Economic Impacts of Transportation Infrastructure Investments

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Economic Impacts of Transportation Infrastructure

• Empirical Questions:

  1. How large are the economic benefits of transportation infrastructure projects?

  2. What economic mechanisms explain these benefits?

• I will provide an eclectic (aka narcissistic) tour of some of the answers seen in the literature so far.
  • (For a real survey, see Redding and Turner, 2015.)
Motivation

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2. Often huge, lumpy investments, with lots of scope for error. (Made even worse by persistence of economic geography.)

3. At the moment, economists are not particularly involved in decisions about where (and how much) to invest.
Example #1: US Transportation Network, 1840-1911
Waterways and No railroads (1840)
Example #1: US Transportation Network, 1840-1911
Waterways and 1850 railroads
Example #1: US Transportation Network, 1840-1911
Waterways and 1860 railroads
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Waterways and 1870 railroads
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Waterways and 1880 railroads
Example #1: US Transportation Network, 1840-1911
Waterways and 1887 railroads
Example #1: US Transportation Network, 1840-1911
Waterways and 1911 railroads
Example #2: India, 1853-1930
Waterways and 1853 (first track) railroads
Example #2: India, 1853-1930
Waterways and 1860 railroads
Example #2: India, 1853-1930
Waterways and 1870 railroads
Example #2: India, 1853-1930

Waterways and 1880 railroads
Example #2: India, 1853-1930
Waterways and 1890 railroads
Example #2: India, 1853-1930
Waterways and 1900 railroads
Example #2: India, 1853-1930
Waterways and 1910 railroads
Example #2: India, 1853-1930
Waterways and 1920 railroads
Example #2: India, 1853-1930
Waterways and 1930 railroads
Fogel’s “Social Savings” Method

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- Basic idea (nice formalization of methodology in Diewert, 1986; broad idea as old as Dupuit, 1848):
  - Firms and consumers demand “transport services”
  - They therefore have a derived demand curve that traces out their willingness to pay for these services
  - Infrastructure investments move out the supply curve
  - If no market failures in economy, social surplus generated is new area under the demand curve
  - Full GE? Just need envelope demand curve (“benefit function”) that adjusts for changes in other prices
  - Hard to estimate this demand curve. But can bound the surplus in usual Paasche/Laspeyres way.
  - Upper-bound (i.e. \((p_0 - p_1)Q_1\)) for US freight transport via rail was 2% of GDP in 1890.
Drawbacks of the “Social Savings” Method

• **Theory:**
  2. Market failures elsewhere in the economy (e.g. agglomeration, congestion externalities)
  3. How to study geographic distributional issues? (Does the exporter or the importer get the benefit from $Q_1$?)
Drawbacks of the “Social Savings” Method

• **Theory:**
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• **Implementation:**
  1. How to measure $\Delta p$ (what is true user cost of transport services?)
  2. Observed $\Delta p$ or $Q_1$ may have been caused by other changes in the economy (no control group)
  3. Have to repeat for each type of $Q$ (e.g. Leunig, 2006 for passenger travel). What is $Q$ for idea flows?
  4. Inherently *ex post* (without estimate of benefit function).
Alternative Method: Statistical Comparisons (True “Econometrics”)

- Try to find quasi-experimental variation and compare “treated” (T) regions to “control” (C) regions

- But that only identifies ATE under no spillovers assumption (SUTVA): C group is not affected by the fact that T got treated.

- Treatment spillovers are doubly hazardous when it comes to counterfactuals:
  - Suppose \( \Delta Y(T) = 10, \Delta Y(C) = 5 \) (positive spillover). Analyst would estimate \( \hat{ATE} = 5 \) yet true social benefit is 15.
  - Suppose \( \Delta Y(T) = 10, \Delta Y(C) = -5 \) (negative spillover). Analyst would estimate \( \hat{ATE} = 15 \) yet true social benefit is 5.
Treatment Spillovers from Transportation Infrastructure

- It seems likely that treatment spillovers are particularly prevalent in this context. (As Fogel himself stressed.)

- Transportation infrastructure projects are inherently about changing interactions among regions.

- Consider a simple example of 3 regions ($A$, $B$, $C$). Suppose a new rail link is built between $A$ and $B$.

  - Direct effect: benefits $A$ and $B$.
  - Trade cost network effect: $C$ benefits because it can use this $AB$ link to access $A$ or $B$.
  - Trade diversion: $C$ harmed because $A$ now has privileged access in $B$.
  - Supply chains: $C$ benefits if it buys goods from $B$ that require inputs from $A$.

  ...yet some of these statements can flip in IRTS models.

  ...and those are just the goods market interactions.
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Attempts to Solve the Treatment Spillovers Problem

• Only solution is to find a pure control group.

• Equivalently (and more pragmatically):
  • Don’t work with a dummy variable for whether a given program \( P \) assigned \( T(P)_i = 1 \) or \( T(P)_i = 0 \) to each unit \( i \).
  • Instead, work with a continuous treatment intensity variable \( T(P)_i \), where \( T(P)_i = 0 \) is a truly unaffected control.

