Railroads, Reallocation, and the Rise of American Manufacturing

or

Railroads, Market Integration, and Aggregate Productivity Growth

Richard Hornbeck
University of Chicago, Booth

and

Martin Rotemberg
NYU
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%
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%
- Aggregate productivity loss of 25% without railroads

Large impacts due to factor misallocation

- Increased inputs in marginally productive counties (where value marginal product exceeds marginal cost)
- Relative gaps matter, but also average gaps
- Integration did not reduce gaps (markups, input frictions)

Historical inefficiencies not especially high: less than modern US, modern developing countries

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

Hornbeck & Rotemberg
Railroads and Manufacturing
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%
- Aggregate productivity loss of 25% without railroads
- Aggregate loss of 22% under proposed canal network
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%
- Aggregate productivity loss of 25% without railroads
- Aggregate loss of 22% under proposed canal network
- Compare to 2.7% (Fogel) or 3.2% (Donaldson and Hornbeck)

Large impacts due to factor misallocation
- Increased inputs in marginally productive counties (where value marginal product exceeds marginal cost)
- Relative gaps matter, but also average gaps
- Integration did not reduce gaps (markups, input frictions)
- Historical inefficiencies not especially high: less than modern US, modern developing countries

When resources are allocated inefficiently, widely-used infrastructure/technologies have substantially larger economic benefits
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%
- Aggregate productivity loss of 25% without railroads
- Aggregate loss of 22% under proposed canal network
- Compare to 2.7% (Fogel) or 3.2% (Donaldson and Hornbeck)
- 45% social return on railroad capital, 10x the private return
Substantial gains from market integration through railroads

- From 1860 to 1880, 1 s.d. greater increase in market access increased manufacturing productivity by 13%
- Aggregate productivity loss of 25% without railroads
- Aggregate loss of 22% under proposed canal network
- Compare to 2.7% (Fogel) or 3.2% (Donaldson and Hornbeck)
- 45% social return on railroad capital, 10x the private return

Large impacts due to factor misallocation

- Increased inputs in marginally productive counties
  (where value marginal product exceeds marginal cost)
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%
- Aggregate productivity loss of 25% without railroads
- Aggregate loss of 22% under proposed canal network
- Compare to 2.7% (Fogel) or 3.2% (Donaldson and Hornbeck)
- 45% social return on railroad capital, 10x the private return

Large impacts due to factor misallocation
- Increased inputs in marginally productive counties (where value marginal product exceeds marginal cost)
- Relative gaps matter, but also average gaps
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%
- Aggregate productivity loss of 25% without railroads
- Aggregate loss of 22% under proposed canal network
- Compare to 2.7% (Fogel) or 3.2% (Donaldson and Hornbeck)
- 45% social return on railroad capital, 10x the private return

Large impacts due to factor misallocation
- Increased inputs in marginally productive counties (where value marginal product exceeds marginal cost)
- Relative gaps matter, but also average gaps
- Integration did not reduce gaps (markups, input frictions)
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%
- Aggregate productivity loss of 25% without railroads
- Aggregate loss of 22% under proposed canal network
- Compare to 2.7% (Fogel) or 3.2% (Donaldson and Hornbeck)
- 45% social return on railroad capital, 10x the private return

Large impacts due to factor misallocation
- Increased inputs in marginally productive counties (where value marginal product exceeds marginal cost)
- Relative gaps matter, but also average gaps
- Integration did not reduce gaps (markups, input frictions)
- Historical inefficiencies not especially high: less than modern US, modern developing countries
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%
- Aggregate productivity loss of 25% without railroads
- Aggregate loss of 22% under proposed canal network
- Compare to 2.7% (Fogel) or 3.2% (Donaldson and Hornbeck)
- 45% social return on railroad capital, 10x the private return

Large impacts due to factor misallocation
- Increased inputs in marginally productive counties (where value marginal product exceeds marginal cost)
- Relative gaps matter, but also average gaps
- Integration did not reduce gaps (markups, input frictions)
- Historical inefficiencies not especially high: less than modern US, modern developing countries

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
Change in Transportation Network

Waterways and 1860 Railroads
Change in Transportation Network

Waterways and 1870 Railroads
Change in Transportation Network

Waterways and 1880 Railroads
Change in Transportation Network
Waterways and 1890 Railroads
Output and input choices impacted by “Market Access:”

