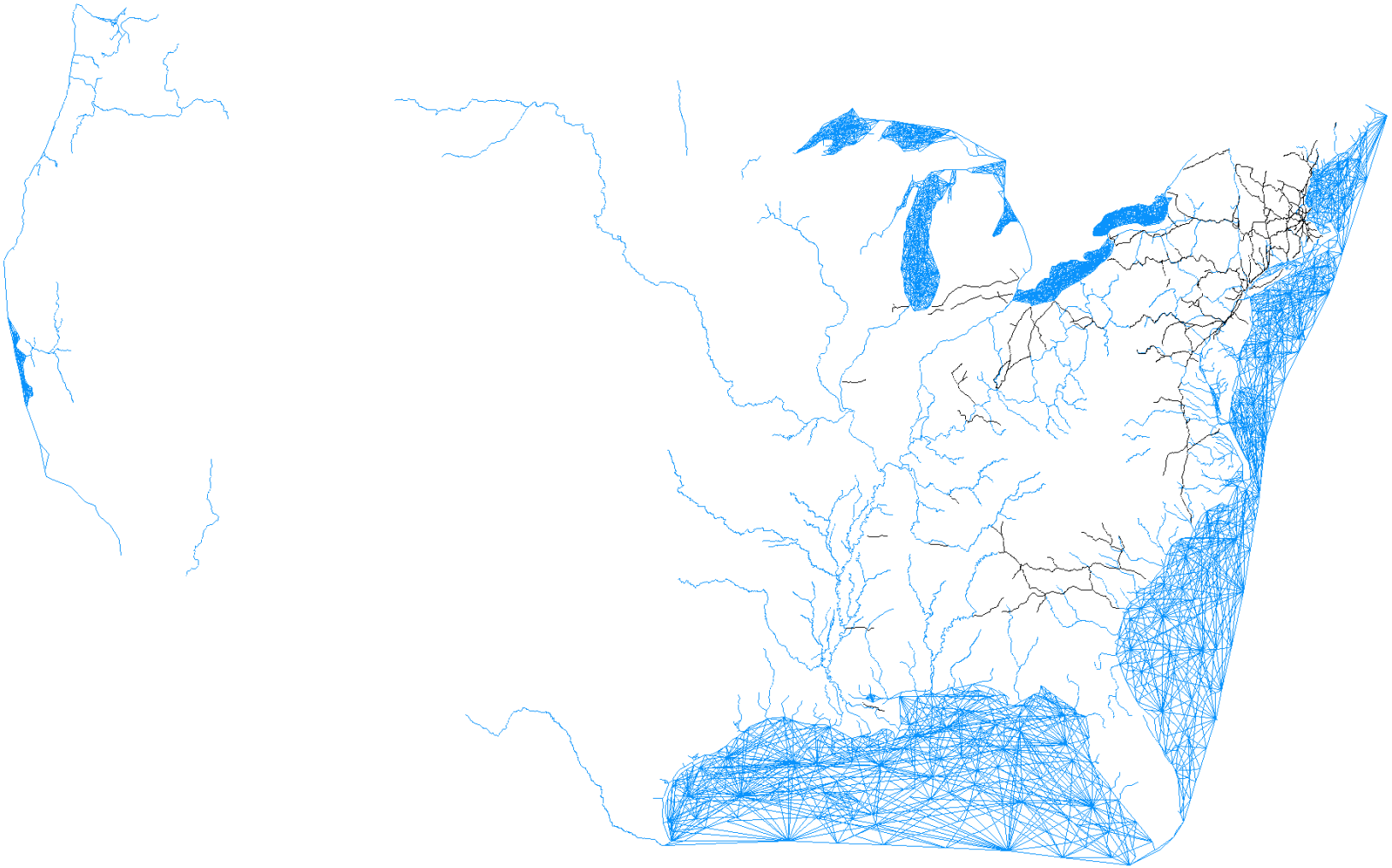
Change in Transportation Network

Waterways and No Railroads



Change in Transportation Network

Waterways and 1850 Railroads



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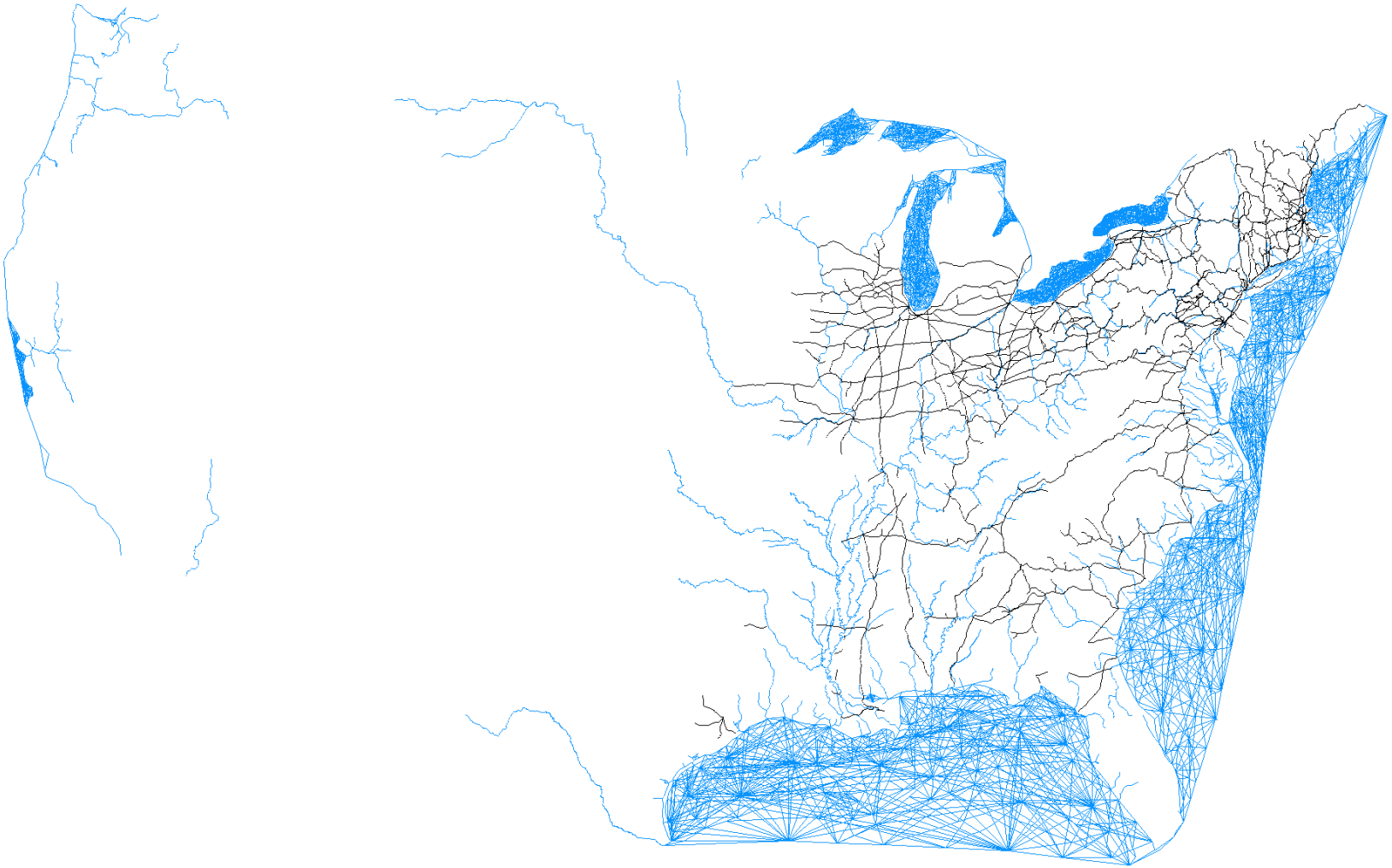
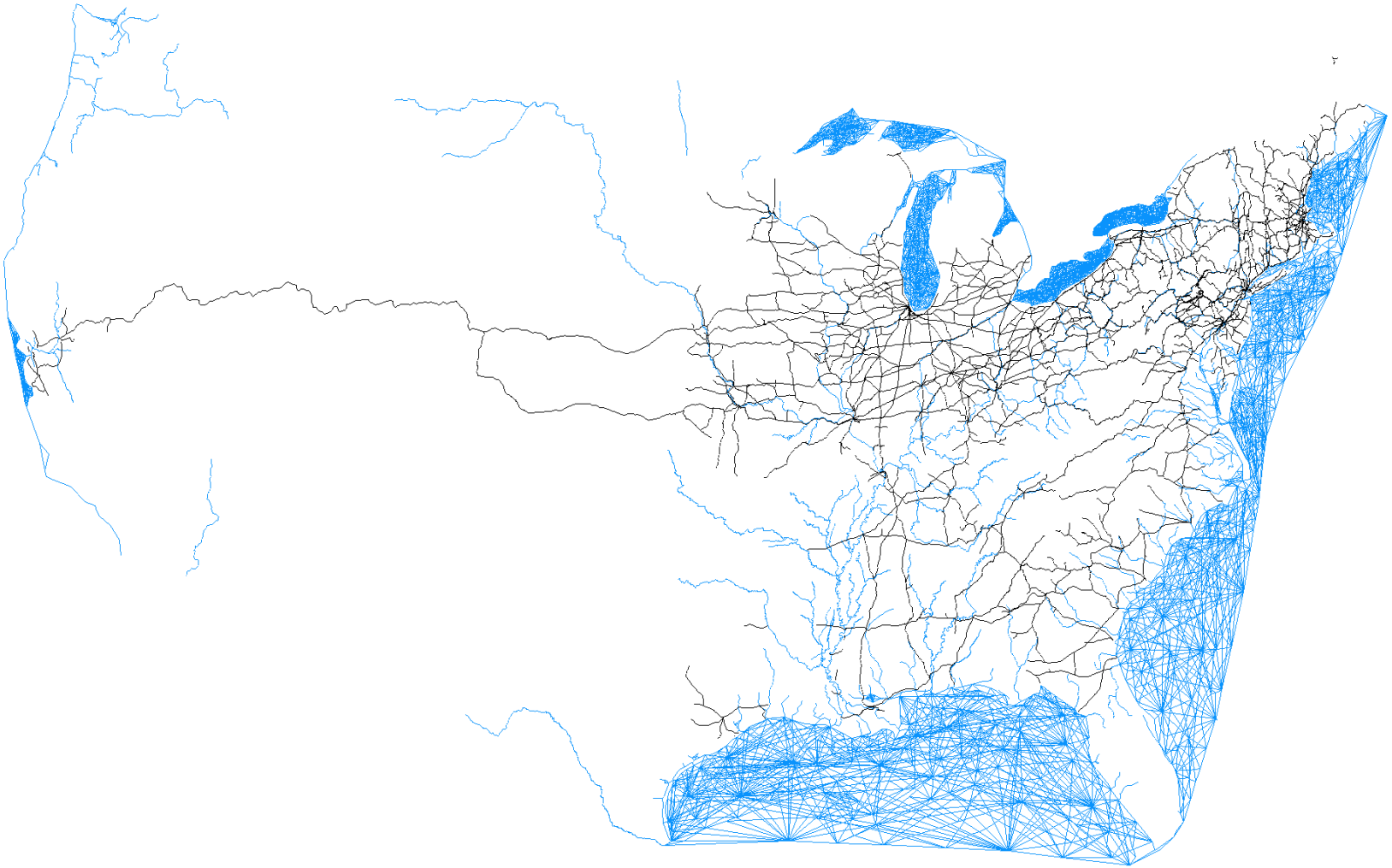


