(Don't) Take Me Home: Home Bias and the Effect of Self-Driving Trucks on Interstate Trade

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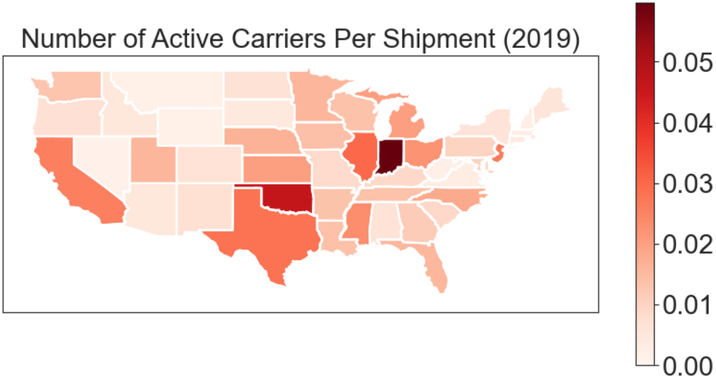
Self-Driving Trucks are on the horizon

Trucker (Carrier) home locations are unevenly spread through US



▸ Map: All Carriers ▸ Map: Carriers per Capita

Question

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I argue that

1. Human drivers' preference to return home ("home bias") generates geographic specialization in freight
2. $+$ uneven geographic distribution of homes $\rightarrow$ freight prices in driver-rich vs driver-poor states
3. Self-Driving trucks will eliminate this home bias.

This Paper

Overview

1. Build model of trucking freight with home bias
2. Estimate home bias and route costs using highway inspection and transaction data
3. Simulate self-driving-truck counterfactuals without home bias (w/ and w/o other effects)

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Preview

1. I estimate a home bias of 70 dollars-per-day and per-mile marginal costs of 1.61 dollars-per mile.
2. A transition to self-driving trucks without home bias would see carriers shift toward driver-poor states, lowering trade costs vs. driver-rich states.
3. The elimination of home-bias explains about 20% of full effect of automation.

Overview

1. Background and Data
2. Model
3. Estimation
4. Counterfactuals

Background

Context

Trucking Freight is Important

- **Transportation**: 80% of total U.S. domestic freight by value in 2019.
- **Labor**: Over 2 million workers in truck transportation in 2019.
- **Environmental**: 1% of on-road vehicles, 28% of vehicle greenhouse gas emissions.

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▸ Freight Mode Shares (CFS) ▸ Spot vs. Contract Prices

Structure

- Focus on **general freight**, **over-the-road**, **truckload** market
- Large number of small firms
- Limited returns to scale (vs. less-than-truckload, parcel)
- Highway driving (vs. local delivery)

Literature Review

- **Economics and Transportation Literature on Trucking**
  - Regulation (Rose 1985, 1987)
  - Asset Ownership (Hubbard 2001, Baker and Hubbard 2003, Baker and Hubbard 2004)
  - Contracts/Relationship (Masten 2009, Scott et al 2016, Aemireddy et al 2019, Acocella et al 2020, Harris and Nguyen 2021, ...)
  - Dynamic and backhaul incentives (Behrens and Picard 2011, Allen et al 2020, Heilmann 2020)
- **IO of Transportation** Brancaccio et al 2020, Bucholz 2021, Frechette et al 2019, Chen 2020, Rosaia 2021
- **Trade on Networks** Fagjelbaum and Schaal 2020, Allen and Arkolakis 2020, ...
- **Transportation Costs and Cities** Redding and Turner 2015, Duranton and Turner 2012, Hummels 2007, Glaeser and Kohlhase 2004, ...

Data

- **Prices and Quantities**: DAT RateView
  - Transactions, 2016-2020
- **Carrier Locations**: Highway Inspections
  - Random inspections, 2018-2020
  - For each inspection, home state + current state ▸ Inspection Picture
- **Route Characteristics**
  - Routes: Open Street Map
  - Road Chars: Highway Performance Monitoring System
  - Diesel prices: AAA
  - Rivers: Army Corps of Engineers
  - Snowiness: Weather Stations

Model

Setup

- **Agents**: There are two types of agents:
  1. **Carriers** (Supply)
  2. **Shippers** (Demand).
- **Locations**: There is a set of locations L.

