

Optimal Transport Networks in Spatial Equilibrium

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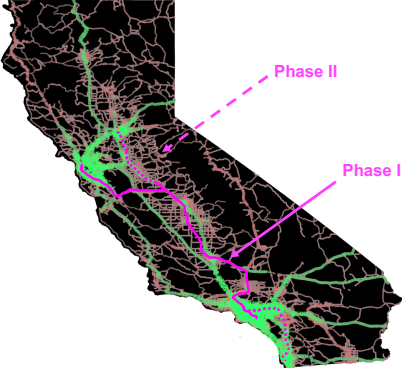
NBER Economics of Infrastructure Investment Conference, 03/12/2020

Introduction

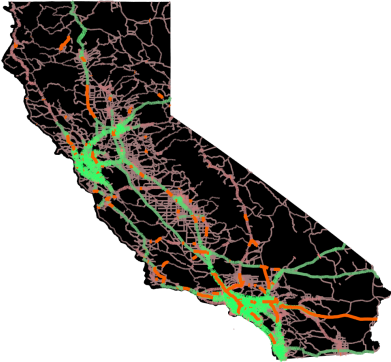
- Large investments in infrastructure
 - ▶ 20% of World Bank spending
 - ▶ 6% of government spending around the world
- Large implications for welfare and growth
 - ▶ Transport of goods: lower prices, greater market access
 - ▶ Transport of people: access to jobs, diffusion of knowledge
- **How should these investments be allocated in a transport network?**

California Road Network and Current Infrastructure Projects

High Speed Rail



CALTRANS Capital Outlay Projects



Questions

- Are these investments efficient?
- Where should the optimal investments be allocated?
 - ▶ What is the optimal size of the network?
 - ▶ What would be the productivity gains?
- Existing methods to analyze specific investments do not determine the *ideal* ones
 - ▶ Eaton and Kortum (2002), Allen and Arkolakis (2014), Redding (2016),...
 - ▶ Duranton et al. (2014), Faber (2014),...
- Challenging due to
 - ▶ Reallocation of economic activity and trading routes
 - ▶ Large dimension of the problem

New Methods: *Optimal Transport Networks in Spatial Equilibrium* (2019)

- We study transport of goods: lower prices, greater market access. We combine:
 - *Quantitative trade model*
 - ▶ Cities trade differentiated goods
 - ▶ Differences in productivity and amenities
 - ▶ Workers choose where to live
 - + *Optimal transport* (e.g. [Galichon, 2016](#))
 - ▶ Goods flow through a transport network (formally a graph)
 - ▶ Shipping companies choose best routes
 - ▶ Shipping cost on a link: \uparrow with quantity shipped, \downarrow with infrastructure
 - + *Optimal network problem*. Choose infrastructure in every link considering:
 - ▶ Response of the market economy
 - ▶ Resources available to build the network

Application

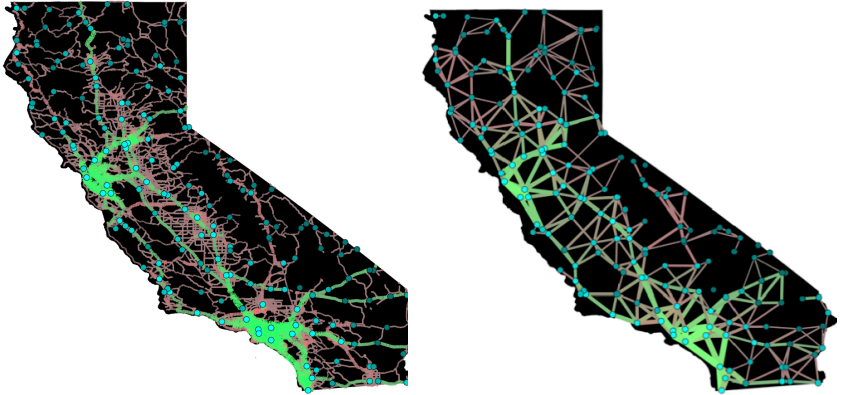
- In the paper: application to road infrastructure in European economies
- Today: application to road network in California and across U.S. states
 - ▶ with Nicole Gorton (UCLA)

Graph

50 km x 50 km square network, 8 neighbors per interior node



Graph Representation of CA Cities and Highways

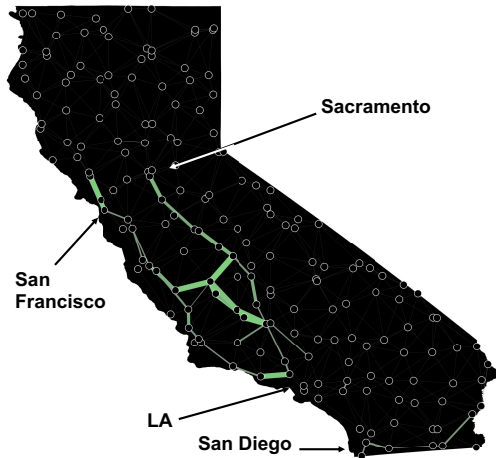


The problem of designing the network determines how much to build on each link

Parametrization

- Productivity and amenities by location to match GDP and population ([G-Econ Dataset](#))
- Trading costs to match level of internal trade
- Congestion matches response of travel time to vehicle-miles ([Couture et al. 2018](#))
- Building costs as function of terrain characteristics ([Federal Highway Administration](#))