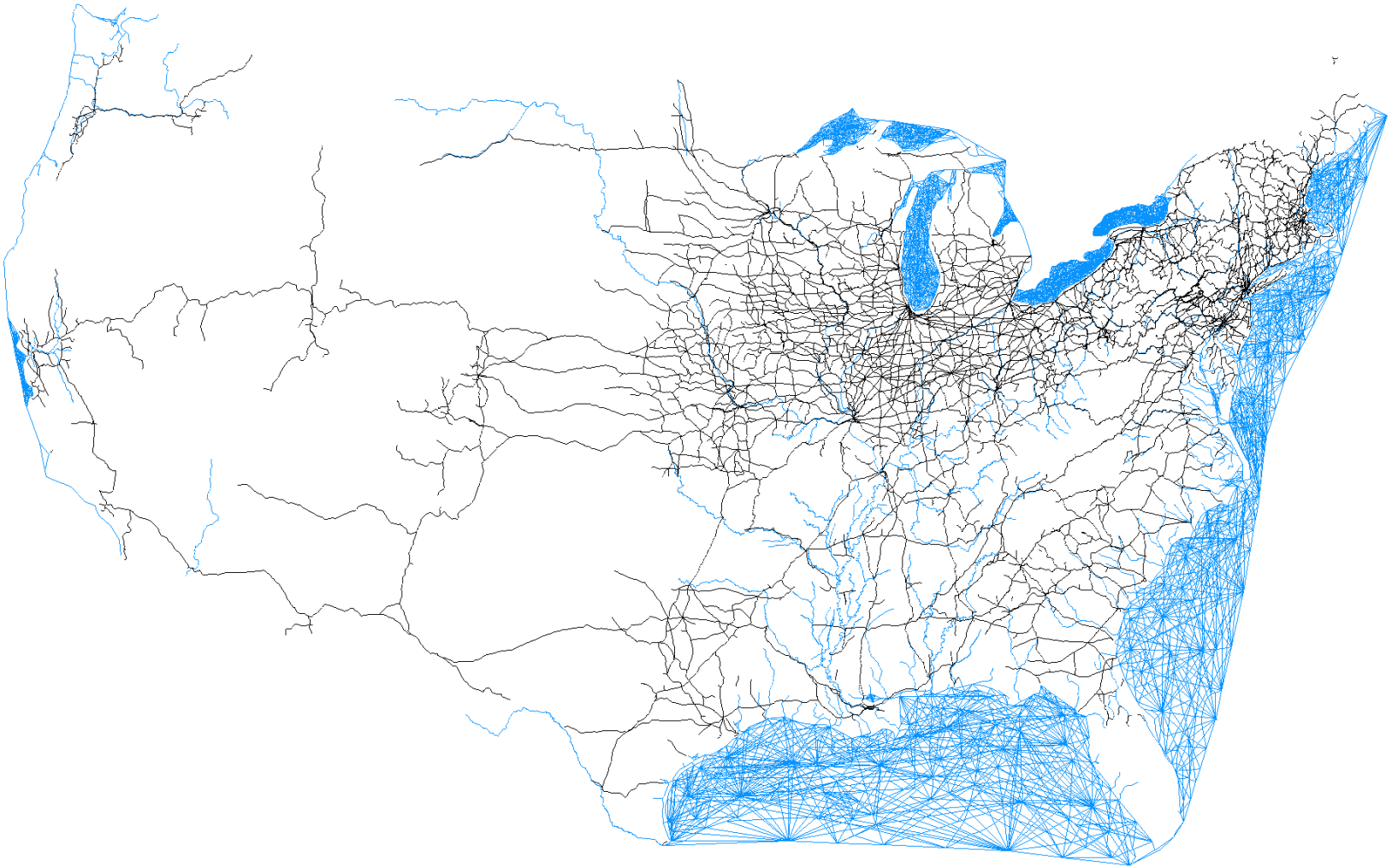
Change in Transportation Network

Waterways and 1870 Railroads



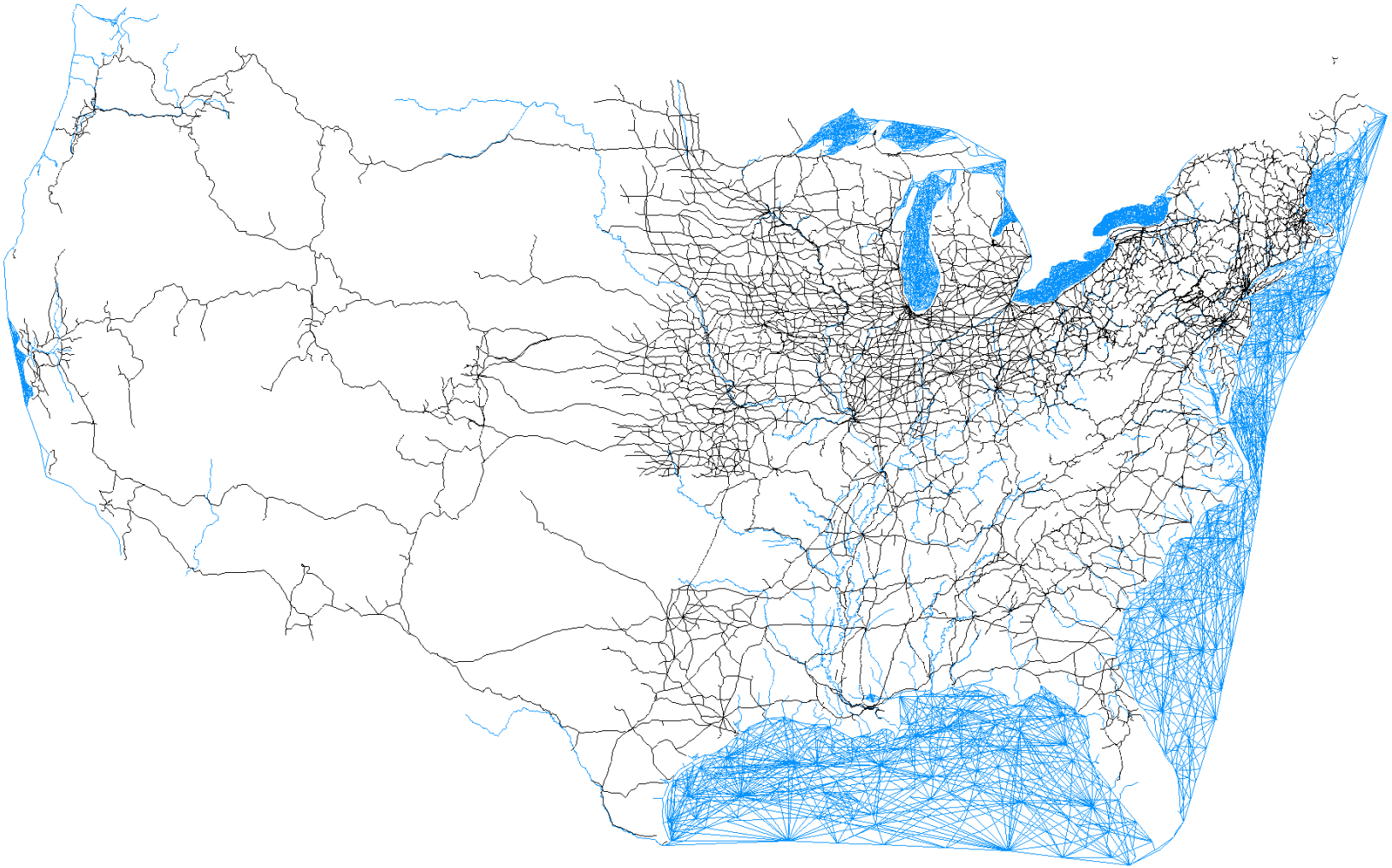
Change in Transportation Network

Waterways and 1880 Railroads



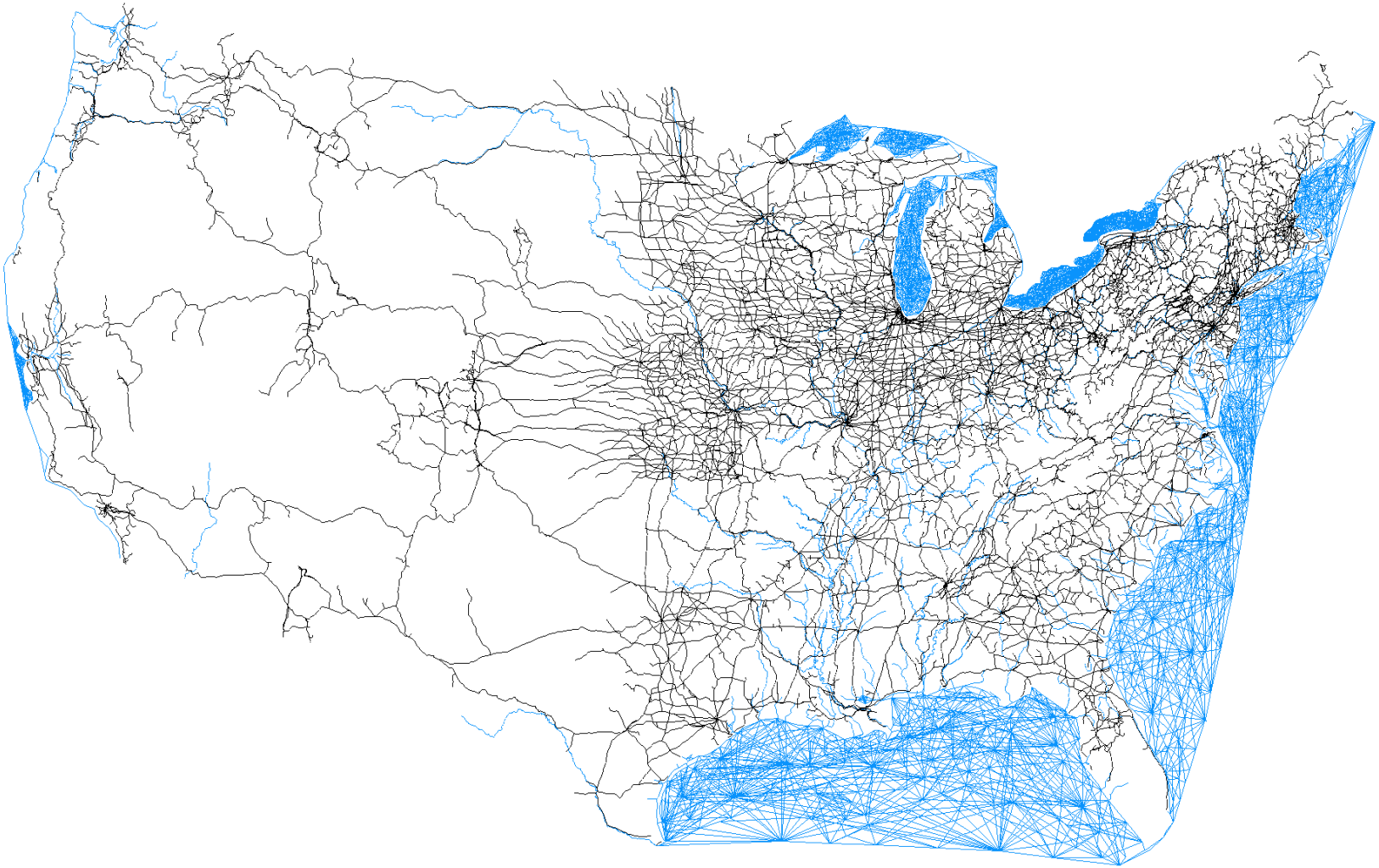
Change in Transportation Network

Waterways and 1890 Railroads



Change in Transportation Network

Waterways and 1900 Railroads



Measuring Railroad Impacts through "Market Access"

