Transport Costs in the Age of Highways: Evidence from United States 1955-2010.

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Research Question

Measurement and data-construction paper

What are the road-network transportation costs in the United States between 1955 and 2010?

We construct **county-pair** transportation costs in 2010 $US **per trip** in seven benchmark years:

1955, 1960, 1970, 1980, 1990, 2000, 2010

Presentation Structure

1. Introduction: motivation, historical context
2. Methodology
3. Data Sources
4. Results
   a. Levels of transportation costs
   b. Changes over time
   c. Spatial patterns
   d. Counterfactuals

Introduction

- increased interest in the effects of infrastructure on various economic outcomes

    a) effects of the US interstate highway system (IHS) e.g. Baum-Snow 2007, 2019, Chandra and Thompson 2000, Duranton and Turner 2012, Duranton, Morrow, Turner 2014, Michaels 2008, Lin and Brinkman 2019, Allen and Arkolakis 2019, Jaworski et al 2019, 2020, Herzog 2021, Frue 2021

    b) effect of infrastructure projects in developing countries e.g. Baum-Snow et al 2017, Datta 2012, Faber 2014, Ghani et al 2014, Quin 2017

    c) effect of infrastructure projects in history e.g., Donaldson and Hornbeck 2016, Donaldson 2018

Introduction

Different approaches to quantify transport infrastructure:

a) **an indicator** whether an infrastructure is present or not (Michaels 2008, Datta 2012, Faber 2014, Quin 2017, Frye 2021)
b) stock measures:
  i. **number of highway rays** (Baum-Snow 2007, 2019 Baum-Snow et al 2017),
  ii. **total mileage of highways** (Duranton and Turner 2012, Duranton, Morrow, Turner 2014)
c) minimum **journey time** along infrastructure (Gibbons et al 2019, Herzog 2021)
d) **monetary values** of transportation costs along infrastructure (Donaldson and Hornbeck 2016, Donaldson 2018, Jaworski et al 2019)

Introduction

- Non-monetary measures of transport infrastructure:
  o used most often
  o they are considered as a proxy of transport/trade costs.

Limitations:

1. Effects of such transport costs/infrastructure over time are identified as long as **physical layout changes**

2. Physical characteristics are only **one element** of transport costs

Introduction

We construct a **<u>monetary measure</u>** of transport costs that, on top of physical transport network includes time and spatial variation in:

fuel consumption

petrol prices

driving speed

wage cost of drivers

tire costs, truck maintenance, truck depreciation to be added

We estimate such costs for 3105 pairs of US counties in 2010$US for the benchmark years 1955, 1960, 1970, 1980, 1990, 2000, 2010

Historical Context

- Building a road network goes back to the early nineteenth century with early turnpike and toll roads

- 'Paused' during railway era

- Post WWI construction of roads and highways without the support from the federal government

- The interwar decades saw an emergence of a uniform scheme for designating interstate routes: U.S. Highway system, an integrated network of highways numbered within a nationwide grid

