Optimal Transport Networks in Spatial Equilibrium

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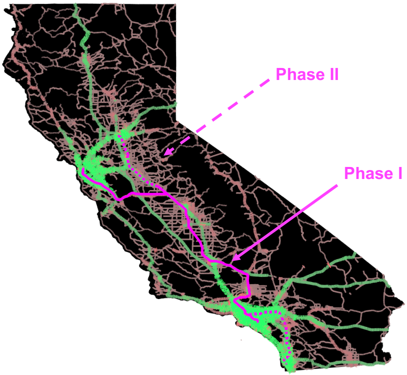
Introduction

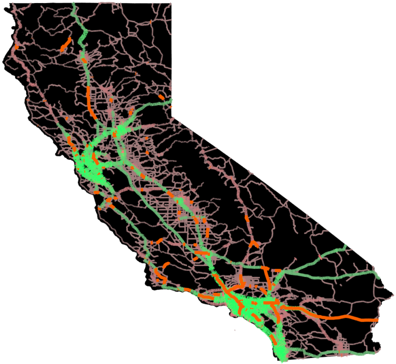
- Large investments in infrastructure
  - 20% of World Bank spending
  - 6% of government spending around the world
- Large implications for welfare and growth
  - Transport of goods: lower prices, greater market access
  - Transport of people: access to jobs, diffusion of knowledge
- **How should these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

California Road Network and Current Infrastructure Projects

High Speed Rail



CALTRANS Capital Outlay Projects



Questions

1. Where should the investments be allocated?
2. How large should the overall network be?
3. What would be the productivity gains?

- Existing methods to analyze returns to specific investments
  - Eaton and Kortum (2002), Allen and Arkolakis (2014), Redding (2016),...
  - Duranton et al. (2014), Faber (2014),...
- But these questions require an efficient benchmark
- Challenges
  - Large investments in one segment affect rate of return in others
  - 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
  - Given resources to grow the network

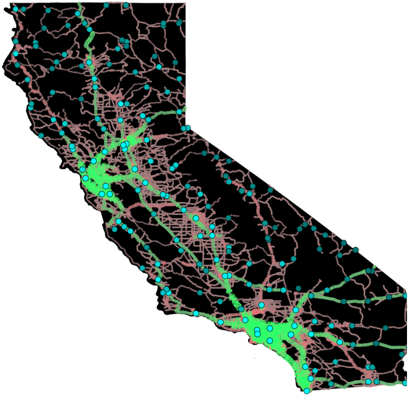
Application

- 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

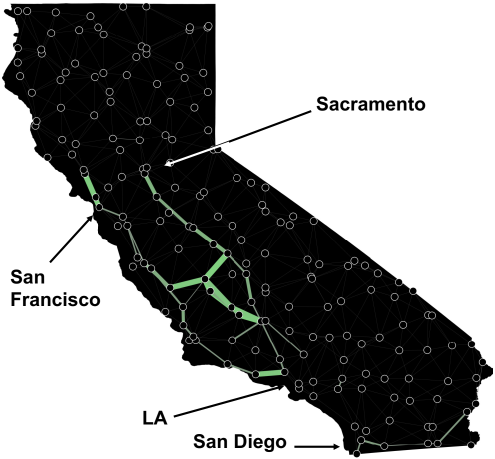


The problem of designing the network determines how much to build on each link

Parametrization

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

Optimal 10% Expansion of CA Road Network

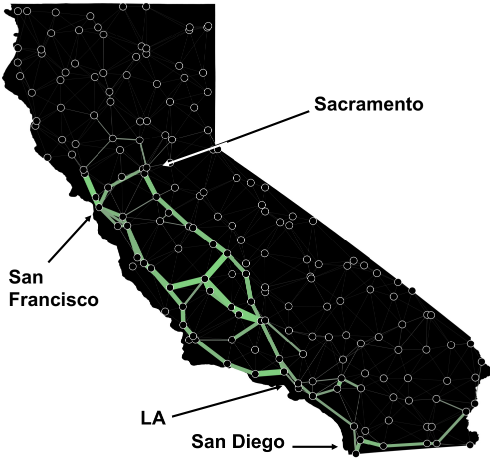


- Annual cost: ~$0.4 billion
- Benefit (0.04% GDP): ~$0.7 billion
- Benefit / Cost = 1.6

