Optimal Transport Networks in Spatial Equilibrium

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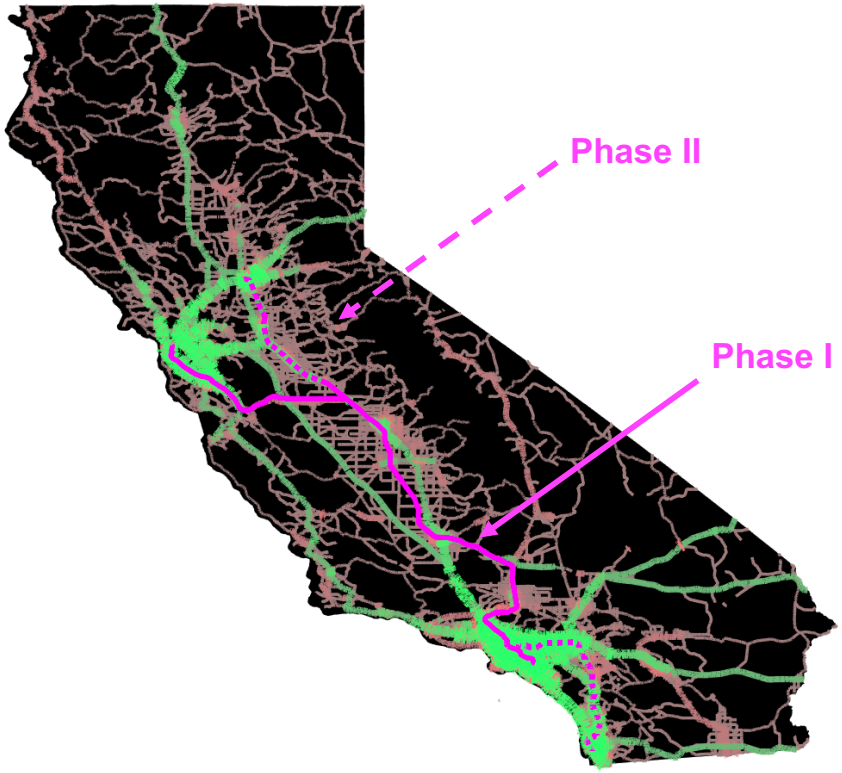
NBER Economics of Infrastructure Investment Conference, 03/12/2020

Introduction

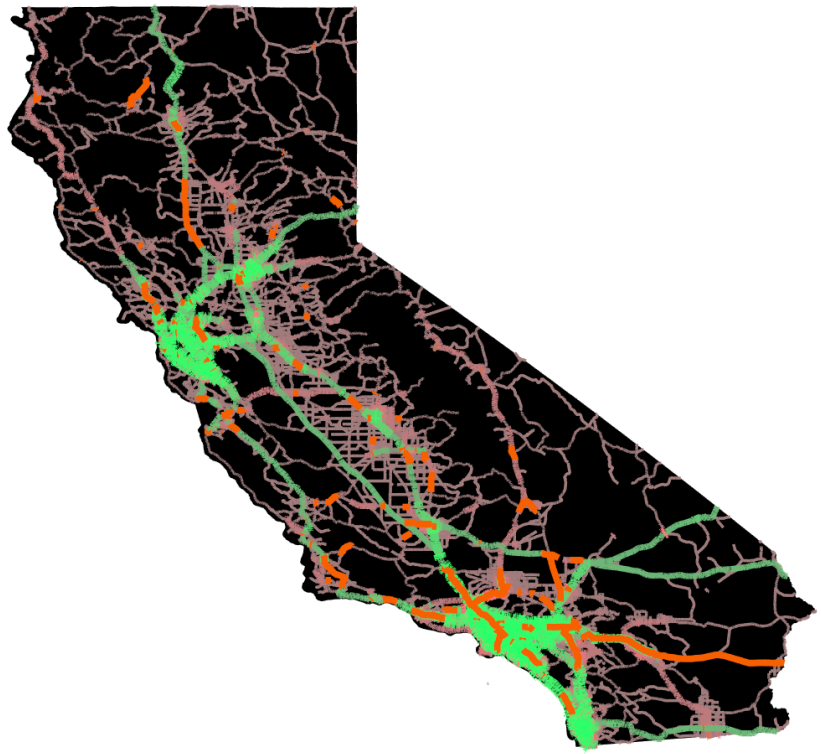
- Large investments in infrastructure
  - 20% of World Bank spending
  - 6% of government spending around the world
- Large implications for welfare and growth
  - Transport of goods: lower prices, greater market access
  - Transport of people: access to jobs, diffusion of knowledge
- **How should these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