- Further construction after WWII

1926 US Highway System

1950 US Highway System
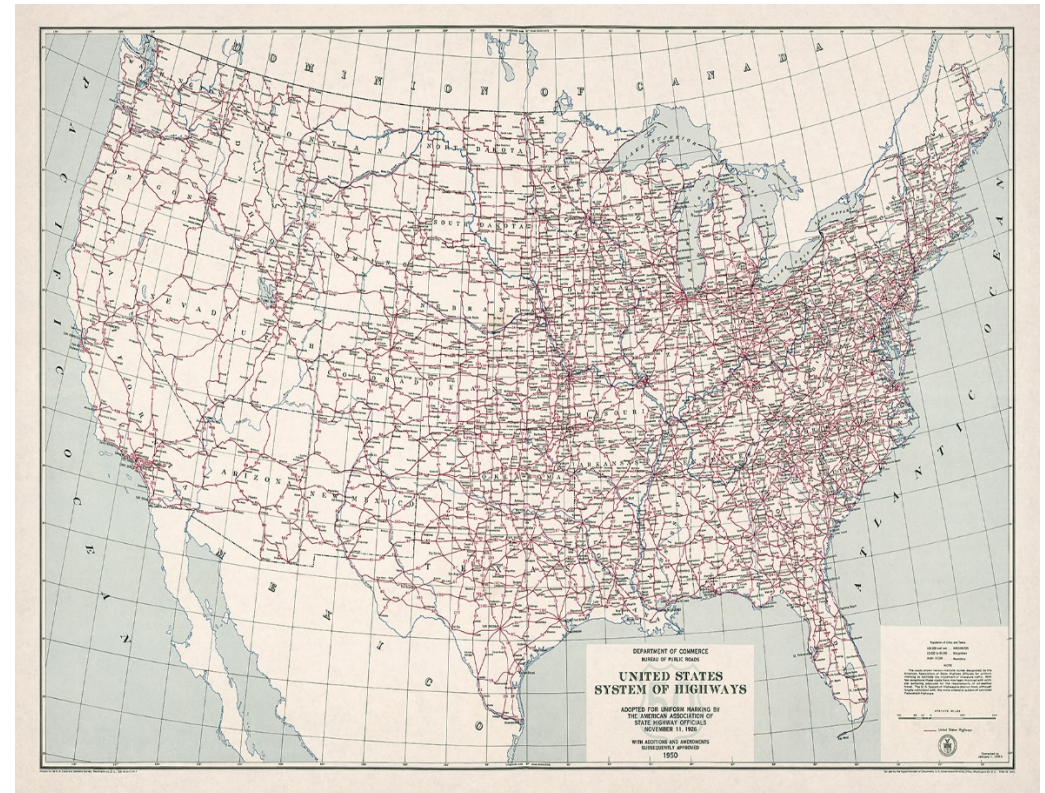
1956 Interstate Highway System

- Federal-Aid Highway Act of 1956 (and federal tax rate to build it)

- Adoption of uniform IHS **design standards** to facilitate:
    i. high-speed
    ii. access-controlled roads

- New interstate highways were built as an upgrade or replacement of the exiting U.S. highways
- New routes built along the existing routes, so called **parallel routing**

I-55 Missouri (Parallel Routing)
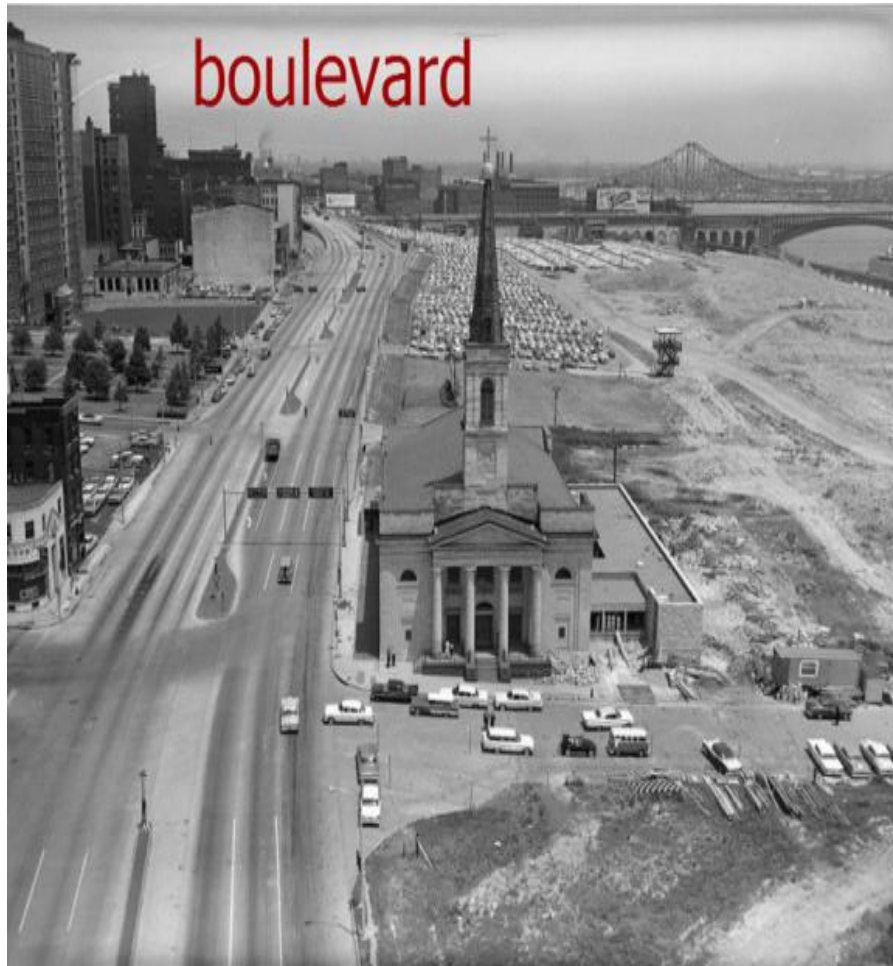
I-70 St. Louise (Controlled Access)
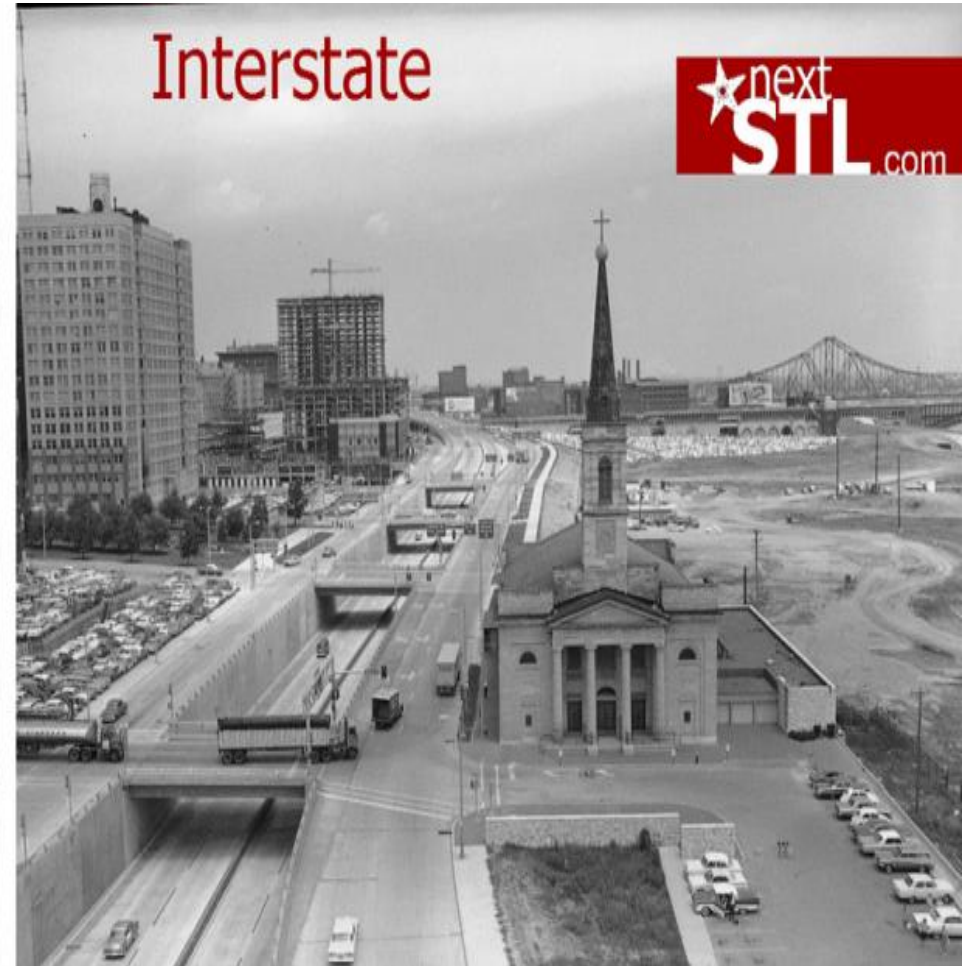
Table 1: Composition of the US road network