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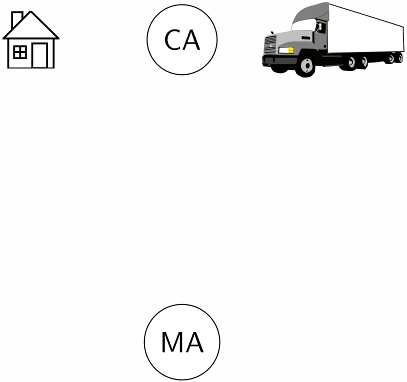
  1. **Carriers** (Supply)
  2. **Shippers** (Demand).
- **Locations**: There is a set of locations L.
- **Types**: Carriers are differentiated by their **home location** $h \in L$.
- **Timing**: Each period is 1 day.



Carrier Locations

Carriers may begin a period

1. in a location $i \in L$, or

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Carrier Locations

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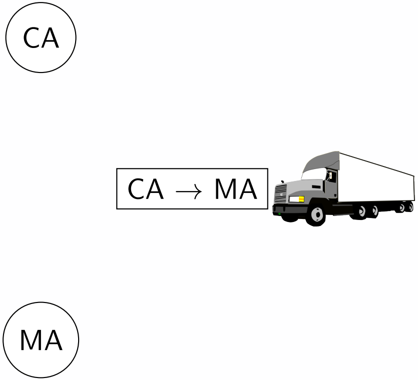
2. en-route $i \to j$ for $i, j \in L$.



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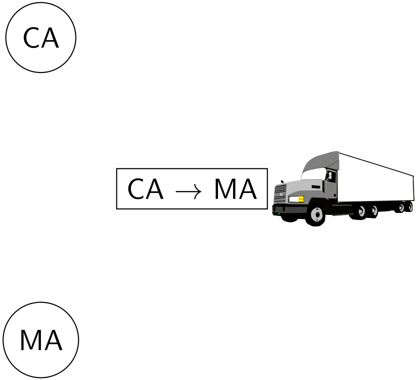
There are total C^h carriers of type h.

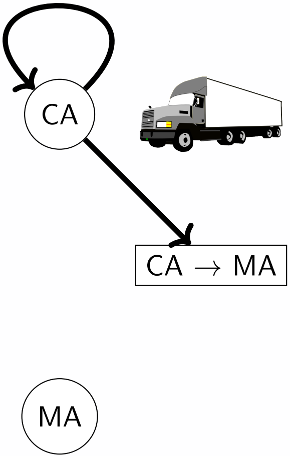
$$\sum_i C_i^h + \sum_{ij} C_{ij}^h = C^h \qquad (1)$$



Carrier Choices

Each period, a carrier of type h in location i can choose to:

1. Accept a job to any destination $j \in L$
2. Choose to take an outside option and remain in i



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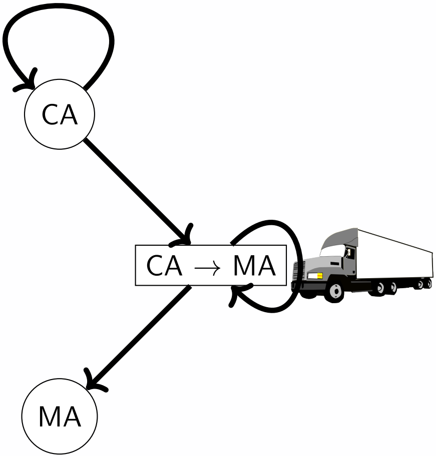
If the carrier takes a job to j, or is travelling at $i \to j$,

1. With probability λ_{ij}, it arrives at the destination.
2. With probability $1 - \lambda_{ij}$, it continues travelling.

▸ Comparison with Fixed Travel Time



Carrier Static Payoffs

- A carrier c which begins the period in its home location $h(c)$ receives a **home bias** flow payoff, b.

$$b \times 1_{h(c)=i} + \begin{cases} \alpha p_{ij} + \gamma X_{ij} + \xi_{ij} + \epsilon_{cj} & \text{Accept job to } j \\ \ldots & \\ \epsilon_{c,OO} & \text{Outside Option} \end{cases} \tag{2}$$

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- A carrier who takes the outside option receives an iid logit cost shock of $\epsilon_{c,OO}$.
- Let δ_{ij} denote the mean flow payoff of a route.