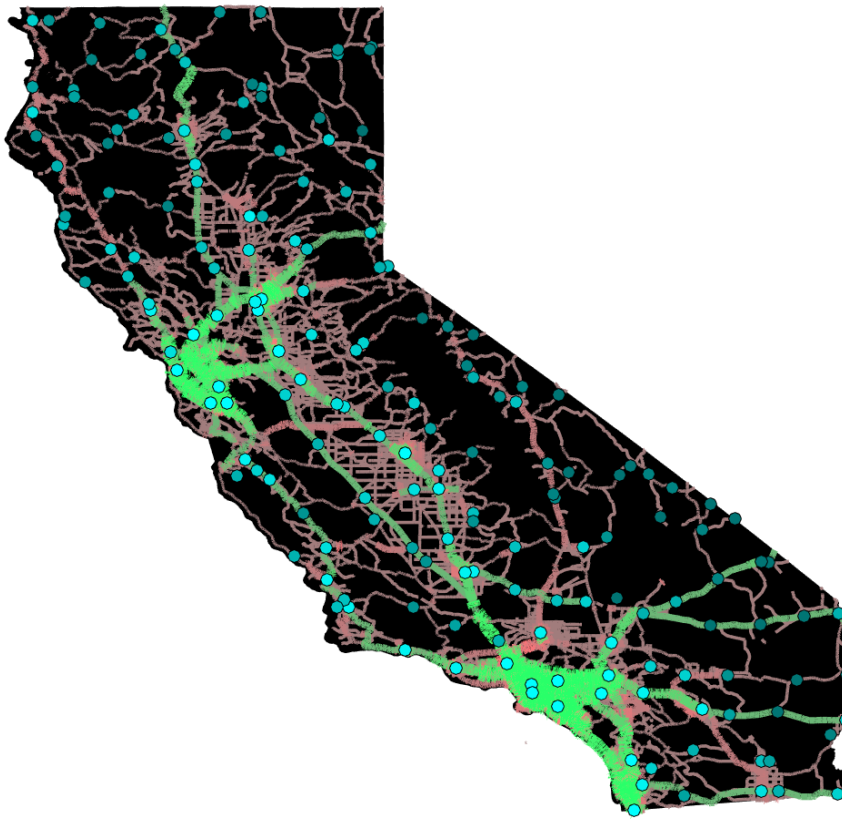
- In the paper: application to road infrastructure in European economies
- Today: application to road network in California and across U.S. states
  - with Nicole Gorton (UCLA)