	Interstates	US routes	State routes	Other	Total
2014 Mileage	45,637.31	132,715.53	209,166.82	49,371.34	436,891.48
% of total	10.45	30.38	47.88	11.3	100
% pre 1955	92.44	97.11	94.52	-	-

Source: National Highway Planning Network version 14.05.
'Other' category contains county, township, municipal and unsigned roads.

Methodology
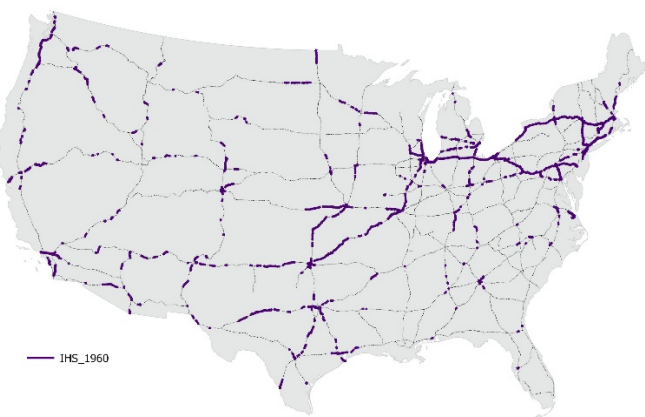
Methodology developed by Combes and Lafourcade (2005)

Three steps:

1. Road transport network

2. Calculation of so-called transport reference costs in $US 2010

3. Using 1 and 2, Dijkstra algorithm is used to find the minimum cost route ($US2010) between the population centroids of US counties
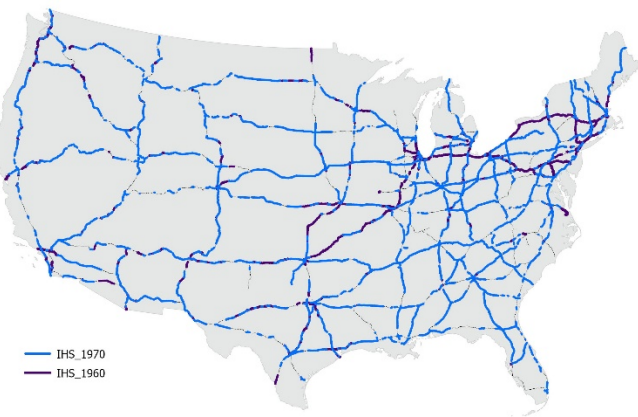
Step 1: Road Transport Network

- National Highways Planning Network 14.05

- All roads built, excluded planned roads

- Digitization of IHS in 1960, 1970, 1980, 1990, 2000, 2010 using PR-511, Interstate Density Maps,