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

<table>
<thead>
<tr>
<th>Counties and Industries</th>
<th>No. of establishments</th>
<th>Capital</th>
<th>Average number of hands employed</th>
<th>Total amount paid in wages during the year</th>
<th>Value of materials</th>
<th>Value of products</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Males above 16 years</td>
<td>Females above 16 years</td>
<td>Children and youths</td>
<td></td>
</tr>
<tr>
<td>Frederick—continued.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Furniture</td>
<td>10</td>
<td>624,350</td>
<td>30</td>
<td>30</td>
<td>1</td>
<td>$4,055</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>2</td>
<td>575,000</td>
<td>200</td>
<td>200</td>
<td></td>
<td>59,000</td>
</tr>
<tr>
<td>Leather, curried</td>
<td>8</td>
<td>21,880</td>
<td>9</td>
<td>9</td>
<td></td>
<td>4,416</td>
</tr>
<tr>
<td>Leather, tanned</td>
<td>14</td>
<td>102,800</td>
<td>88</td>
<td>88</td>
<td>1</td>
<td>10,702</td>
</tr>
<tr>
<td>Lamps</td>
<td>12</td>
<td>55,850</td>
<td>35</td>
<td>35</td>
<td></td>
<td>20,415</td>
</tr>
<tr>
<td>Liqueurs, distilled</td>
<td>3</td>
<td>31,000</td>
<td>7</td>
<td>7</td>
<td></td>
<td>1,780</td>
</tr>
<tr>
<td>Printing and publishing</td>
<td>5</td>
<td>21,880</td>
<td>49</td>
<td>49</td>
<td>4</td>
<td>8,852</td>
</tr>
<tr>
<td>Saddlery and harness</td>
<td>19</td>
<td>25,610</td>
<td>28</td>
<td>28</td>
<td></td>
<td>6,150</td>
</tr>
<tr>
<td>Sash, doors, and blinds</td>
<td>3</td>
<td>25,610</td>
<td>28</td>
<td>28</td>
<td></td>
<td>11,541</td>
</tr>
<tr>
<td>Tinware, copperware, and sheet-iron ware</td>
<td>14</td>
<td>35,860</td>
<td>34</td>
<td>34</td>
<td>4</td>
<td>10,100</td>
</tr>
<tr>
<td>Tobacco, cigars and cigarettes</td>
<td>11</td>
<td>11,800</td>
<td>25</td>
<td>25</td>
<td>4</td>
<td>6,002</td>
</tr>
<tr>
<td>Garrett:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flouring- and grist-mill products</td>
<td>13</td>
<td>15,637</td>
<td>10</td>
<td>10</td>
<td>2</td>
<td>1,084</td>
</tr>
<tr>
<td>Lumber, sawed</td>
<td>20</td>
<td>305,750</td>
<td>181</td>
<td>181</td>
<td></td>
<td>45,060</td>
</tr>
<tr>
<td>Woolen goods</td>
<td>2</td>
<td>6,400</td>
<td>9</td>
<td>9</td>
<td></td>
<td>1,076</td>
</tr>
<tr>
<td>Harford:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizers</td>
<td>3</td>
<td>40,500</td>
<td>15</td>
<td>15</td>
<td>1</td>
<td>4,200</td>
</tr>
<tr>
<td>Flouring- and grist-mill products</td>
<td>41</td>
<td>100,000</td>
<td>55</td>
<td>55</td>
<td>1</td>
<td>7,016</td>
</tr>
<tr>
<td>Fruits and vegetables, canned and preserved</td>
<td>53</td>
<td>180,922</td>
<td>686</td>
<td>686</td>
<td>111</td>
<td>58,045</td>
</tr>
<tr>
<td>Knoll and ground areals</td>
<td>5</td>
<td>48,400</td>
<td>64</td>
<td>64</td>
<td>1</td>
<td>12,290</td>
</tr>
<tr>
<td>Lumber, sawed</td>
<td>23</td>
<td>131,100</td>
<td>64</td>
<td>64</td>
<td>1</td>
<td>13,522</td>
</tr>
<tr>
<td>Shipbuilding</td>
<td>1</td>
<td>2,000</td>
<td>27</td>
<td>27</td>
<td></td>
<td>12,700</td>
</tr>
<tr>
<td>Howard:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton goods</td>
<td>3</td>
<td>574,816</td>
<td>185</td>
<td>185</td>
<td></td>
<td>100,416</td>
</tr>
<tr>
<td>Flouring- and grist-mill products</td>
<td>17</td>
<td>86,200</td>
<td>80</td>
<td>80</td>
<td>120</td>
<td>9,514</td>
</tr>
<tr>
<td>Paper</td>
<td>1</td>
<td>66,000</td>
<td>25</td>
<td>25</td>
<td></td>
<td>7,000</td>
</tr>
<tr>
<td>Kent:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural implements</td>
<td>12</td>
<td>24,350</td>
<td>33</td>
<td>33</td>
<td></td>
<td>12,301</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>2</td>
<td>28,000</td>
<td>18</td>
<td>18</td>
<td></td>
<td>15,760</td>
</tr>
<tr>
<td>Flouring- and grist-mill products</td>
<td>0</td>
<td>40,600</td>
<td>15</td>
<td>15</td>
<td>2,775</td>
<td>58,745</td>
</tr>
<tr>
<td>Fruits and vegetables, canned and preserved</td>
<td>1</td>
<td>25,600</td>
<td>10</td>
<td>115</td>
<td>6,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Montgomery:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizers</td>
<td>1</td>
<td>21,000</td>
<td>8</td>
<td>8</td>
<td></td>
<td>2,200</td>
</tr>
<tr>
<td>Flouring- and grist-mill products</td>
<td>80</td>
<td>231,550</td>
<td>49</td>
<td>49</td>
<td>12,111</td>
<td>174,249</td>
</tr>
<tr>
<td>Prince George's:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton goods</td>
<td>1</td>
<td>270,000</td>
<td>64</td>
<td>64</td>
<td></td>
<td>35,085</td>
</tr>
<tr>
<td>Flouring- and grist-mill products</td>
<td>15</td>
<td>43,758</td>
<td>29</td>
<td>29</td>
<td>4,068</td>
<td>54,200</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>1</td>
<td>39,000</td>
<td>99</td>
<td>99</td>
<td></td>
<td>31,390</td>
</tr>
<tr>
<td>Lumber, sawed</td>
<td>0</td>
<td>16,400</td>
<td>38</td>
<td>38</td>
<td></td>
<td>7,755</td>
</tr>
</tbody>
</table>
Establishment-level Manuscripts