Graph

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



Graph Representation of CA Cities and Highways



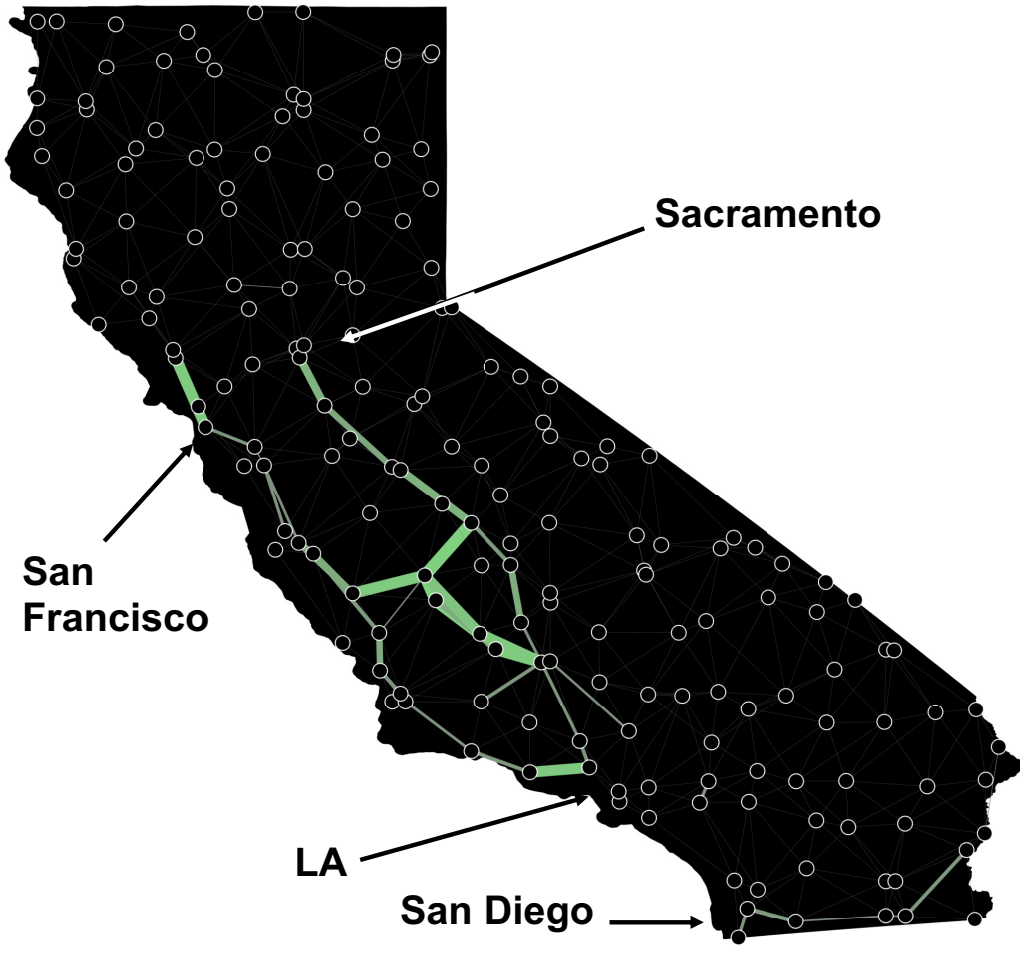


The problem of designing the network determines how much to build on each link