- Non-IHS roads: physical layout from NHPN 14.05 and digitization of historical maps

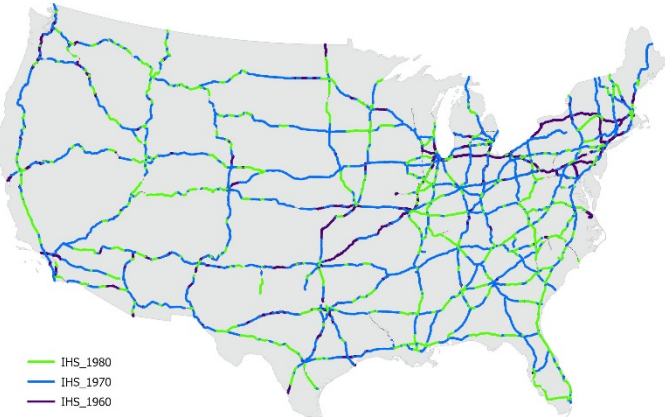- Road 'arcs': rural/urban, interstate/non-interstate
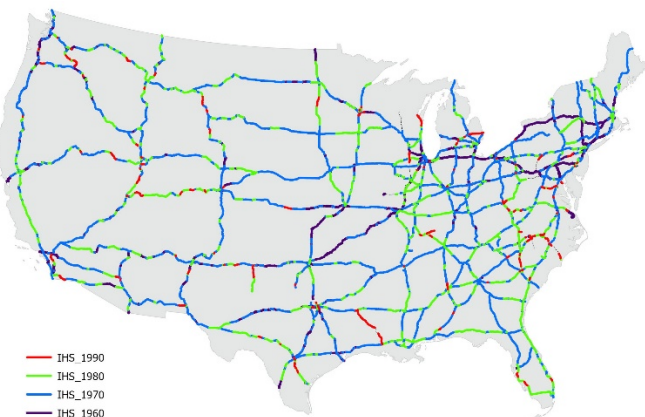
Interstate Highway System in 1960
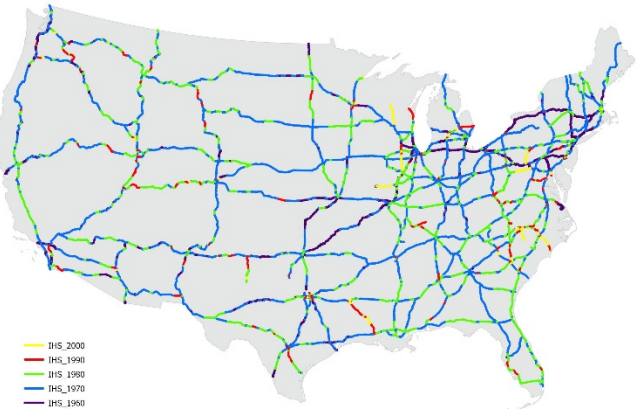
IHS_1960

Interstate Highway System in 1970

IHS_1970
IHS_1960

Interstate Highway System in 1980

IHS_1980
IHS_1970
IHS_1960

Interstate Highway System in 1990

IHS_1990
IHS_1980
IHS_1970
IHS_1960

Interstate Highway System in 2000

IHS_2000
IHS_1990
IHS_1980
IHS_1970
IHS_1960

Step 2: Transport Reference Costs

$$DistCost_{ij}^t = \sum_{a \in I_{ij}^t} fuel_a^t . d_a^t$$

$$TimeCost_{ij}^t = wage^t \sum_{a \in I_{ij}^t} t_{r(a,t)}^t$$

$$t_{r(a,t)}^t = \frac{d_a^t}{speed_{r(a,t)}}$$

$$\textcolor{red}{MinTC_{ij}^t = min\left(DistCost_{ij}^t + TimeCost_{ij}^t\right)}$$

Step 2: Transport Reference Costs

I. Petrol prices – state and time variation

II. Fuel consumption – state and time variation

III. Speed – state/time/type of roads variation (1344 different speeds)

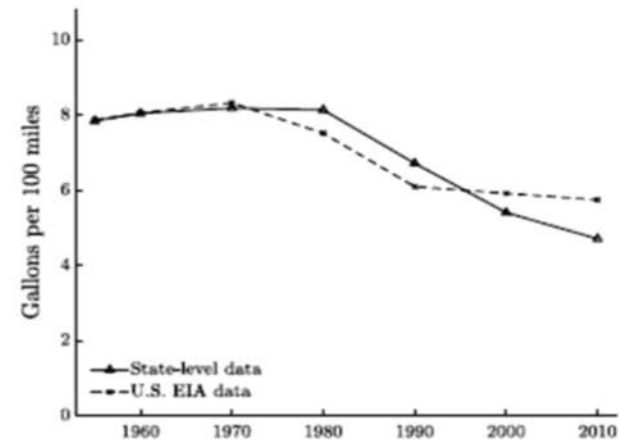IV. Earnings of truck drivers – time variation, assume national labor market
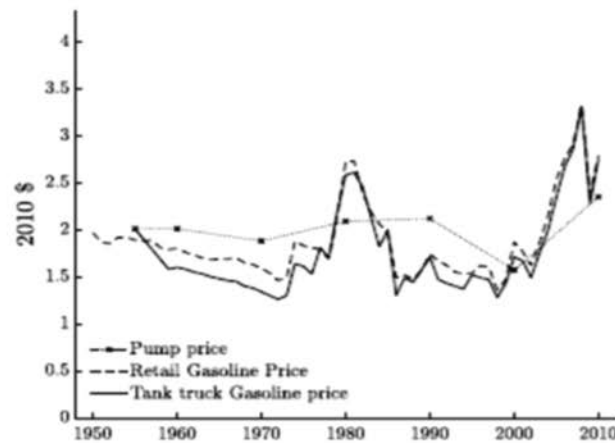
Transport Reference Costs