$$b \times 1_{h(c)=i} + \begin{cases} \overbrace{\alpha_{ij} + \gamma X_{ij} + \xi_{ij}}^{\delta_{ij}} + \epsilon_{cj} & \text{Accept job to } j \\ \dots & \\ \epsilon_{c,OO} & \text{Outside Option} \end{cases} \tag{2}$$

Carrier Value Function

Let V_i^h denote the carrier's value function in a location, and W_{ij}^h the value function when travelling.

$$V_{ic}^h = b \times 1_{h(c)=i} + \max \begin{cases} \delta_{ij} + \epsilon_{cj} + \overbrace{\beta E\left[W_{ij}^h\right]}^{\text{Begin Travelling}} \\ \dots \\ \epsilon_{c,OO} + \overbrace{\beta E\left[V_i^h\right]}^{\text{Start Again}} \end{cases} \tag{3}$$

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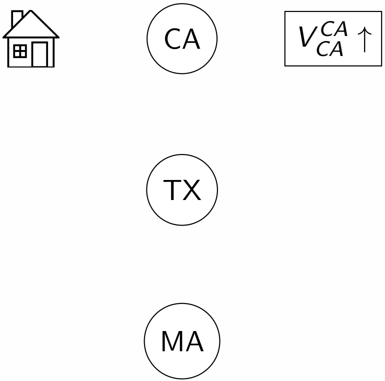
Travelling value function depends on probability of arrival.

$$E[W_{ij}^h] = \underbrace{\lambda_{ij} E[V_j^h]}_{\text{Arrival}} + \underbrace{(1-\lambda_{ij})\beta E[W_{ij}^h]}_{\text{Continue Travelling}} \tag{4}$$

Model: How does home bias affect carrier choices?

- Home bias raises the value function V_i^h of a carrier at home



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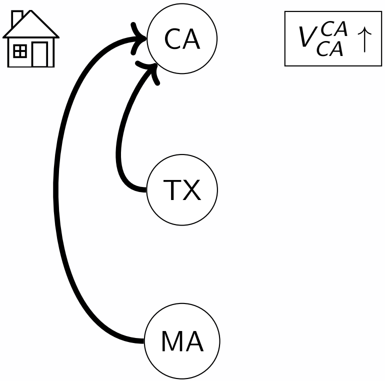

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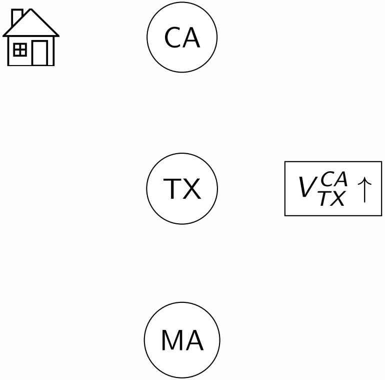

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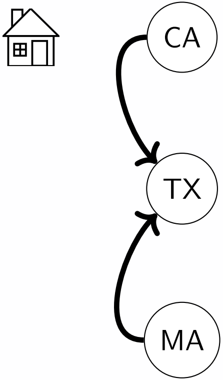

$\boxed{V_{TX}^{CA} \uparrow}$

Aggregate Supply

Probability that a type h carrier currently in i chooses to go to j

$$s_{ij}^h = \frac{\exp(\delta_{ij} + \beta E[W_{ij}^h])}{\sum_{k \in L} \exp(\delta_{ik} + \beta E[W_{ik}^h]) + \exp(\beta E[V_i^h])} \tag{5}$$

Aggregate supply along a lane sums over types.

$$s_{ij} = \sum_h \frac{C_i^h}{\sum_{h'} C_i^{h'}} s_{ij}^h \tag{6}$$

Shippers

- In each ij lane, there is a mass of N_{ij} shippers, each with shipping value $\omega_{ij} + v$ where $v \sim_{iid} Exp(\sigma)$.
- Each shipper chooses between purchasing 1 unit of shipping and an outside option. The shipper's problem is

$$\max\{v + \omega_{ij} - p_{ij}, 0\}$$

- Aggregate demand is

$$D_{ij} = N_{ij} \times P(v + \omega_{ij} > p_{ij}) = N_{ij} \exp(\sigma p_{ij} + \omega_{ij})$$

Equilibrium Conditions

A steady-state equilibrium of this model is a vector of prices, quantities, and carrier locations such that:

- Carriers make optimal decisions
- Shippers make optimal decisions
- Markets clear in each lane

$$\forall i, j, \quad S_{ij}(p) = D_{ij}(p)$$

- For each location, number of carriers of each type constant

$$C_i^h = \underbrace{\sum_j C_j^h s_{ji}^h}_{\text{Inflows}} + \underbrace{C_i^h s_{i,OO}^h}_{\text{Outside Option}}$$

Model: Identification of Home Bias with Inspections

Consider the share of active carriers in each state who are from California.