• But how to construct this treatment intensity variable \( T(P) \)?
  • Requires some theory—dimensionality of \( T(P) \) function is too daunting for truly nonparametric work.
  • Donaldson and Hornbeck (2016), building on Hanson (1998) and Redding and Venables (2004): gravity trade model theory suggests “market access” approach
Market Access Approach

- Adao, Costinot and Donaldson (2017): All efficient trade models can be represented by a “factor demand system” \( \chi_{ij}(\omega_j, y_j) \)

- “Gravity models” just happen to have the simplest possible \( \chi_{ij}(\omega_j, y_j) \) function (one immobile factor, isoelastic, homothetic). For example:
  - Armington (1969) regional endowments model
  - Eaton and Kortum (2002) productivity heterogeneity (Frechet-distributed) Ricardian model
  - Krugman (1980) monopolistic competition model
  - Melitz (2003) heterogeneous (Pareto-distributed) firms monopolistic competition model
  - Arkolakis, Costinot and Rodriguez-Clare (2013) models more generally (?)
Market Access Approach (Continued)

- This logic implies:
  - If gravity fits well (and $R^2 \approx 0.8$)
  - And there are no market failures
    (or weaker: externalities exist but scale with market size)
  - And locations use immobile factor in same proportions
    (or weaker: approximately so)
  - And trade costs are symmetric
    (or weaker: quasi-symmetric)
  - Then we have...

\[
\ln(\text{Price of immobile factor})_i = \alpha + \beta \ln(\text{Market Access})_i + \varepsilon_i
\]

- This expression is stable under counterfactuals
- Captures all benefits/costs of any change in MA on the immobile factor in the model
Empirical Definition of “Market Access”

Market access is defined recursively:

\[ MA(N)_i = \sum_j (\tau_{ij})^{-\theta} N_j (MA_j)^{-(1+\theta)} \]

\[ = \sum_j \frac{(\tau_{ij})^{-\theta} N_j}{\sum_k (\tau_{kj})^{-\theta} N_k (MA_k)^{-(1+\theta)}} \]

\[ = \sum_j \frac{(\tau_{ij})^{-\theta} N_j}{\sum_k \sum_l (\tau_{kl})^{-\theta} N_l (MA_l)^{-(1+\theta)}} \]

\ldots

So explore different truncations:

- Most simple: \( MA(N)_i = \sum_{j \neq i} (\tau_{ij})^{-\theta} N_j \).
- Very highly correlated with one or two more iterations
- Very highly correlated with precise, model-based solution
  (using data on \( N \) to solve system of equations in \( MA \))
Donaldson and Hornbeck (2016): Some Details...

- Change in railroad network from 1870-1890
- 2,327 U.S. counties with Census data in those years
- Price of “immobile factor” is agricultural land
- Have to choose a $\theta$
  - Harris (1954) used $\theta = 1$ and called it “market potential”
  - Most commonly used value (Head and Mayer, 2014) is $\theta = 5$
  - But, surprisingly, it doesn’t matter (at least below $\theta = 26.83$, our upper 95% CI)
- Have to measure $\tau_{ijt}$:
  - Tried to measure mode-wise freight rates (for relevant goods), including fixed trans-shipment costs, as close to Fogel (1964) as possible
  - Then feed freight rates into least-cost route algorithm (Dijkstra) for all $2,327 \times 2,327$ calculations in each year
  - Lots of adjustments for small/local access from county to network
Nonparametric Relationship Between $\Delta$ MA and $\Delta$ Land Value

The total U.S. population level is held constant, which we denote by $N(PoN)$. We then use the new county populations to calculate each county's market access in the no-railroad counterfactual, following equation (12), as before.

Table IV, row 4, reports an estimated counterfactual decline in land value of 56.6%, which suggests that the endogenous reallocation of population in response to the removal of railroads has only a small effect on the loss in land value attributable to the removal of railroads.

The calculations provide a predicted counterfactual population for each county in the no-railroad scenario, which is itself of interest.

Figure V, Panel A, maps the substantial counterfactual changes in population, in which darker shades correspond to...

Residual changes in sample counties are calculated by regressing changes in the indicated variable on state fixed effects and county longitude and latitude, as in equation (13). This figure then plots the local polynomial relationship between residual changes in log land value and residual changes in log market access, based on an Epanechnikov kernel function with default bandwidth of 0.06. The shaded region reflects the 95% confidence interval.

For each county in 1890 by using data on the population share in each county in 1890 and trade costs in 1890. This procedure draws on our estimate of $\gamma = 8.22$ and the assumed parameter values $\alpha = 0.19$ and $\beta = 0.60$. The calculations provide a predicted counterfactual population for each county in the no-railroad scenario, which is itself of interest.