Main Trends

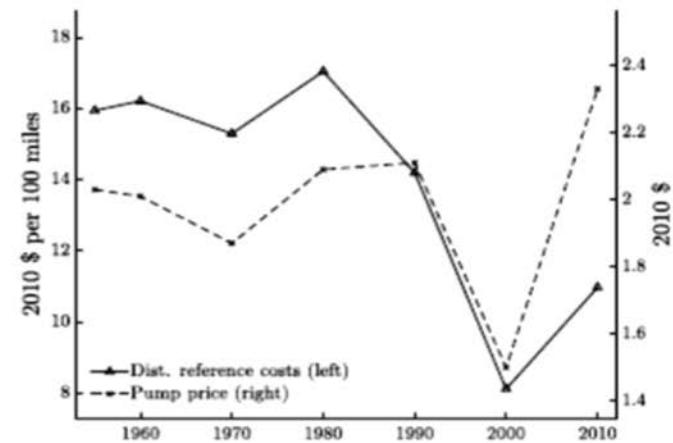# Figure 2: Determinants of distance costs
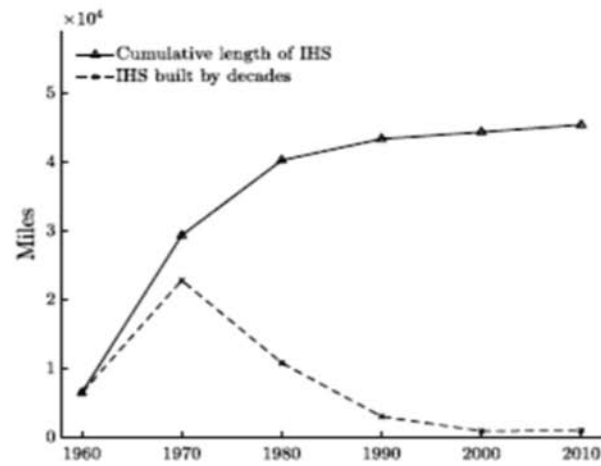
(a) Length of the IHS by decade

(b) Fuel Consumption

(c) Gasoline Prices

(d) Distance Reference Cost and Gasoline Price

Table 4: Average Speed by Type of Roads, 1955-2010

	1955	1960	1970	1980	1990	2000	2010
Urban							
(1) Interstate	-	50.04	56.94	56.54	58.64	57.82	56.66
(2) Other	46.42	48.22	54.87	54.48	56.41	55.00	53.90
Rural							
(3) Interstate	-	51.74	58.88	58.53	61.16	61.72	61.95
(4) Other	48.45	49.98	56.87	56.53	56.74	57.20	57.42
All roads							
	47.43	49.99	56.89	56.52	58.24	57.94	57.48

Source: Detailed description of sources is in Appendix A.4.
Notes: Speeds in miles per hour. 1960: average of 1958 and 1959; 1970: average of 1967 and 1969; 1980: average of 1977 and 1979; 1990: average of 1987 and 1989.

1955	1960	1970	1980	1990	2000	2010	1955-2010
Hourly earnings of truck drivers (2010 US$)							
16.6	18.3	21.2	25.5	21.8	18.8	18.2	10%

Table 6: Total Transport Reference Costs per 100 miles, 2010 US$

	1955	1960	1970	1980	1990	2000	2010
			Urban				
(1) Interstate	-	52.79	52.51	62.11	51.45	40.56	43.08
(2) Other	51.68	54.16	53.91	63.81	52.92	42.22	44.72
			Rural				
(3) Interstate	-	51.58	51.28	60.58	49.92	38.51	40.34
(4) Other	50.18	52.83	52.55	62.12	52.70	40.91	42.65
			All roads				
	50.93	52.84	52.56	62.16	51.75	40.55	42.70

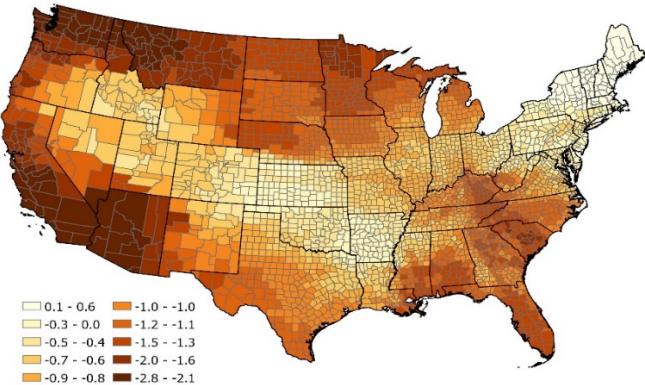Source: Detailed description of sources is in Appendix A.2 to A.4.

