Optimal Transport Networks in Spatial Equilibrium

Pablo D. Fajgelbaum    Edouard Schaal

UCLA/NBER, CREI/CEPR

NBER Economics of Infrastructure Investment Conference, 06/10/2020
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?
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

- 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
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: ↑ with quantity shipped, ↓ 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
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)
• 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 shows 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
- Provides an **efficient benchmark** to evaluate investments
  - Applicable using data on value added and population
  - Flexible to accommodate more detailed data
- Many forces are not (yet) included:
  - Alternative modes of transport
  - International trade
  - Distortions
  - Agglomeration and spillovers in production
  - Dynamics
- Potential applications for future work
  - Optimal urban network
  - Developing countries
  - Political economy and competing planners