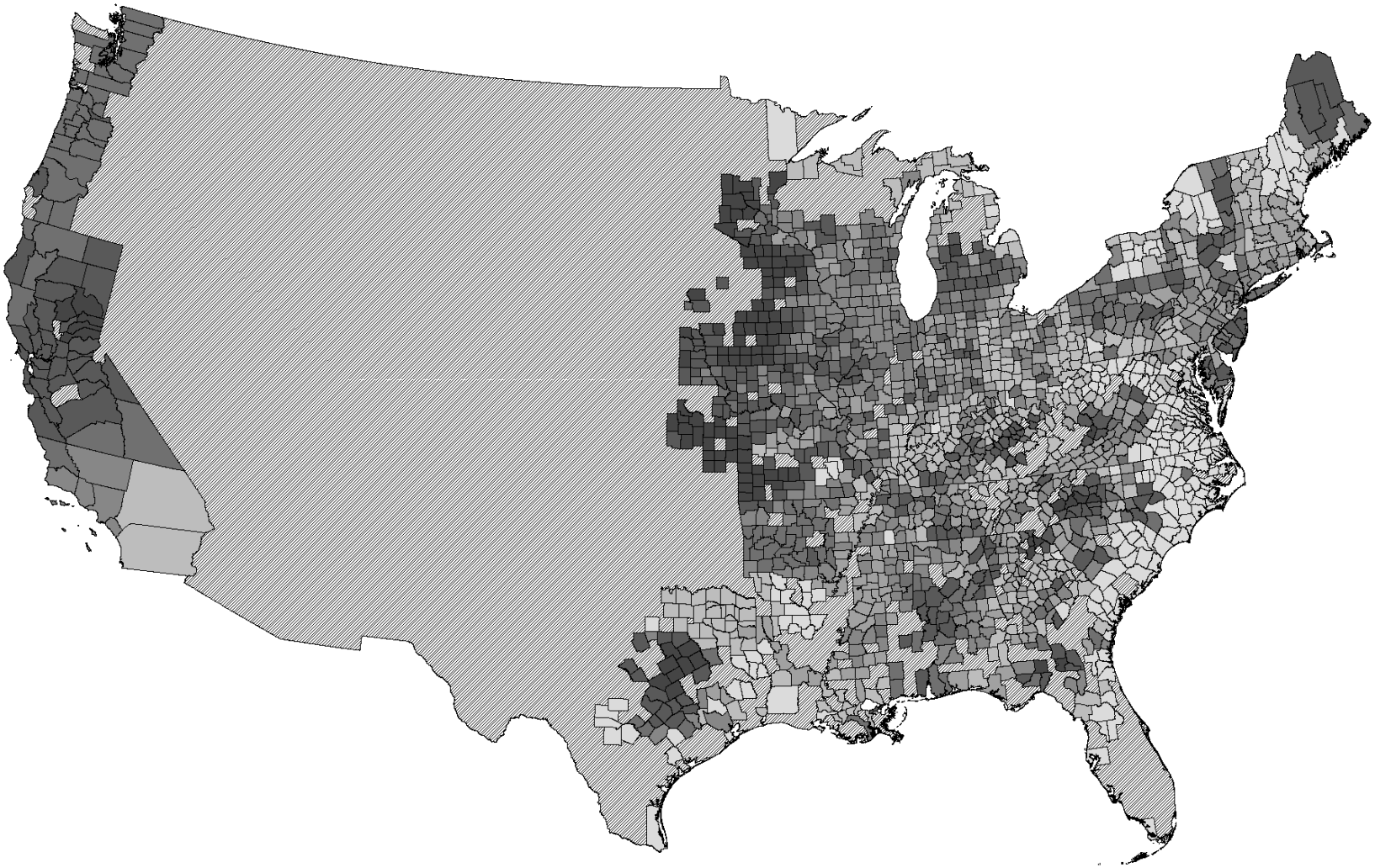
Eaton-Kortum (2002), Donaldson-Hornbeck (2016)

Output and input choices impacted by "Market Access:"

- Full version: $MA_c = \sum_d \tau_{cd}^{-\theta} Y_d MA_d^{-1}$
- Approximation: $MA(\mathbf{L})_c = \sum_{d \neq c} \tau_{cd}^{-\theta} L_d$