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

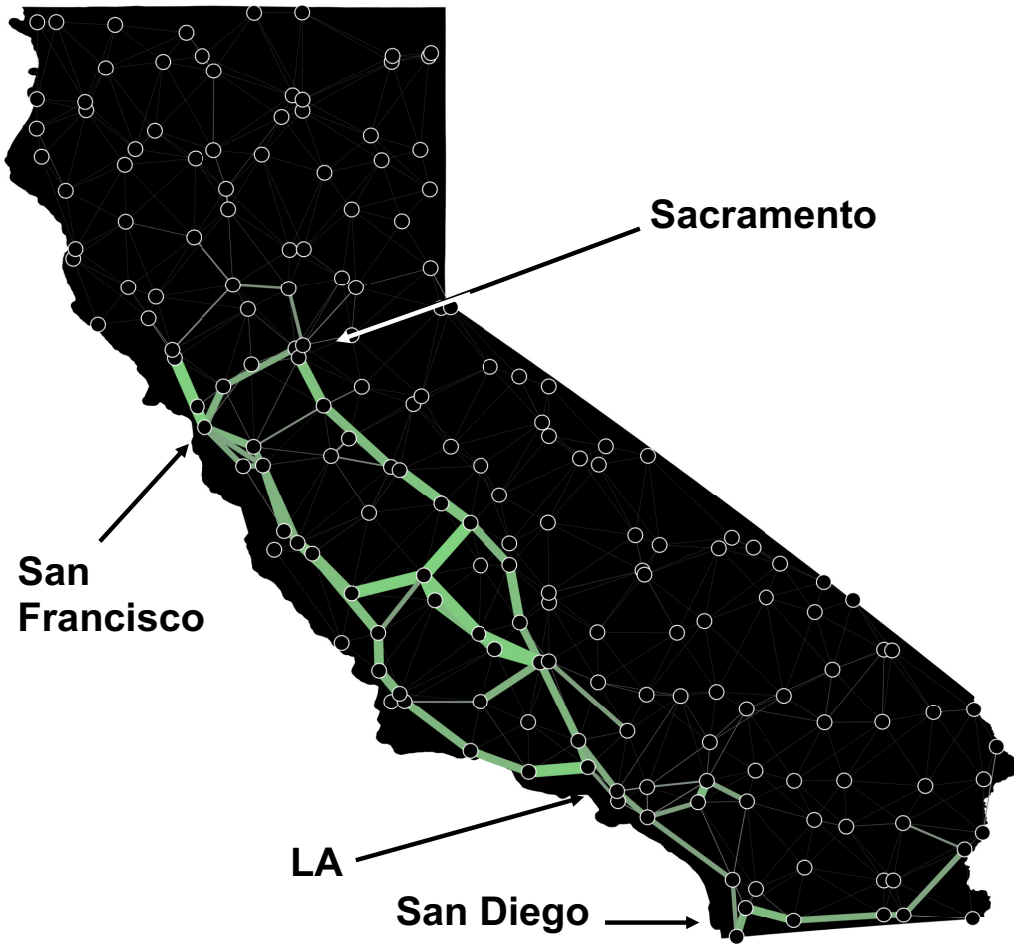


- Annual cost: ~$0.4 billion
- Benefit (0.04% GDP): ~$0.7 billion
- Benefit / Cost = 1.6