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Counterfactuals

TABLE VI

COUNTERFACTUAL IMPACTS ON LAND VALUE, ALLOWING FOR TRANSPORTATION RESPONSES

<table>
<thead>
<tr>
<th>Percent Decline in Land Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline counterfactual without railroads in 1890</td>
</tr>
<tr>
<td>Allowing for transportation responses</td>
</tr>
<tr>
<td>1. Extended canal network</td>
</tr>
<tr>
<td>2. Improved country roads, wagon cost of 14 cents</td>
</tr>
<tr>
<td>3. Extended canal network and improved country roads</td>
</tr>
<tr>
<td>4. Increased water shipping rates, doubled</td>
</tr>
</tbody>
</table>

Notes. Each row reports the counterfactual impact on land value from the removal of railroads, given some potential response in the transportation network (as described in Section VIII). In row 1, the railroad network is removed and the canal network is extended. In row 2, the railroad network is removed and the wagon freight rate is lowered to reflect improvements in country roads. In row 3, the railroad network is removed and both adjustments are made from rows 1 and 2. In row 4, the railroad network is removed and waterway freight rates are doubled. Robust standard errors clustered by state are reported in parentheses.
I think the MA approach has some attractions:

- Simple way to use a relatively small amount of theory (and pretty robust, empirically successful theory—gravity theory) to structure empirical thinking about measuring treatment intensity.

- Passes some internal consistency (over-identification) tests here (though Baum Snow et al (2017) reject that in China)

- Doesn’t give wildly different answers from Fogel’s social savings calculations

- But, some obvious limitations...
Limitation #1: Couldn’t Account for Negative Spillovers (on Peripheral Locations) seen in Faber (2016)

Figure 1: China’s National Trunk Highway System

The figure shows Chinese county boundaries in 1999 in combination with the targeted city nodes and the completed expressway routes of the National Trunk Highway System (NTHS) in the year 2007.
Limitation #2: Wouldn’t Account for Huge Impacts of Air Travel/Shipping seen in... Feyrer (2009)
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Figure 3. Constructing the Airport-Level Instrument, SFO Example

Notes: The thick red line is drawn 6000 miles from San Francisco International Airport (SFO). The buffer around the thick line indicates which other airports (cities) that are located within 5500-6500 miles from SFO. For each of the 819 observations, the airport-level instrument is the share of other cities within the buffer that are located below 6000 miles.
Limitation #2: Wouldn’t Account for Huge Impacts of Air Travel/Shipping seen in...Campante and Yanazigawa-Drott (2017)

Figure 6. Number of Firms with Cross-Ownership Links, by Distance between Closest Airports

A: All Firms

![Graph showing number of firms with cross-ownership links by distance between airports.]

B: Firms within 100 miles of Airport

![Graph showing number of firms with cross-ownership links by distance between airports limited to within 100 miles of sample airport.]
Limitation #3: Wouldn’t Deliver the Path-Dependent Impacts seen in Bleakley and Lin (2012)

Figure A.1
The Density Near Fall-Line/River Intersections

This map shows the contemporary distribution of economic activity across the southeastern United States measured by the 2003 nighttime lights layer. For information on sources, see notes for Figures II and IV.
Limitation #3: Wouldn’t Deliver the Path-Dependent Impacts seen in Bleakley and Lin (2012)

The map in the upper panel shows the contemporary distribution of economic activity across the southeastern United States, measured by the 2003 nighttime lights layer from NationalAtlas.gov. The nighttime lights are used to present a nearly continuous measure of present-day economic activity at a high spatial frequency. The fall line (solid) is digitized from Physical Divisions of the United States, produced by the U.S. Geological Survey. Major rivers (dashed gray) are from NationalAtlas.gov, based on data produced by the United States Geological Survey. Contemporary fall-line cities are labeled in the lower panel.
Limitation #3: Wouldn’t Deliver the Path-Dependent Impacts seen in Bleakley and Lin (2012)

Panel A: Average by absolute distance from the fall line

Panel B: Average by renormalized distance from the fall line
Concluding Remarks

• I have offered only a few examples of what we have learned about impacts of transportation infrastructure investments

• Some serious omissions:
  • Incorporating market failures (e.g. Asturias et al, 2015)
  • Incorporating input-output linkages (e.g. analogous to Caliendo et al, 2017)
  • Effects on passenger flows (e.g. Leunig, 2006; Bernard et al, 2016)
  • Effects on migration (e.g. Morten and Oliviera, 2016)
  • Intra-city infrastructure (e.g. Duranton and Turner, 2012; Baum-Snow et al, 2016)
  • Effects on innovation (e.g. Perelman, 2016)
  • Effects on inequality (e.g. Michaels, 2010)

• Areas where (I think) more work is badly needed:
  • Serious interaction with market failures (e.g. agglomeration, misallocation) and industrial policy
  • Serious approach to dynamics, growth, persistence
  • More flexible approaches to the spatial spillovers problem