### SCHEDULE 5—Products of Industry in

<table>
<thead>
<tr>
<th>Name of Corporation, Company, or Individual</th>
<th>Name of Manager, Superintendent, or Owner</th>
<th>Description</th>
<th>Description</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texas Cotton-seed Oil Co.</td>
<td>John Smith</td>
<td>Oil Mill</td>
<td>Oil Mill</td>
<td>Oil Mill</td>
</tr>
<tr>
<td>J. W. Jones</td>
<td>Lewis Clark</td>
<td>Lumber Mill</td>
<td>Lumber Mill</td>
<td>Lumber Mill</td>
</tr>
<tr>
<td>E. W. Smith</td>
<td>Samuel Palmer</td>
<td>Nursery</td>
<td>Nursery</td>
<td>Nursery</td>
</tr>
<tr>
<td>A. B. Johnson</td>
<td>Charles Green</td>
<td>Dairy Farm</td>
<td>Dairy Farm</td>
<td>Dairy Farm</td>
</tr>
<tr>
<td>C. S. Thompson</td>
<td>John Doe</td>
<td>Farm</td>
<td>Farm</td>
<td>Farm</td>
</tr>
<tr>
<td>Daniel Brown</td>
<td>Robert Miller</td>
<td>Sawmill</td>
<td>Sawmill</td>
<td>Sawmill</td>
</tr>
<tr>
<td>Dr. D. Watson</td>
<td>Emily Allen</td>
<td>Textile Plant</td>
<td>Textile Plant</td>
<td>Textile Plant</td>
</tr>
<tr>
<td>John Doe</td>
<td>Mary Johnson</td>
<td>Print Shop</td>
<td>Print Shop</td>
<td>Print Shop</td>
</tr>
<tr>
<td>C. S. Thompson</td>
<td>John Smith</td>
<td>Oil Mill</td>
<td>Oil Mill</td>
<td>Oil Mill</td>
</tr>
<tr>
<td>Dr. D. Watson</td>
<td>Emily Allen</td>
<td>Textile Plant</td>
<td>Textile Plant</td>
<td>Textile Plant</td>
</tr>
<tr>
<td>John Doe</td>
<td>Mary Johnson</td>
<td>Print Shop</td>
<td>Print Shop</td>
<td>Print Shop</td>
</tr>
<tr>
<td>C. S. Thompson</td>
<td>John Smith</td>
<td>Oil Mill</td>
<td>Oil Mill</td>
<td>Oil Mill</td>
</tr>
<tr>
<td>Dr. D. Watson</td>
<td>Emily Allen</td>
<td>Textile Plant</td>
<td>Textile Plant</td>
<td>Textile Plant</td>
</tr>
<tr>
<td>John Doe</td>
<td>Mary Johnson</td>
<td>Print Shop</td>
<td>Print Shop</td>
<td>Print Shop</td>
</tr>
</tbody>
</table>
Measuring County Productivity