- 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

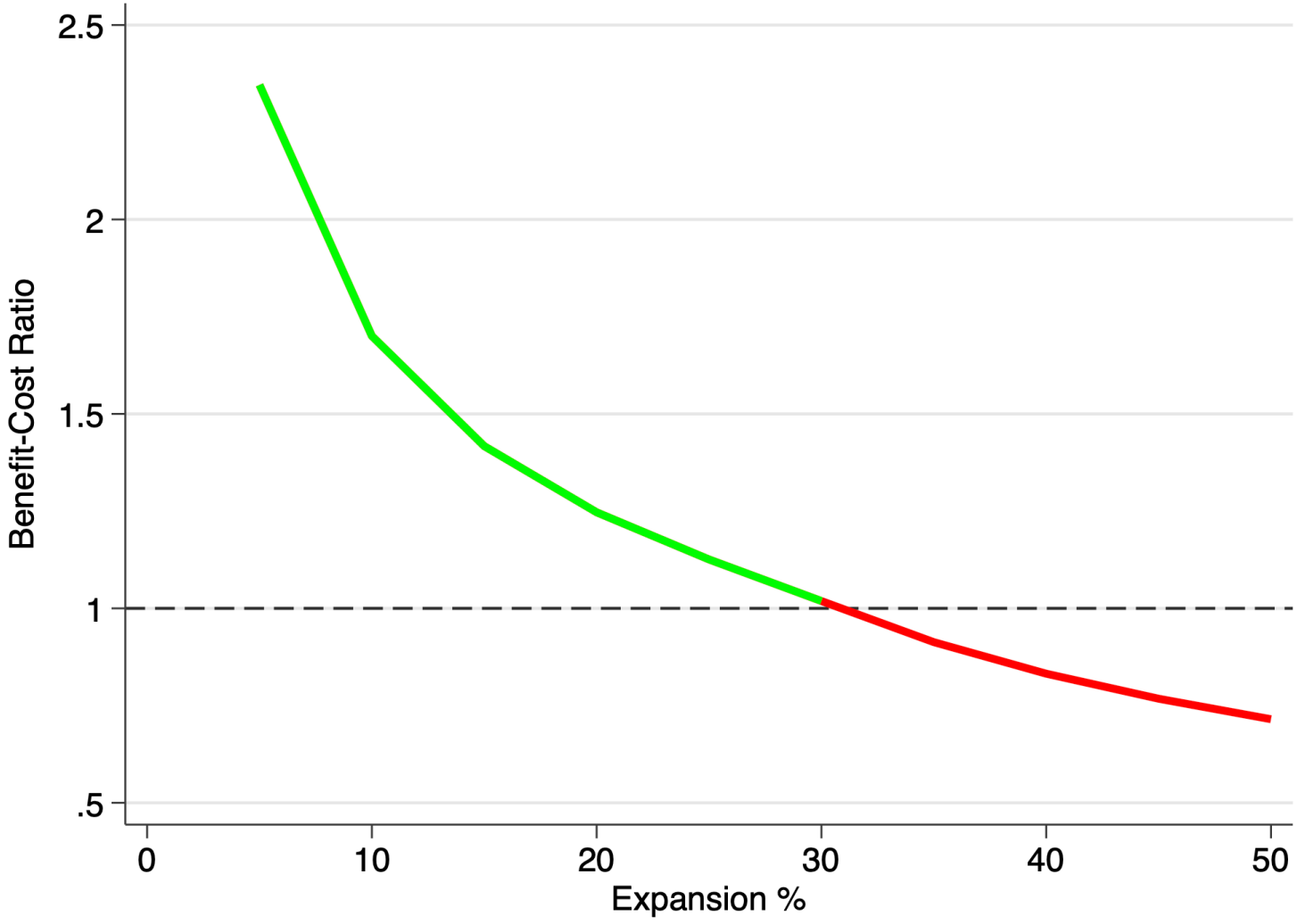


- Annual cost: ~$2.0 billion
- Benefit (0.08% GDP): ~$1.3 billion
- Benefit / Cost = 0.7

- Optimal investments along
  - LA-Santa Barbara-San Jose (US 101)
  - LA-Bakersfield-Sacramento (US 99)
  - LA-San Diego (I5)

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?



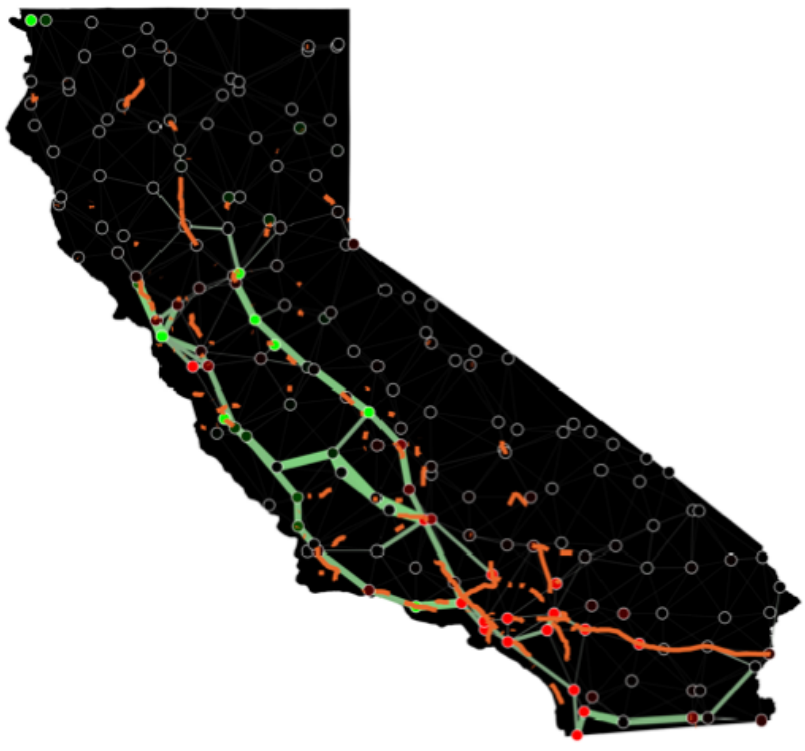
Note: green (red) locations grow (shrink) in the optimal 50% network expansion

How does the optimal expansion compare to existing projects?