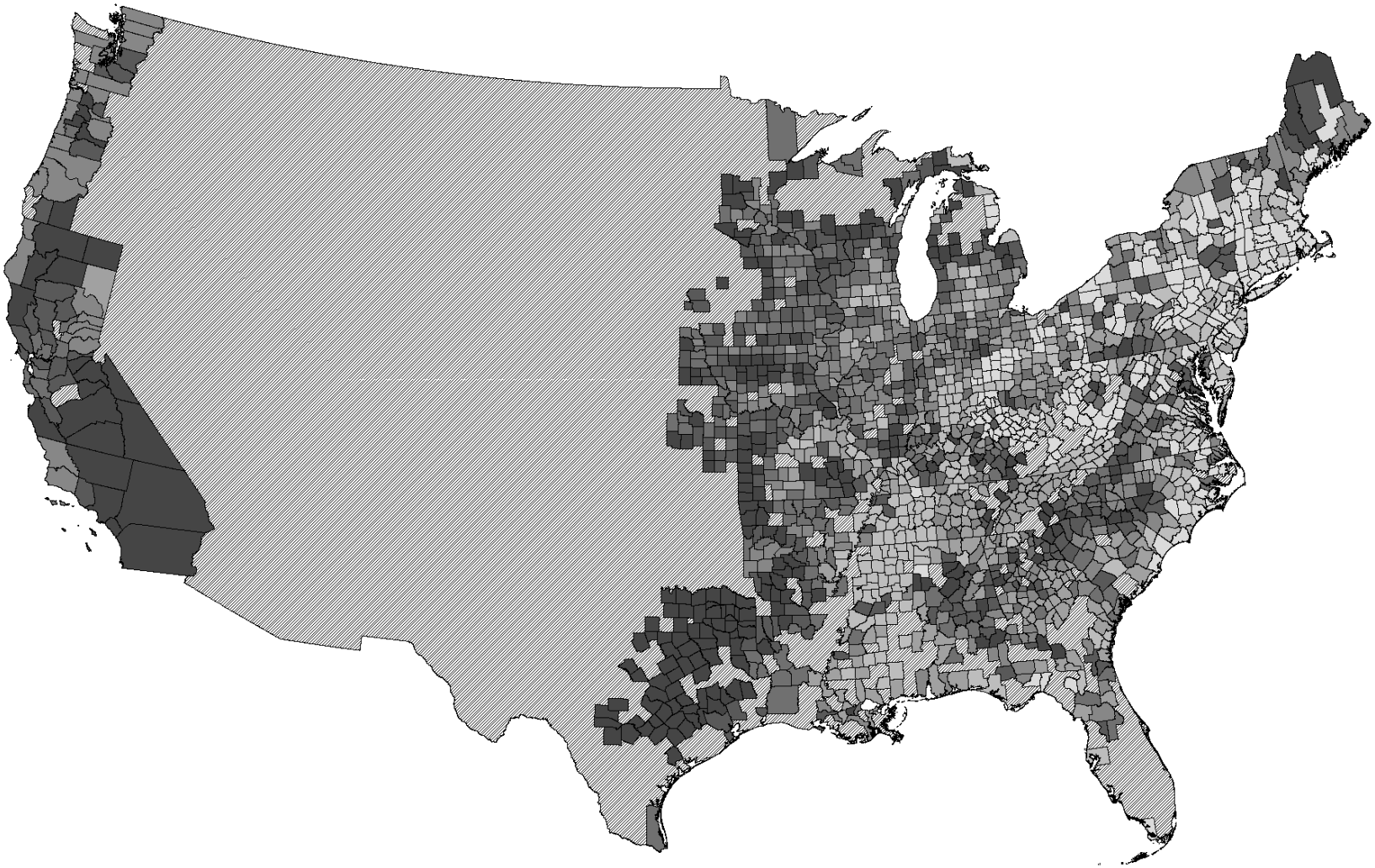
Changes in Log Market Access

1860 to 1870



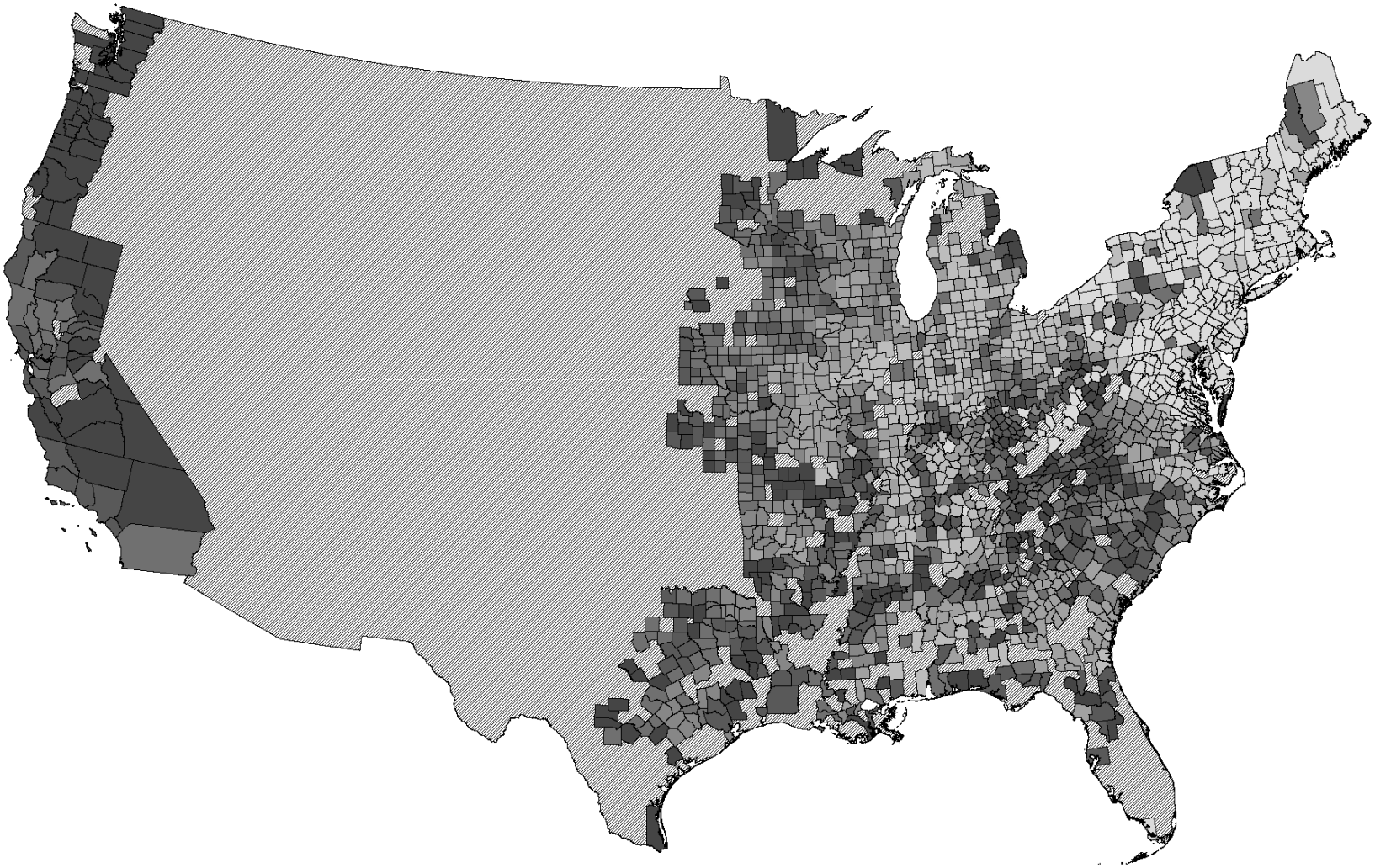
Changes in Log Market Access

1870 to 1880



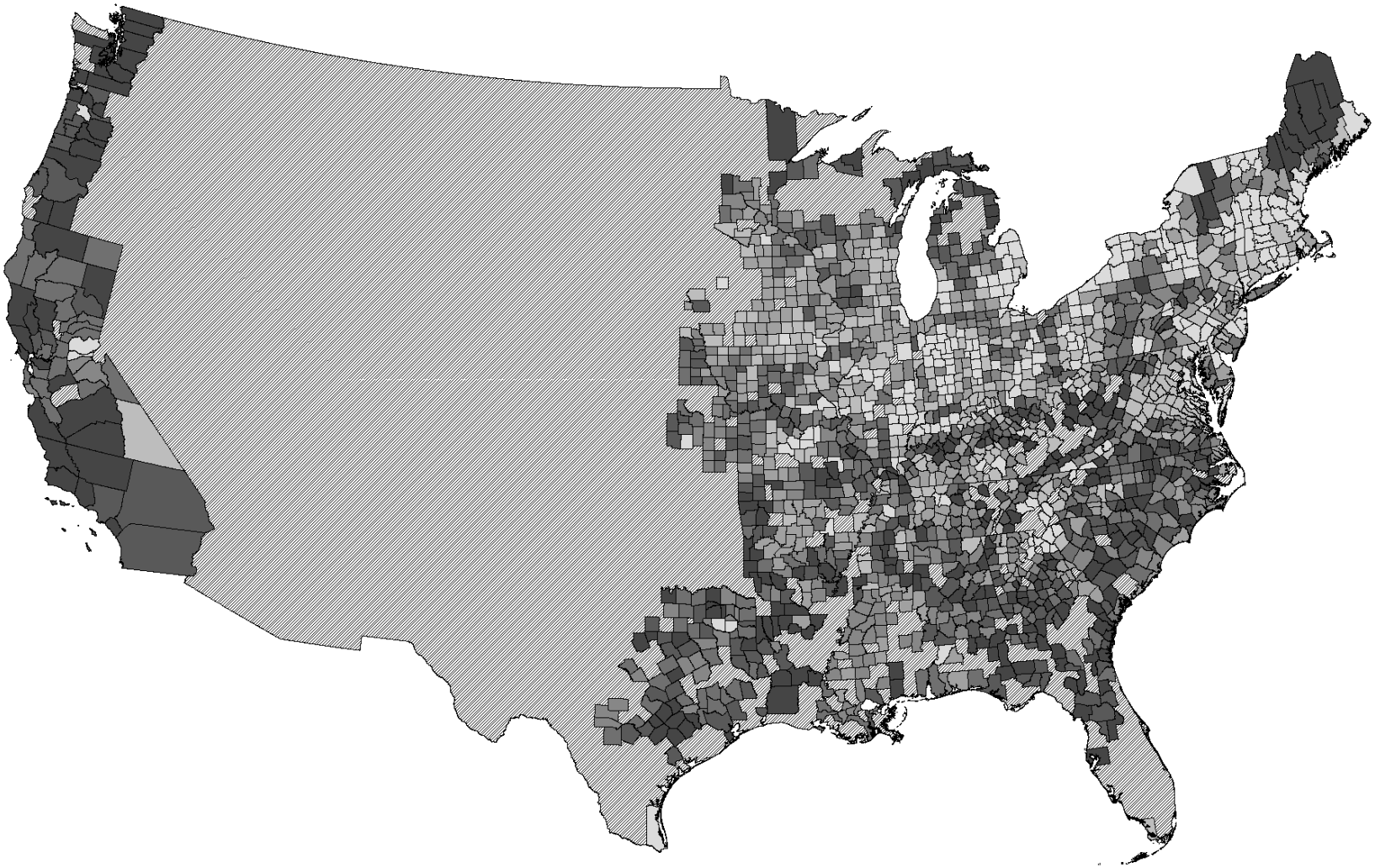
Changes in Log Market Access

1880 to 1890



Changes in Log Market Access

1890 to 1900



Data from Census of Manufacturers

County-level tabulations (Haines)

- 1860, 1870, 1880, 1890, 1900
- Value of output, material costs, labor costs, capital stock