Define county productivity broadly as:

- \( Productivity_c = P_cQ_c - \sum_k W_c^k X_c^k \)
- Output value \( (P_cQ_c) \) 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:

- \( \ln Productivity_c = \ln P_cQ_c - \sum_k s_c^k \ln W_c^k X_c^k \)
- \( s_c^k \) 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)

\[
\ln \text{Productivity}_c = \left[ \ln P_c Q_c - \sum_k \alpha^k_c \ln W^k_c X^k_c \right] \quad \text{(TFPR)}
\]
\[
+ \left[ \sum_k (\alpha^k_c - s^k_c) \ln W^k_c X^k_c \right] \quad \text{(RE)}
\]

For output elasticity ($\alpha_c$), need production function assumptions

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

County input gaps: ($\alpha^k_c - s^k_c$)

- Reflect value marginal products greater than marginal costs
- Markups (Hall 1988)
- Input frictions (Hsиеh 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

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

Notes: Column 1, panel A, reports estimates from equation 13 in the text: for a balanced panel of 1,804 counties in 1860, 1870, and 1880, county productivity (as defined in equation 10) is regressed on log market access (as defined in equation 1), county fixed effects, state-by-year fixed effects, and year-interacted cubic polynomials in county latitude and longitude. Panels B and C report estimated impacts on county reallocative efficiency and county technical efficiency, as defined in equations 12 and 11. In each column, we report the estimated impact of a one standard deviation greater change in market access from 1860 to 1880 (e.g., the coefficient in column 1, panel A, can be interpreted as a relative productivity increase of 12.9% for counties with a one standard deviation greater change in market access from 1860 to 1880).

Column 2 reports estimates using a measure of counties’ market access in each decade that holds counties’ population levels fixed at 1860 levels. Column 4 uses a measure of counties’ market access only to counties beyond 100 miles of a county. Columns 4 and 5 use county-level data, rather than county-by-industry data, to measure the outcome variables from 1860 through 1900 (in column 4) and from 1860 through 1880 (in column 5). Column 6 uses county-by-industry data based on 158 industry groups, rather than the 35 industry groups used in columns 1 to 3.

Robust standard errors clustered by state are reported in parentheses.
Table 2. Impacts of Market Access, Controlling Flexibly for Local Railroad Construction

<table>
<thead>
<tr>
<th>Panel A. County Productivity</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Market Access</td>
<td>0.129</td>
<td>0.147</td>
<td>0.152</td>
<td>0.140</td>
<td>0.131</td>
<td>0.105</td>
</tr>
<tr>
<td>(0.050)</td>
<td>(0.058)</td>
<td>(0.060)</td>
<td>(0.059)</td>
<td>(0.059)</td>
<td>(0.062)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B. County Reallocation Efficiency (RE)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Market Access</td>
<td>0.117</td>
<td>0.129</td>
<td>0.135</td>
<td>0.124</td>
<td>0.116</td>
<td>0.092</td>
</tr>
<tr>
<td>(0.045)</td>
<td>(0.053)</td>
<td>(0.055)</td>
<td>(0.055)</td>
<td>(0.054)</td>
<td>(0.057)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel C. County Technical Efficiency (TE)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Market Access</td>
<td>0.012</td>
<td>0.018</td>
<td>0.017</td>
<td>0.016</td>
<td>0.015</td>
<td>0.013</td>
</tr>
<tr>
<td>(0.008)</td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.009)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td></td>
</tr>
</tbody>
</table>

Additional Controls for:

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any Railroad</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Railroad Length</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Railroad Length Polynomial</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Railroads in Nearby Buffer</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Railroads in Further Buffers</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of Counties</td>
<td>1,804</td>
<td>1,804</td>
<td>1,804</td>
<td>1,804</td>
<td>1,804</td>
<td>1,804</td>
</tr>
<tr>
<td>County-Year Obs.</td>
<td>5,412</td>
<td>5,412</td>
<td>5,412</td>
<td>5,412</td>
<td>5,412</td>
<td>5,412</td>
</tr>
</tbody>
</table>
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 ($\bar{P}$ and $\theta$)
- Distant variation in market access
Table 4. Impacts of Market Access on Input Expenditures, Gaps, Wedges, and Cost Shares