Step 3: County-Pair Transport Costs

- Dijsktra algorithm finds minimum cost routes between county population centroids among a universe of all possible routes

- 3105x3105 county pairs yielding 4,818,960 optimal transport costs routes in each benchmark year

- County (unweighted) average of minimum transport costs to all other counties – spatial variation
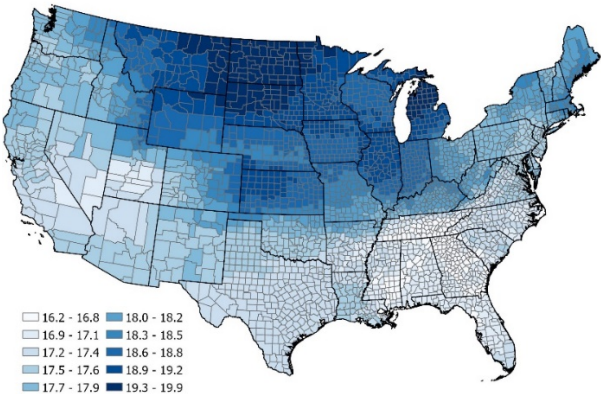
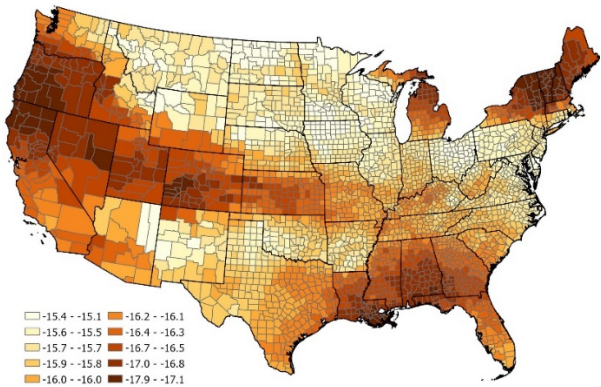**Map 1: Percentage Change in County Average Real Transportation Costs 1955-2010.**

Legend:
- -17.2 - -16.2
- -16.1 - -15.6
- -15.5 - -15.0
- -14.9 - -14.6
- -14.5 - -14.1
- -14.0 - -13.6
- -13.5 - -13.1
- -13.0 - -12.4
- -12.3 - -11.4
- -11.3 - -9.6
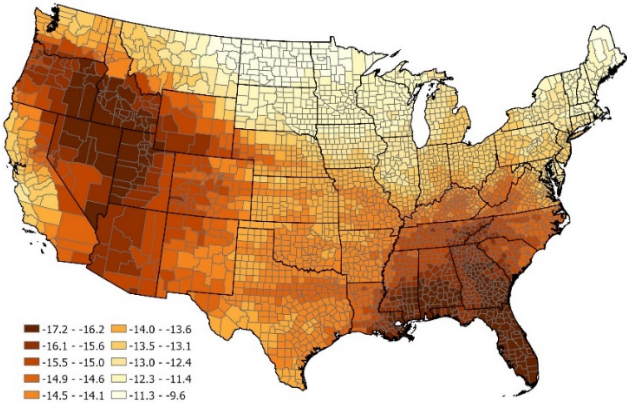
Map 2: Percentage Change in County Average Real Transportation Costs 1960-1970.

Legend:
- 0.1 - 0.6
- -0.3 - 0.0
- -0.5 - -0.4
- -0.7 - -0.6
- -0.9 - -0.8
- -1.0 - -1.0
- -1.2 - -1.1
- -1.5 - -1.3
- -2.0 - -1.6
- -2.8 - -2.1

Map 3: Percentage Change in County Average Real Transportation Costs 1970-1980.