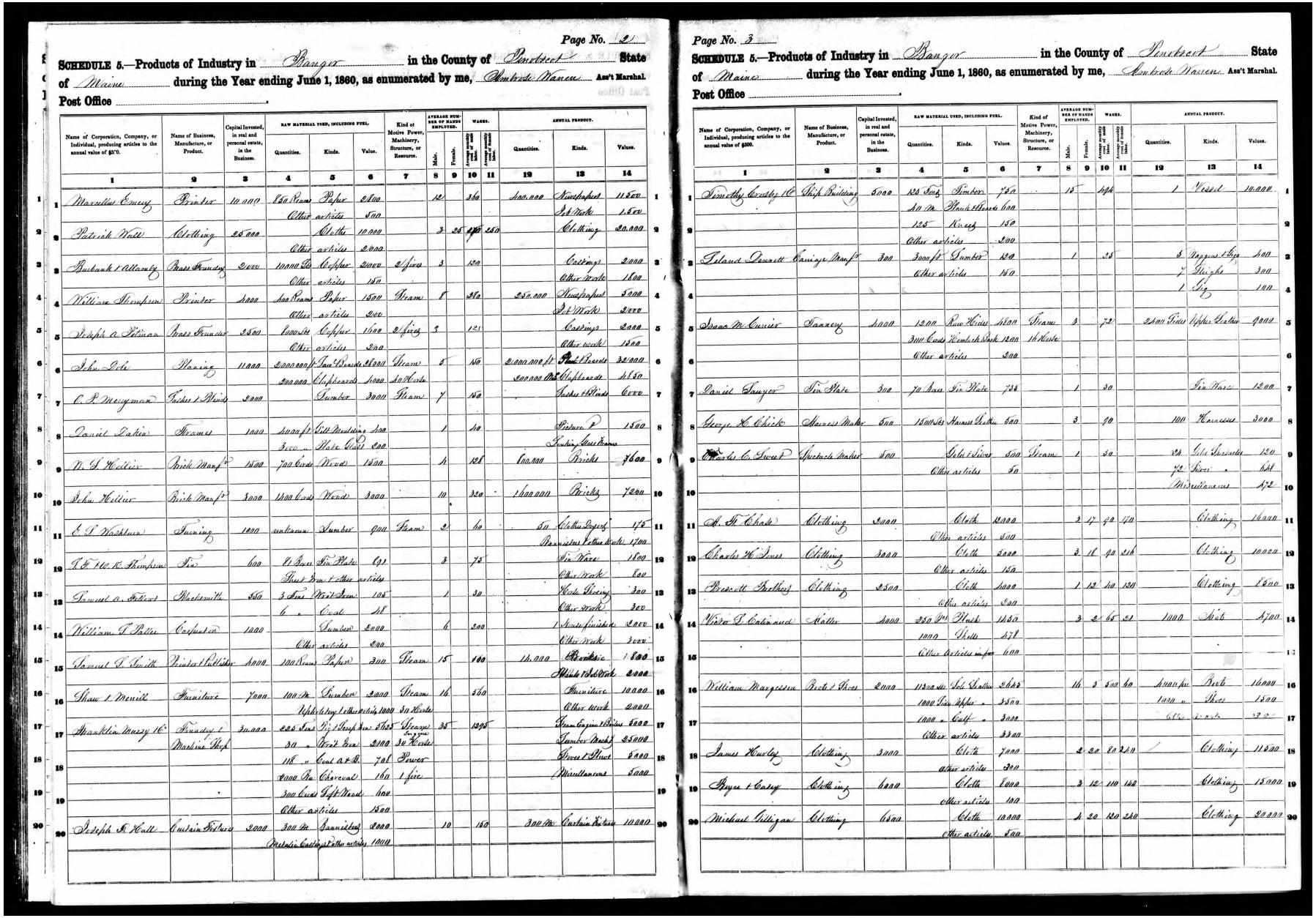
County-by-industry tabulations (entered)

- 1860, 1870, 1880
- Construct industry groups (45 or 159)

County-By-Industry Tables

Counties and industries.	No. of establishments.	Capital.	Average number of hands employed.			Total amount paid in wages during the year.	Value of materials.	Value of products.
			Males above 16 years.	Females above 15 years.	Children and youths.			
FREDERICK—continued.								
Furniture	16	$34,350	30	.....	1	$6,055	$18,942	$30,598
Iron and steel	2	575,000	200	.....	.....	50,000	112,000	185,000
Leather, curried	8	21,850	9	.....	.....	2,416	25,061	30,420
Leather, tanned	14	101,100	56	.....	1	16,702	140,602	208,857
Lime	12	55,950	95	.....	.....	20,415	36,978	79,690
Liquors, distilled	3	31,000	7	.....	.....	1,780	18,785	29,180
Printing and publishing	5	21,800	49	4	.....	8,850	8,100	28,700
Saddlery and harness	19	21,850	23	.....	3	6,155	27,276	47,391
Sash, doors, and blinds	3	52,000	28	.....	.....	11,541	33,000	48,000
Tinware, copperware, and sheet-iron ware	14	33,381	34	.....	.....	10,100	30,481	56,376
Tobacco, cigars and cigarettes	11	11,800	25	.....	4	6,602	16,714	32,007
GARRETT:								
Flouring- and grist-mill products	12	18,637	10	.....	.....	1,984	26,465	32,535
Lumber, sawed	20	308,750	181	.....	2	45,640	219,237	330,515
Woolen goods	2	6,500	8	3	4	3,075	8,732	20,722
HARFORD:								
Fertilizers	3	40,500	15	.....	1	4,300	32,050	41,550
Flouring- and grist-mill products	41	169,000	55	.....	.....	7,916	252,799	299,364
Fruits and vegetables, canned and preserved	56	186,992	890	603	411	83,155	338,482	535,894
Kaolin and ground earths	5	48,400	44	.....	.....	12,280	8,300	31,060
Lumber, sawed	23	111,150	64	.....	1	12,322	49,842	81,697
Shipbuilding	1	2,000	27	.....	.....	12,700	13,806	28,000
HOWARD:								
Cotton goods	3	574,816	195	213	120	100,418	433,031	738,000
Flouring- and grist-mill products	17	88,200	36	.....	.....	9,514	101,280	124,591
Paper	1	50,000	25	.....	.....	7,000	48,000	60,000
KENT:								
Agricultural implements	12	24,250	33	.....	.....	12,301	9,000	32,342
Fertilizers	2	23,000	16	.....	.....	1,700	14,825	21,050
Flouring- and grist-mill products	9	40,600	15	.....	.....	2,775	68,745	70,550
Fruits and vegetables, canned and preserved	1	22,000	10	115	.....	6,000	3,000	35,000
MONTGOMERY:								
Fertilizers	1	21,000	8	.....	.....	2,200	26,000	31,500
Flouring- and grist-mill products	30	321,550	49	.....	.....	11,111	174,249	202,177
PRINCE GEORGE'S:								
Cotton goods	1	270,000	64	109	28	35,985	141,516	222,661
Flouring- and grist-mill products	15	45,738	24	.....	.....	4,608	54,920	64,465
Iron and steel	1	60,000	190	.....	15	31,300	47,042	80,700
Lumber, sawed	9	16,400	38	.....	.....	7,755	18,002	32,947

Establishment-level Manuscripts



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SCHEDULE 5.—Products of Industry in Bangor in the County of Penobscot State of Maine during the Year ending June 1, 1860, as enumerated by me, Ambrose Warren Ass't Marshal.

Post Office

	Name of Corporation, Company, or Individual, producing articles to the annual value of $500.	Name of Business, Manufacture, or Product.	Capital Invested, in real and personal estate, in the Business.	Raw Material Used, Including Fuel. Quantities.	Kinds.	Value.	Kind of Motive Power, Machinery, Structure, or Resource.	Average Number of Hands Employed. Male.	Female.	Wages. Average monthly (with board) Male.	Average monthly (with board) Female.	Annual Product. Quantities.	Kinds.	Values.	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	Marcellus Emery	Printer	10 000	150 Reams	Paper	2800		12		350		300 000	Newspapers	11500	1
				Other articles		500							Job Work	1500	
2	Patrick Neill	Clothing	25 000		Cloth	10000		3	25	175	150		Clothing	20000	2
				Other articles		2000									
3	Burbank & Abbott	Brass Founding	2000	10000 lbs	Copper	2000	2 fires	3		120			Castings	2000	3
				Other articles		150							Other work	1500	
4	William Thompson	Printer	5000	500 Reams	Paper	1500	Steam	5		350		250 000	Newspapers	5000	4
				Other articles		200							Job Work	2000	
5	Joseph A Pitman	Brass Founder	3500	1000 lbs	Copper	1600	2 fires	3		125			Castings	2000	5
				Other articles		200							Other work	1500	
6	John Dole	Planing	11000	2000 000 ft	Pine Boards	28000	Steam	6		150		2 000 000 ft	Pine Boards	32000	6
				200 000	Clapboards	5000	50 Horse					200 000 M	Clapboards	4650	
7	C P Merryman	Timber & Planks	2000		Lumber	3000	Steam	7		150			Timber & Planks	6000	7
8	Daniel Larkin	Frames	1000	5000 ft	Gill Moulding	500		1		10			Pictures &	1500	8
				3000 "	Plate Glass	200							Looking Glass Frames		
9	W. S. Hollis	Brick Manf.	1500	700 Cords	Wood	1500		4		125		600 000	Bricks	7600	9
10	John Hollis	Brick Manf.	3000	1500 Cords	Wood	3000		10		320		1 800 000	Bricks	7200	10
11	E T Washburn	Turning	1000	unknown	Lumber	900	Steam	2		60		50	Bottom Dowels	175	11
													Bannisters & other work	1700	
12	T. F. & C. K. Thompson	Tin	600	10 Boxes	Tin Plate	650		3		75			Tin Ware	1500	12
				Sheet Iron & other articles									Other work	500	
13	Samuel A. Fellows	Blacksmith	550	3 Tons	Wrot Iron	105		1		30			Work Jobbing	300	13
				6 "	Coal	36							Other work	200	
14	William T. Potter	Carpenter	1000		Lumber	2000		6		200		1	House finishing	2000	14
				Other articles		200							Other work	3000	
15	Samuel D. Smith	Printer & Publisher	4000	100 Reams	Paper	300	Steam	15		100		18 000	Periodicals	1800	15
													Blank Book Work	2000	
16	Shaw & Merrill	Furniture	7000	100 M	Lumber	2000	Steam	16		350			Furniture	10000	16
				Veneering & other articles		1000	30 Horse						Other work	2000	
17	Franklin Mussey & Co	Foundry & Machine Shop	30 000	220 Tons	Pig Iron	6765	Steam Engines	35		1295			Steam Engines & Boilers	6000	17
				30 "	Wrot Iron	2100	30 Horse						Lumber Work	25000	
				115 "	Coal & &c.	761	Power						Screws & Planes	5000	18
				2000 lbs	Charcoal	160	1 fire						Miscellaneous	5000	
				300 Cords	Soft Wood	600									19
				Other articles		1500									
20	Joseph S. Hall	Curtain Fixtures	2000	300 lbs	Japanned	2000		10		150		300 lbs	Curtain Fixtures	10000	20
				Metallic Castings & other articles		1000									