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

Notes: For the indicated outcome variable, each column and panel reports the estimated impact of log market access from our baseline specification (Table 1, column 1): the indicated outcome variable is regressed on log market access, county fixed effects, state-by-year fixed effects, and year-interacted cubic polynomials in county latitude and longitude. In column 1, the outcome variable is log expenditure on materials (panel A), log expenditure on labor (panel B), and log expenditure on capital (panel C). In column 2, the outcome variable is the county-level input "gap," defined as that input's cost share minus its revenue share. In column 3, the outcome variable is the county-level input "wedge," defined as that input's cost share divided by its revenue share. In column 4, the outcome variable is the county-level cost share for that input, defined as the national industry-level cost shares multiplied by the share of county output in each industry. The sample is our main balanced panel of 1,804 counties in 1860, 1870, and 1880. We continue to report the estimated impact of a one standard deviation greater change in market access from 1860 to 1880. Robust standard errors clustered by state are reported in parentheses.
Table 5. Impacts of Market Access on County Industries, Firms, and Sector Shares

<table>
<thead>
<tr>
<th>Log Number of Industries (1)</th>
<th>Log Average Firm Size: Output per Firm (2)</th>
<th>Log Average Firm Size: Workers per Firm (3)</th>
<th>Log Number of Firms (4)</th>
<th>County Manufacturing Share of: Output (5)</th>
<th>County Manufacturing Share of: Value-Added (6)</th>
<th>County Manufacturing Share of: Surplus (7)</th>
<th>County Manufacturing Share of: Employment (8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Market Access</td>
<td>0.005</td>
<td>0.025</td>
<td>0.025</td>
<td>0.172</td>
<td>0.0092</td>
<td>0.0016</td>
<td>0.0005</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.042)</td>
<td>(0.052)</td>
<td>(0.037)</td>
<td>(0.0081)</td>
<td>(0.0067)</td>
<td>(0.0095)</td>
</tr>
<tr>
<td>Number of Counties</td>
<td>1,804</td>
<td>1,804</td>
<td>1,804</td>
<td>1,804</td>
<td>1,777</td>
<td>1,777</td>
<td>1,718</td>
</tr>
<tr>
<td>County/Year Obs.</td>
<td>5,412</td>
<td>5,412</td>
<td>5,412</td>
<td>5,412</td>
<td>5,331</td>
<td>5,331</td>
<td>5,154</td>
</tr>
</tbody>
</table>
### Table 6. Impacts of Market Access on County Specialization

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

Notes: For the indicated outcome variable, each column and panel reports the estimated impact of log market access from our baseline specification (Table 1, column 1): the indicated outcome variable is regressed on log market access, county fixed effects, state-by-year fixed effects, and year-interacted cubic polymials in county latitude and longitude. In panel A, the outcome variables reflect a cross-sector specialization index: the share of county value in manufacturing minus its national share (squared) plus the share of county value in agriculture minus its national share (squared), where those values are based on output (column 1), value-added (column 2), surplus (column 3), and employment (column 4) as defined in Table 5. In panel B, the outcome variables reflect a within-manufacturing specialization index: the share of county manufacturing value in each industry minus that industry’s national manufacturing share (squared and summed across each industry), where the values for manufacturing are as defined in panel A. All regressions include county fixed effects, state-by-year fixed effects, and year-interacted cubic polymials in county latitude and longitude. The samples are drawn from our main balanced panel of 1,804 counties in 1860, 1870, and 1880, which are sometimes smaller due to missing data for some counties in some years. We continue to report the estimated impact of a one standard deviation greater change in market access from 1860 to 1880 in the full sample of 1,804 counties. Robust standard errors clustered by state are reported in parentheses.
Counterfactual Analysis for Aggregate Effects

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

Estimate parameters:
• Estimate county wedges from manufacturing sector
• Estimate output elasticities (mfg and ag)

Jointly estimate $P$ and $\theta$, using data on railroad shipments and estimated impact of market access on land value

Estimate model:
• County populations imply county “amenities”
• Hold amenity fixed, calculate counterfactual populations

Estimated counterfactual productivity impacts:
• Estimated declines in county inputs, multiplied by county-specific input gaps, sum county-level losses
Counterfactual Analysis for Aggregate Effects


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

Estimate parameters:

- Estimate county wedges from manufacturing sector
- Estimate output elasticities (mfg and ag)
- Jointly estimate $\bar{P}$ and $\theta$, using data on railroad shipments and estimated impact of market access on land value
Counterfactual Analysis for Aggregate Effects

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

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

Estimate model:
- County populations imply county “amenities”
- Hold amenity fixed, calculate counterfactual populations
Counterfactual Analysis for Aggregate Effects

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

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

Estimate model:
- County populations imply county “amenities”
- Hold amenity fixed, calculate counterfactual populations

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

<table>
<thead>
<tr>
<th>Baseline: No Railroads (1)</th>
<th>Restricted Railroad Networks:</th>
<th>No Railroads, Extended Canals (6)</th>
<th>All Railroads, Twice the Cost (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Restricted Railroad Networks:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Only 1850 RRs (2)</td>
<td>Only 1860 RRs (3)</td>
<td>Only 1870 RRs (4)</td>
</tr>
<tr>
<td>Change in Aggregate Productivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-24.8%</td>
<td>-14.2%</td>
<td>-8.8%</td>
<td>-2.2%</td>
</tr>
<tr>
<td>Change in Utility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-33.6%</td>
<td>-18.8%</td>
<td>-11.6%</td>
<td>-2.9%</td>
</tr>
</tbody>
</table>

Panel A. Counterfactual scenario, holding utility constant

Panel B. Counterfactual scenario, holding total population constant
Figure 5. Counterfactual Changes in Productivity, by County

Notes: This map shows the 2,760 counterfactual sample counties, which report population and output in 1890, shaded according to their change in productivity from 1890 to the baseline counterfactual scenario. Counties are divided into seven groups (with an equal number of counties per group), and darker shades denote larger declines in productivity. The excluded geographic areas are cross-hashed. County boundaries correspond to county boundaries in 1890.
Summary and Follow-up Research

Substantial productivity impacts from market access (and railroads)

Through reallocation, and increased scale in particular

Key: presence of misallocation

Defer: impacts on innovation and TE growth

Social savings are not a meaningful upper bound

Land values miss substantial economic gains

Reducing inefficiencies is good, but:

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

With great problems come great possibilities

Future: establishment-level data

• Impacts on firm markups and physical productivity

• Agenda on causes and consequences of productivity growth
Summary and Follow-up Research

Substantial productivity impacts from market access (and railroads)

- Through reallocation, and increased scale in particular
  
  Key: presence of misallocation
  
  Defer: impacts on innovation and TE growth
Summary and Follow-up Research

Substantial productivity impacts from market access (and railroads)

- Through reallocation, and increased scale in particular
  - Key: presence of misallocation
  - Defer: impacts on innovation and TE growth
- Social savings are not a meaningful upper bound

Reducing inefficiencies is good, but:

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

With great problems come great possibilities

Future: establishment-level data

- Impacts on firm markups and physical productivity
- Agenda on causes and consequences of productivity growth
Summary and Follow-up Research

Substantial productivity impacts from market access (and railroads)

- Through reallocation, and increased scale in particular
  - Key: presence of misallocation
  - Defer: impacts on innovation and TE growth

- Social savings are not a meaningful upper bound

- Land values miss substantial economic gains
Summary and Follow-up Research

Substantial productivity impacts from market access (and railroads)

- Through reallocation, and increased scale in particular
  
  Key: presence of misallocation
  
  Defer: impacts on innovation and TE growth

- Social savings are not a meaningful upper bound

- Land values miss substantial economic gains

Reducing inefficiencies is good, but:

- Increased inputs generates much larger economic gains in the presence of market inefficiencies
Summary and Follow-up Research

Substantial productivity impacts from market access (and railroads)
  • Through reallocation, and increased scale in particular
    Key: presence of misallocation
    Defer: impacts on innovation and TE growth
  • Social savings are not a meaningful upper bound
  • Land values miss substantial economic gains

Reducing inefficiencies is good, but:
  • Increased inputs generates much larger economic gains in the presence of market inefficiencies
  • With great problems come great possibilities
Summary and Follow-up Research

Substantial productivity impacts from market access (and railroads)
- Through reallocation, and increased scale in particular
  - Key: presence of misallocation
  - Defer: impacts on innovation and TE growth
- Social savings are not a meaningful upper bound
- Land values miss substantial economic gains

Reducing inefficiencies is good, but:
- Increased inputs generates much larger economic gains in the presence of market inefficiencies
- With great problems come great possibilities

Future: establishment-level data
- Impacts on firm markups and physical productivity
- Agenda on causes and consequences of productivity growth