- 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

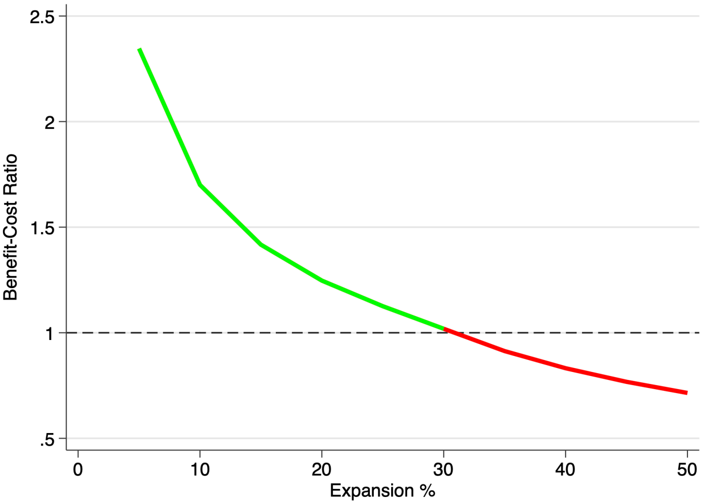


- Annual cost: ~$2.0 billion
- Benefit (0.08% GDP): ~$1.3 billion
- Benefit / Cost = 0.7

- 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

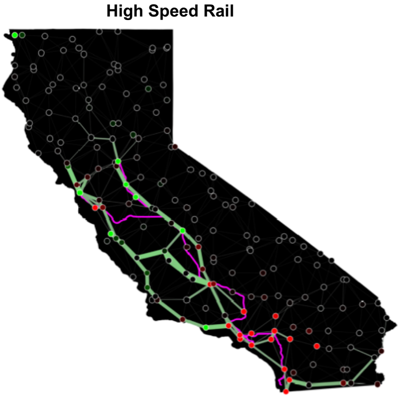


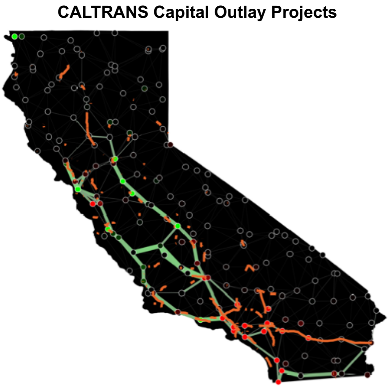
Analysis suggests CA road network should be 30% larger

How is population reallocated?

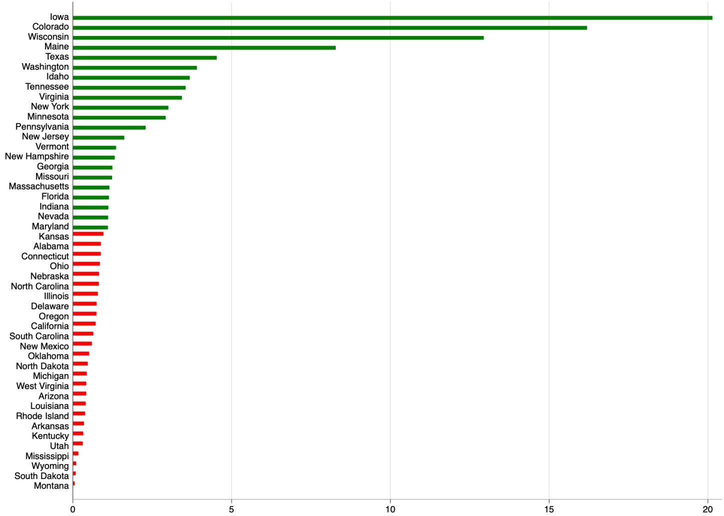
Note: green (red) locations grow (shrink) in the optimal 50% network expansion

How does the optimal expansion compare to existing projects?





Benefit-Cost Ratios across States



Note: figure show benefit-cost ratio of a 50% expansion of the road network of each state

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:
  - Alternative modes of transport
  - International trade
  - Indirect effects through further investments (e.g., building structures)
  - Investments in trade hubs
  - Optimal 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