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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	Timothy Crosby & Co	Ship Building	5000	125 Tons	Timber	7500		15		1.00		1	Vessel	10.000	1
				50 M	Plank & Boards	600									
2				125	Kneed	150									2
				Other articles		300									
3	Leland Dearth	Carriage Manf.	300	3000 ft	Lumber	120		1		25		8	Wagons & Sleighs	800	3
				Other articles		180						2	Sleighs	300	
4												1	Sleigh	100	4
5	Isaac M. Currier	Tannery	5000	1200	Raw Hides	1800	Steam	3		72		2500 Sides	Upper Leather	9000	5
				300 Cords	Hemlock Bark	1200	16 Horse								
6				Other articles		200									6
7	Daniel Dwyer	Tin Plate	300	70 Tons	Tin Plate	735		1		30			Tin Ware	1200	7
8	George H. Chicke	Harness Maker	600	1500 lbs	Harness Leather	600		3		90		100	Harnesses	3000	8
9	Charles C. Sweet	Upholsterer Maker	800		Gilt & Silver	500	Steam	1		30		25	Gilt Cornices	150	9
				Other articles		50						75	Cornices &	650	
10													Miscellaneous	172	10
11	A. H. Chase	Clothing	3000		Cloth	12000		2	17	90	150		Clothing	16000	11
				Other articles		500									
12	Charles W. Jones	Clothing	3000		Cloth	2000		2	11	90	216		Clothing	10000	12
				Other articles		150									
13	Prescott Frothing	Clothing	3500		Cloth	5000		1	12	80	130		Clothing	6000	13
				Other articles		500									
14	Victor T. Catinaud	Hatter	5000	250 lbs	Fluid	1150		3	2	65	52	1000	Hats	5700	14
				1000	Skins	678									
15				Other Articles unspecified		600									15
16	William Margesson	Boots & Shoes	2000	1150 lbs	Sole Leather	2645		16	5	500	60	2000 pr	Boots	10000	16
				1000 "	Upper "	3500						1000 "	Shoes	1500	
17				1000 "	Calf "	3000						Other	work	700	17
				Other articles		3300									
18	James Hurley	Clothing	3000		Cloth	7000		2	20	80	200		Clothing	11800	18
				other articles		300									
19	Joyce & Casey	Clothing	6000		Cloth	6000		3	12	110	150		Clothing	15000	19
				other articles		100									
20	Michael Galligan	Clothing	6000		Cloth	10000		4	20	120	220		Clothing	20000	20
				other articles		800									

Measuring County Productivity

Define county productivity broadly as:

- $Productivity_c = P_c Q_c - \sum_k W_c^k X_c^k$
- Output value ($P_c Q_c$) minus input k costs ($W_c^k X_c^k$)
- ("How much output value is not used up by input costs")
- Solow (1957); Basu and Fernald (2002)

County Productivity, in logs:

- $\ln Productivity_c = \ln P_c Q_c - \sum_k s_c^k \ln W_c^k X_c^k$
- s_c^k is the revenue share of input k

No assumptions on production functions

Measuring County Productivity: TFPR and RE

County productivity can be decomposed into two components:

- TFPR (Revenue Total Factor Productivity, Solow 1957)
- RE (Reallocative Efficiency, Petrin and Levinsohn 2012)

$$\begin{aligned} \ln Productivity_c = & \left[\ln P_c Q_c - \textstyle\sum_k \alpha_c^k \ln W_c^k X_c^k\right] && \text{(TFPR)} \\ & + \left[\textstyle\sum_k (\alpha_c^k - s_c^k) \ln W_c^k X_c^k\right] && \text{(RE)} \end{aligned}$$

For output elasticity (α_c), need production function assumptions

- Assume Cobb-Douglas production with CRS, cost-minimization
- $\alpha_c =$ county output-weighted average of industry cost shares

County input gaps: $(\alpha_c^k - s_c^k)$

- Reflect value marginal products greater than marginal costs
- Markups (Hall 1988)
- Input frictions (Hsieh and Klenow 2009)

Estimating Equation

Regress outcome Y on market access:

$$\ln Y_{ct} = \beta \ln(MA_{ct}) + \alpha_c + \lambda_{s(c)t} + \gamma_t f(x_c, y_c) + \varepsilon_{ct}$$

Estimation details:

- Balanced panel of $1,804$ counties (1890 borders)
- Standard errors clustered by state

Identification:

- Distant influences on market access
- Conditional on local railroads

Table 1. Impacts on County Productivity, Technical Efficiency, and Reallocative Efficiency

	Baseline Specification	Fixed 1860 Population	100-Mile Buffer Market Access	Aggregate Data: 1860 to 1900	Aggregate Data: 1860 to 1880	Finest Detail Cost Shares
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. County Productivity						
Log Market Access	0.129	0.123	0.125	0.163	0.123	0.130
	(0.050)	(0.048)	(0.048)	(0.041)	(0.051)	(0.049)
Panel B. County Reallocative Efficiency (RE)						
Log Market Access	0.117	0.111	0.113	0.160	0.118	0.112
	(0.045)	(0.043)	(0.044)	(0.039)	(0.048)	(0.045)
Panel C. County Technical Efficiency (TE)						
Log Market Access	0.012	0.012	0.012	0.003	0.005	0.017
	(0.008)	(0.008)	(0.008)	(0.005)	(0.007)	(0.007)
Number of Counties	1,804	1,804	1,804	1,804	1,804	1,804
County-Year Obs.	5,412	5,412	5,412	9,020	5,412	5,412

Table 2. Impacts of Market Access, Controlling Flexibly for Local Railroad Construction

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. County Productivity						
Log Market Access	0.129	0.147	0.152	0.140	0.131	0.105
	(0.050)	(0.058)	(0.060)	(0.059)	(0.059)	(0.062)
Panel B. County Reallocative Efficiency (RE)						
Log Market Access	0.117	0.129	0.135	0.124	0.116	0.092
	(0.045)	(0.053)	(0.055)	(0.055)	(0.054)	(0.057)
Panel C. County Technical Efficiency (TE)						
Log Market Access	0.012	0.018	0.017	0.016	0.015	0.013
	(0.008)	(0.009)	(0.009)	(0.009)	(0.010)	(0.010)
Additional Controls for:						
Any Railroad	No	Yes	Yes	Yes	Yes	Yes
Railroad Length	No	No	Yes	Yes	Yes	Yes
Railroad Length Polynomial	No	No	No	Yes	Yes	Yes
Railroads in Nearby Buffer	No	No	No	No	Yes	Yes
Railroads in Further Buffers	No	No	No	No	No	Yes
Number of Counties	1,804	1,804	1,804	1,804	1,804	1,804
County-Year Obs.	5,412	5,412	5,412	5,412	5,412	5,412