What do different levels of home bias predict?

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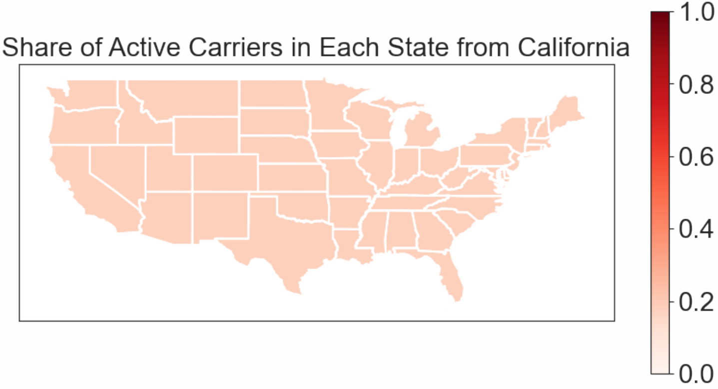
$b = 0$: No home bias, all carrier homogeneous



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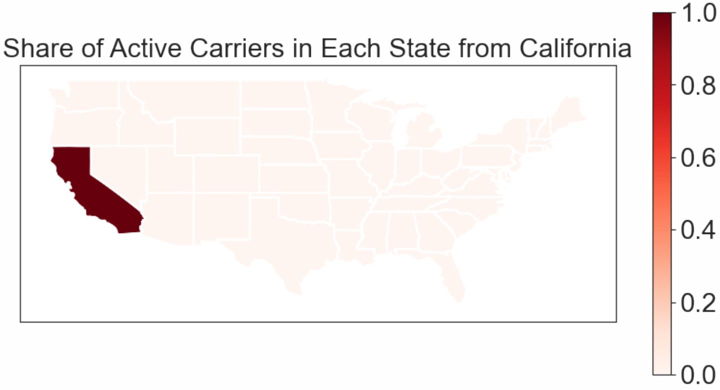
Consider the share of active carriers in each state who are from California.

$b \to \infty$: Carriers stay at home



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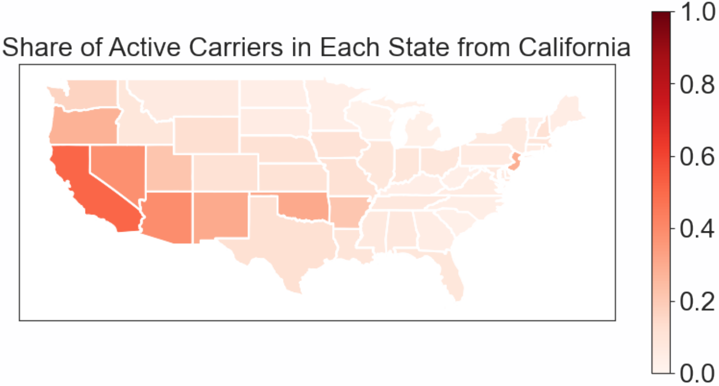

Estimation

Supply-side Estimation: Model Takeaways

Route mean payoffs δ_{ij} for a route from i to j:

$$\delta_{ij} = \alpha p_{ij} + \gamma X_{ij} + \xi_{ij}$$

Value function for a carrier from h to be in i

$$V_{ic}^{h} = b \times 1_{h(c)=i} + \max(\max_{j} \delta_{ij} + \epsilon_{cj} + \beta E\left[W_{ij}^{h}\right], \epsilon_{c,OO} + \beta E\left[V_{i}^{h}\right])$$

Probability s_{ij}^{h} for a carrier from h to go from i to j:

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Data and Parameters

Supply-side Estimation: Big Picture

Standard dynamic discrete choice problem with two differences:

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- I need to estimate home bias b, but I don't have type-specific shares s_{ij}^{h}
  - Use inspections
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Inspection Process Details

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▸ Inspection Process Details

- I allow unobservable shocks ξ_{ij} in my cost function
  - Use approach like BLP for demand estimation.