Legend:
- 16.2 - 16.8
- 16.9 - 17.1
- 17.2 - 17.4
- 17.5 - 17.6
- 17.7 - 17.9
- 18.0 - 18.2
- 18.3 - 18.5
- 18.6 - 18.8
- 18.9 - 19.2
- 19.3 - 19.9

Map 4: Percentage Change in County Average Real Transportation Costs 1980-1990

Legend:
- -15.4 - -15.1
- -15.6 - -15.5
- -15.7 - -15.7
- -15.9 - -15.8
- -16.0 - -16.0
- -16.2 - -16.1
- -16.4 - -16.3
- -16.7 - -16.5
- -17.0 - -16.8
- -17.9 - -17.1

Map 5: Percentage Change in County Average Real Transportation Costs 1990-2000

Legend:
- -20.9 - -20.0
- -21.5 - -21.0
- -21.9 - -21.6
- -22.2 - -22.0
- -22.4 - -22.3
- -22.7 - -22.5
- -22.8 - -22.8
- -23.0 - -22.9
- -23.2 - -23.1
- -23.6 - -23.3
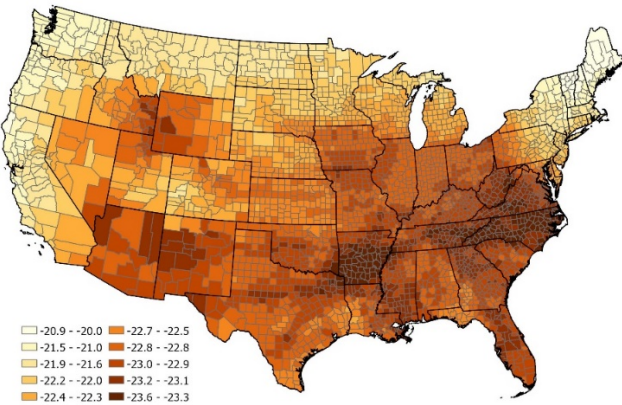
Map 6: Percentage Change in County Average Real Transportation Costs 2000-2010

Legend:
- 3.2 - 4.0
- 4.1 - 4.5
- 4.6 - 4.9
- 5.0 - 5.2
- 5.3 - 5.4
- 5.5 - 5.6
- 5.7 - 5.8
- 5.9 - 6.1
- 6.2 - 6.4
- 6.5 - 6.8
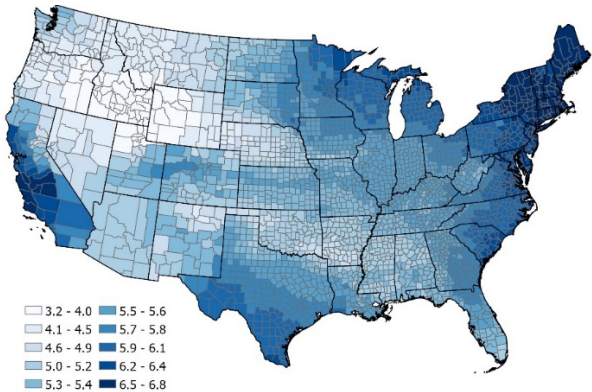
Shift-Share Analysis 1955-2010

Panel C: Contribution to the changes in transportation costs (%)

	_1955-1960_	_1960-1970_	_1970-1980_	_1980-1990_	_1990-2000_	_2000-2010_	_1955-2010_
Distance cost (6)	0.54	-1.71	3.27	-4.49	-11.46	6.85	-9.90
Time cost (7)	6.82	1.19	15.09	-11.60	-9.61	-1.34	-1.77
Total cost (8)	7.36	-0.52	18.36	-16.09	-21.08	5.51	-11.67

Panel D: Contribution to the changes in transportation costs less IHS (%)

	_1955-1960_	_1960-1970_	_1970-1980_	_1980-1990_	_1990-2000_	_2000-2010_	_1955-2010_
Distance cost (9)	0.54	-1.71	3.28	-4.51	-11.48	6.85	-9.95
Time cost (10)	7.03	11.00	14.45	-10.42	-10.35	-2.43	6.57
Total cost (11)	7.57	9.29	17.72	-14.93	-21.83	4.42	-3.39

Panel E: Contribution of IHS (%)

|	_1955-1960_	_1960-1970_	_1970-1980_	_1980-1990_	_1990-2000_	_2000-2010_	_1955-2010_
Difference (8)-(11)	-0.21	-9.81	0.64	-1.16	0.76	1.10	-8.28

Source: Detailed description of sources is in Appendix A.2 to A.4.

# Counterfactual Analysis

- For each benchmark year, we calculate:

    1. Actual county (unweighted) average minimum transport costs to all other counties

    2. Counterfactual county (unweighted) average minimum transport costs to all other counties (assuming no IHS)

- Calculate %Δ between 1 and 2 and plot – spatial variation
- Overlay with the IHS