Robustness Overview

Regional shocks

- Subregion fixed effects, exclude sample areas

Measurement of productivity

- Exclude large changes in productivity
- Inflate firm input costs
- Include home manufacturing

Measurement of market access

- Exclude large changes in market access
- Alternative transportation costs
- Alternative parameters ($\overline{P}$ and θ)
- Distant variation in market access

Table 4. Impacts of Market Access on Input Expenditures, Gaps, Wedges, and Cost Shares

	County Input Expenditure	County Input Gap	County Input Wedge	County Input Cost Share
	(1)	(2)	(3)	(4)
Panel A. Materials				
Log Market Access	0.174	0.0093	0.001	0.0007
	(0.051)	(0.0056)	(0.037)	(0.0025)
Panel B. Labor				
Log Market Access	0.197	-0.0020	-0.057	-0.0008
	(0.063)	(0.0045)	(0.066)	(0.0023)
Panel C. Capital				
Log Market Access	0.159	0.0018	0.034	0.0001
	(0.051)	(0.0026)	(0.030)	(0.0003)
Number of Counties	1,804	1,804	1,804	1,804
County/Year Obs.	5,412	5,412	5,412	5,412

Table 5. Impacts of Market Access on County Industries, Firms, and Sector Shares

	Log Number of	Log Average Firm Size:		Log Number of	County Manufacturing Share of:			
	Industries	Output per Firm	Workers per Firm	Firms	Output	Value-Added	Surplus	Employment
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log Market Access	0.005	0.025	0.025	0.172	0.0092	0.0016	0.0005	0.0044
	(0.024)	(0.042)	(0.052)	(0.037)	(0.0081)	(0.0067)	(0.0095)	(0.0047)
Number of Counties	1,804	1,804	1,804	1,804	1,777	1,777	1,718	1,689
County/Year Obs.	5,412	5,412	5,412	5,412	5,331	5,331	5,154	5,067

Table 6. Impacts of Market Access on County Specialization

	Output Shares	Value-Added Shares	Surplus Shares	Employment Shares
	(1)	(2)	(3)	(4)
Panel A. Cross-Sector Specialization Index (Manufacturing vs. Agriculture)				
Log Market Access	-0.0122	-0.0005	-0.0047	0.0013
	(0.0113)	(0.0069)	(0.0121)	(0.0052)
Number of Counties	1,777	1,777	1,718	1,689
County/Year Obs.	5,331	5,331	5,154	5,067
Panel B. Within-Manufacturing Specialization Index (Across Industries)				
Log Market Access	-0.0103	-0.0467	-0.0113	-0.0016
	(0.0119)	(0.0404)	(0.0099)	(0.0111)
Number of Counties	1,804	1,804	1,804	1,804
County/Year Obs.	5,412	5,412	5,412	5,412

Counterfactual Analysis for Aggregate Effects

Extend Eaton and Kortum (2002), Donaldson and Hornbeck (2016):

- Insert “wedges” between marginal costs and prices
- Derive market access, and its impact on productivity
- Exogenous: wedges, output elasticities, TE

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Estimate parameters:

- Estimate county wedges from manufacturing sector
- Estimate output elasticities (mfg and ag)
- Jointly estimate $\overline{P}$ and θ, using data on railroad shipments and estimated impact of market access on land value

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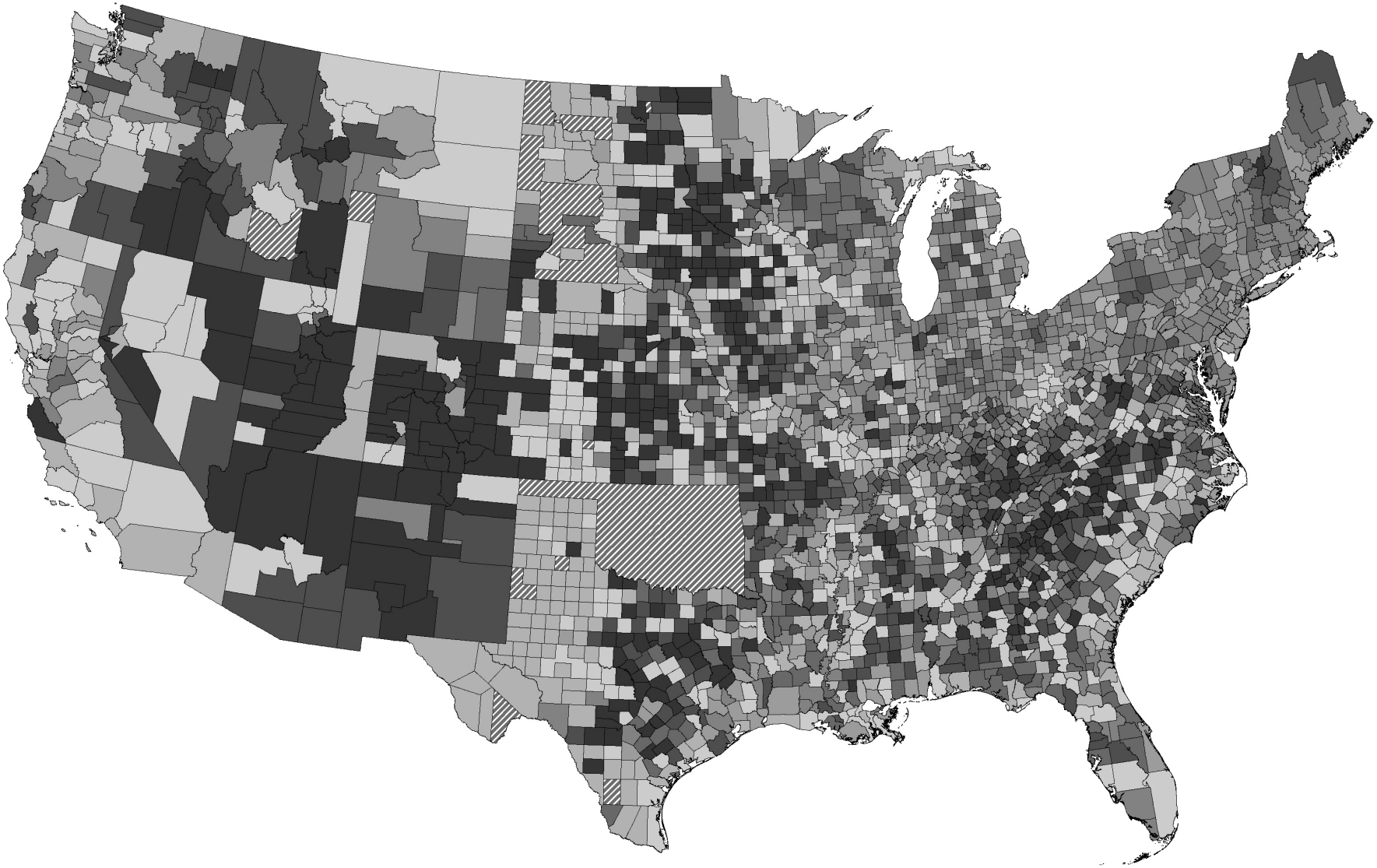
Estimated counterfactual productivity impacts:

- Estimated declines in county inputs, multiplied by county-specific input gaps, sum county-level losses

Table 7. Counterfactual Impacts on Productivity

	Baseline:	Restricted Railroad Networks:				No Railroads,	All Railroads,
	No Railroads	Only 1850 RRs	Only 1860 RRs	Only 1870 RRs	Only 1880 RRs	Extended Canals	Twice the Cost
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Counterfactual scenario, holding utility constant							
Change in Aggregate Productivity	-24.8%	-20.4%	-14.2%	-8.8%	-2.2%	-21.7%	-8.0%
Panel B. Counterfactual scenario, holding total population constant							
Change in Aggregate Productivity	-5.3%	-4.5%	-3.6%	-2.2%	-0.5%	-4.2%	-1.3%
Change in Utility	-33.6%	-27.9%	-18.8%	-11.6%	-2.9%	-29.8%	-11.4%

Figure 5. Counterfactual Changes in Productivity, by County



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Substantial productivity impacts from market access (and railroads)

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- Increased inputs generates much larger economic gains in the presence of market inefficiencies

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Future: establishment-level data

- Impacts on firm markups and physical productivity
- Agenda on causes and consequences of productivity growth