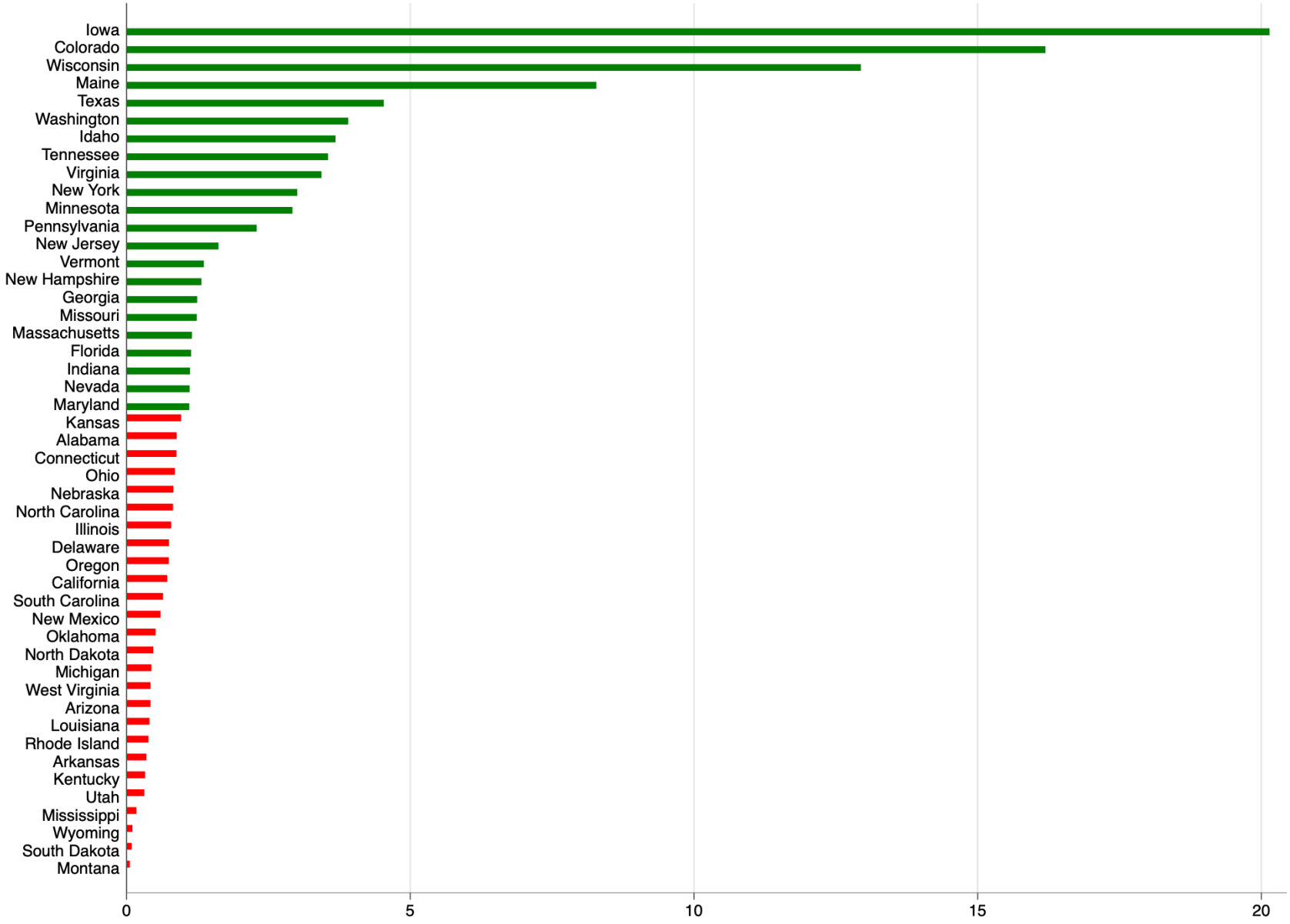
High Speed Rail



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