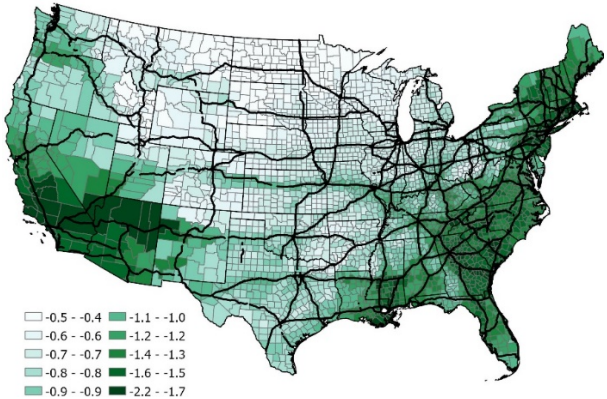# Counterfactual Percentage Change in County Average Transport Costs: Counterfactual Compares Transport Costs with and without IHS
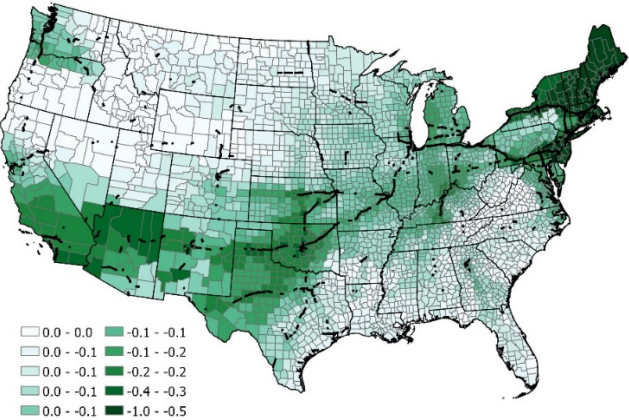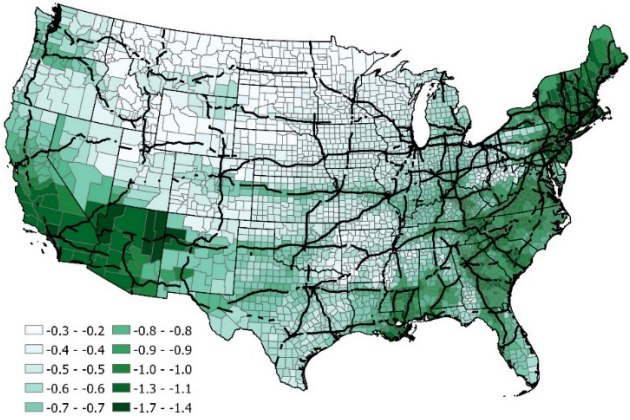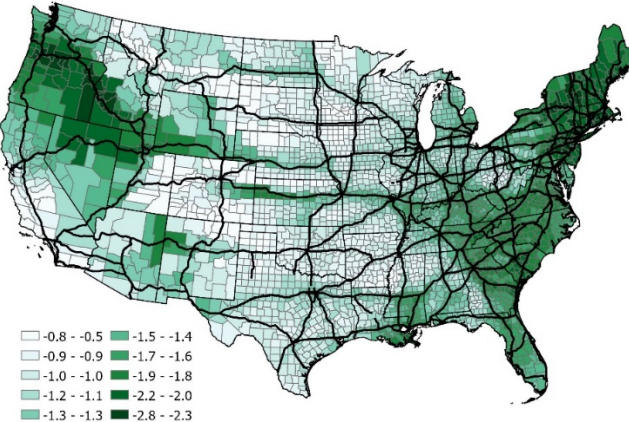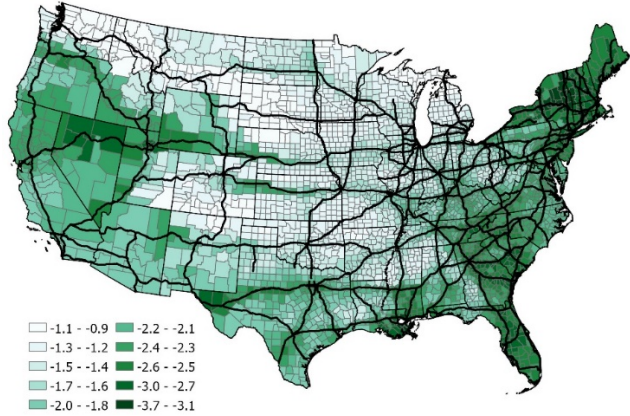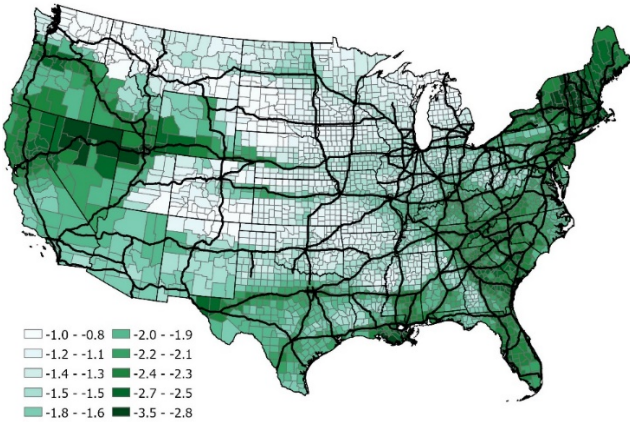
Conclusion

- New measures of county-level roads transport costs in the US

- In addition to road infrastructure, fuel consumption, speed, petrol prices, and truckers' earning are included

- Establish styled facts about the road transport costs 1955-2010

- Spatial and temporal patterns of transport costs

- Importance of IHS for transport costs