BLP Contraction Mapping Analog

- Recall the mean payoffs δ_{ij}:

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- I can solve for predicted aggregate shares s_{ij} as a function of b and δ.

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- $\rightarrow$ For every level of home bias, I can find mean payoffs which match observed shares.
- Differences:
  - Nested value function iteration
  - Equilibrium locations of carriers

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δ^* Algorithm Details

- Given δ_{ij}, I can use IV to recover price and cost coefficients.
- Price Instrument: Availability of River and Water Shipping

Price Instrument Construction Details

Estimation Steps

Supply

- First step: estimate home bias by maximizing likelihood of observed inspections.
  1. Guess home bias b.
  2. Compute mean payoffs which match observed shares.
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▸ Optimization Problem ▸ Data Construction Details

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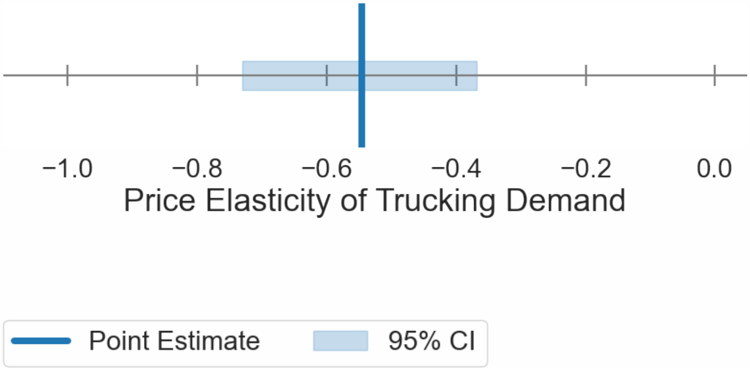
Optimization Problem Data Construction Details

Demand

- Linear IV using route snowiness as cost shifter

Estimation: Demand-side Results



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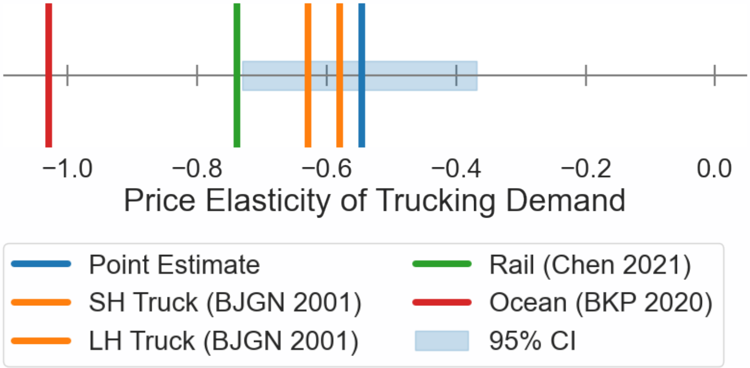

Estimation: Supply-side Results

Parameter	Estimate (Utils)	95% Bootstrap CI	Estimate ($)
Home Bias (Utils)	0.0206	[0.0204, 0.0212]	70.33
Price Sensitivity (000 $)	0.2929	[0.2735, 0.3086]	-

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Costs (γ)			
Diesel ($/gal x 000 miles)	-0.1577	[-0.1697, -0.1447]	-538.4
Distance (000 miles)	-0.4734	[-0.4755, -0.4709]	-1616

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Cracking (std)	-0.0317	[-0.0326, -0.0303]	-108.2
Faulting (std)	-0.0535	[-0.0543, -0.0526]	-182.6
Rutting (std)	-0.0893	[-0.0903, -0.0878]	-304.8

Counterfactuals

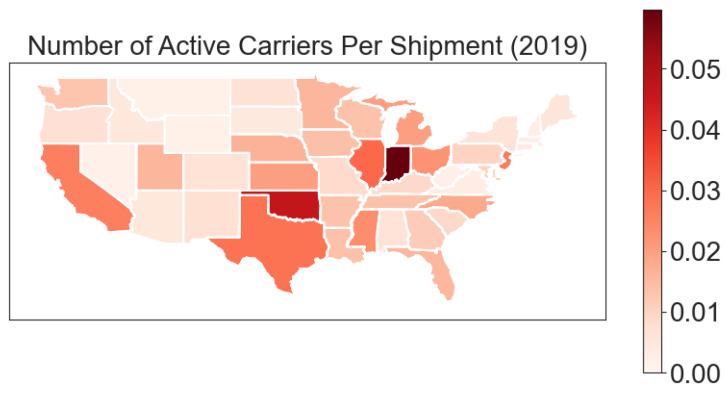
Counterfactual I: Autonomous Trucks

Question: What is the effect of autonomous "homeless" trucks?