Optimal 10% Expansion of CA Road Network



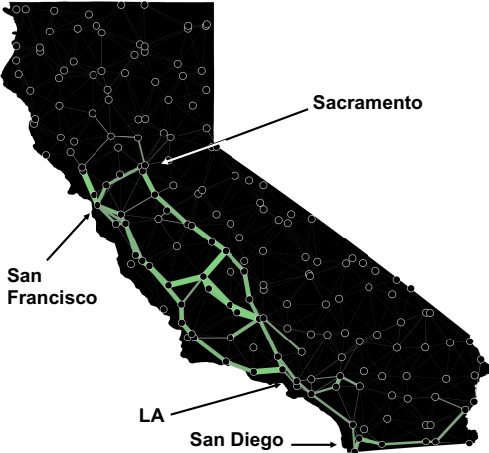
- Annual cost: ~\$0.4 billion
- Benefit (0.04% GDP): ~\$0.7 billion
- Benefit / Cost = 1.6

- Optimal investments along
 - LA-Santa Barbara-San Jose (US 101)
 - LA-Bakersfield-Sacramento (US 99)

Notes:

- Cost: 10% of CA Network * 5% discount + 24k maintenance per lane-mile
- CA ~ 10% of Interstate Highways valued at \$560 billion at 2007 prices (CBO)
- Benefit: 0.04% Gain * 70% Consumption Share * CA GDP at 2007 prices

Optimal 50% Expansion of CA Road Network



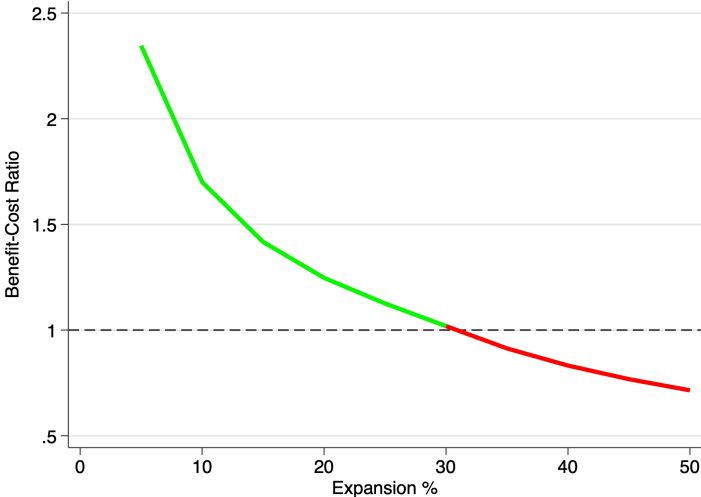
- Annual cost: ~\$2.0 billion
- Benefit (0.08% GDP): ~\$1.3 billion
- Benefit / Cost = 0.7

- Optimal investments along
 - LA-Santa Barbara-San Jose (US 101)
 - LA-Bakersfield-Sacramento (US 99)
 - LA-San Diego (15)

Notes:

- Cost: 50% of CA Network * 5% discount + 24k maintenance per lane-mile
- CA ~ 10% of Interstate Highways valued at \$560 billion at 2007 prices (CBO)
- Benefit: 0.08% Gain * 70% Consumption Share * CA GDP at 2007 prices

Optimal Size of the Expansion



Analysis suggests CA road network should be 30% larger

How is population reallocated?



Note: green (red) locations grow (shrink) in the optimal 50% network expansion

How does the optimal expansion compare to existing projects?

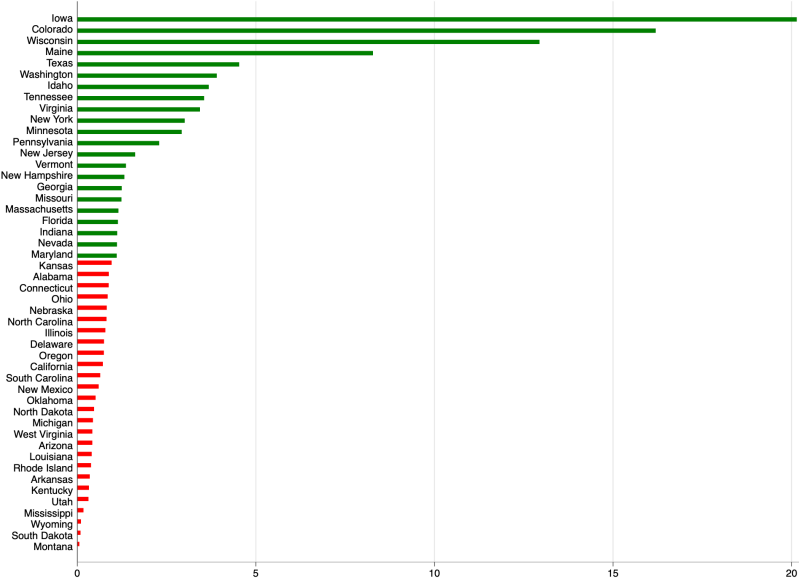
High Speed Rail



CALTRANS Capital Outlay Projects



Benefit-Cost Ratios across States



Potential Applications

- New framework to study optimal transport networks in general equilibrium
 - ▶ Applicable using data on value added and population

- Many forces are not (yet) included:
 - ▶ International trade
 - ▶ Indirect effects through further investments (e.g., building structures)
 - ▶ Investments in trade hubs
 - ▶ Optimal network investments around second best (e.g., distortions)
 - ▶ Agglomeration and spillovers in production
 - ▶ Dynamics

- Potential applications for future work
 - ▶ Optimal urban network
 - ▶ International trade facilitation
 - ▶ Developing countries
 - ▶ Political economy and competing planners