Setup

- Remove carrier heterogeneity and let $b = 0$.
- Agnostic about cost effects: Keep costs constant, consider dispersion.
- Hold demand constant.

Counterfactual I: Distribution of Carrier Homes



Counterfactual I: Counterfactual Results

Two forces:

- **Level effect**: Fewer carriers take outside option $\rightarrow$ more capital utilization, supply shifts out.
- **Dispersion**: Carriers shift away from high trucker-per-capita states.
  1. Fewer carriers $\rightarrow$ lower supply $\rightarrow$ higher export prices.
  2. Fewer carriers wanting to return home $\rightarrow$ higher import prices.
  3. Combination of (1) and (2) $\rightarrow$ higher within-state prices.

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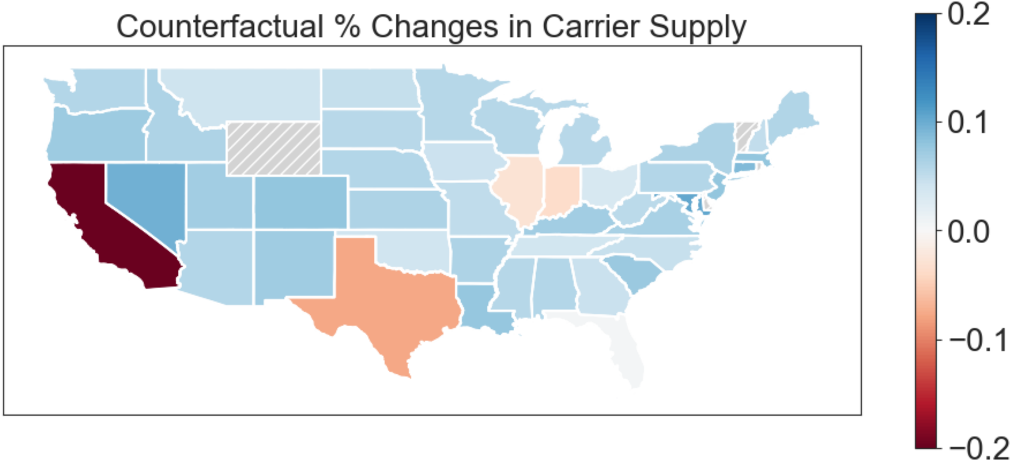
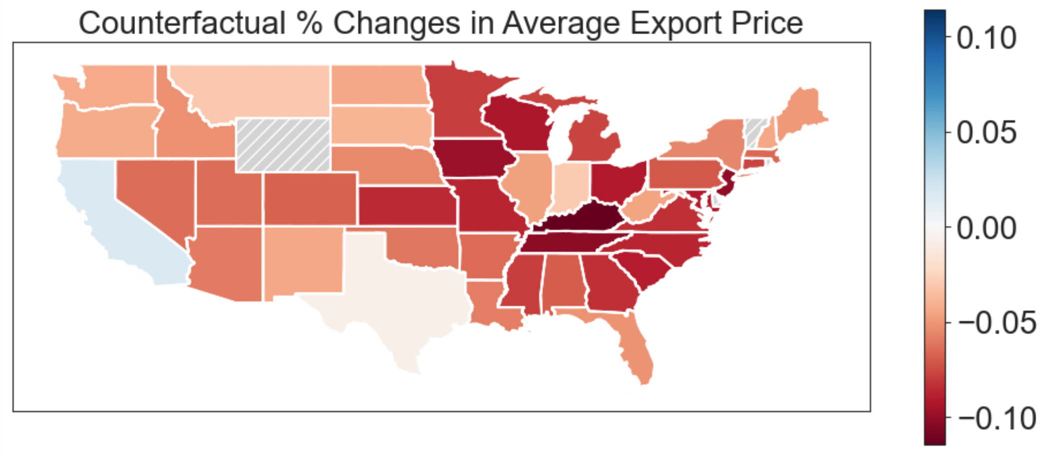
Big picture:

- 5.4% decrease in route prices (Laspeyres Index)
- 2.5% increase in total trucking freight

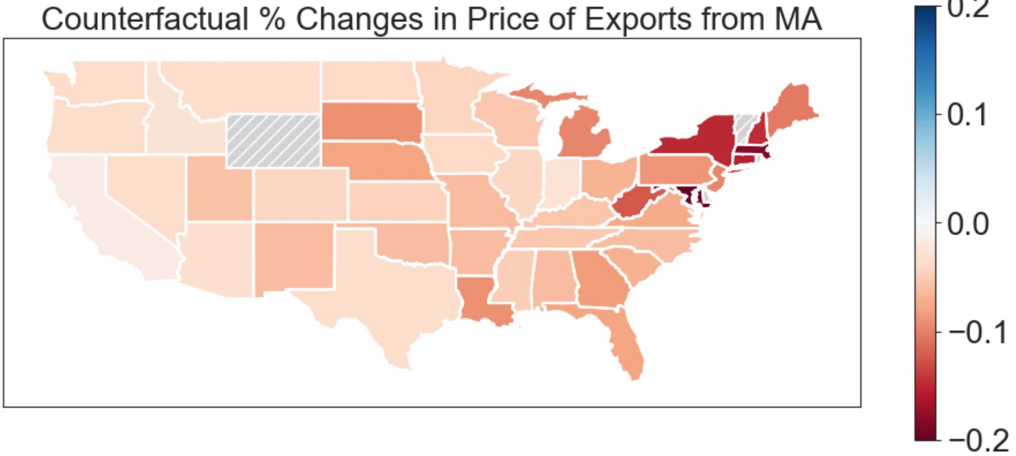
Counterfactual: Carriers reallocate from driver-rich states



Counterfactual: Average Export Prices Fall for driver-poor states



Counterfactual: Short distance prices fall in driver-poor regions



Counterfactual II: Full Counterfactual

Full effects of automation include:

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2. Lower per-mile costs (labor, fuel, accidents)
3. Longer daily range

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Full effects of automation include:

1. No home bias
2. Lower per-mile costs (labor, fuel, accidents) [**-25%** (HK 2020)]
3. Longer daily range [**2x** (Deloitte 2021)]

I take estimates of 2 and 3 from transportation literature and industry and run simulations:

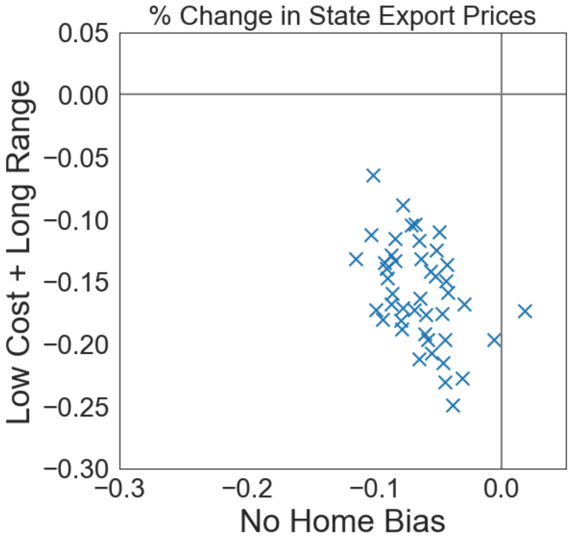
- With each effect alone
- With all 3 effects ("Full")

Full Counterfactual: Home Bias $\approx$ 20% of Total Effect

Counterfactual	Price Index	Total Quantity	Shipper Welfare ($/year)
No Home Bias	-5.4%	+2.5%	+1.50B
Lower Per-Mile Costs	-13.3%	+6.2%	+4.12B
Longer Daily Range	-7.6%	+3.5%	+2.29B
Full Counterfactual	-25.6%	+12.5%	+8.10B

Full Counterfactual: Home Bias negatively corr. with Other Effects

- Intuition: Carrier homes concentrated in states with long average hauls.
- States with long hauls benefits more from low cost / long range.



Conclusion

This paper:

- Estimate daily home bias $\approx \$70$ per day.
- Eliminating home bias:
  - shifts carriers from driver-rich states to driver-poor states.
  - increases capital utilization by reducing outside option
- Home bias effect $\approx 20\%$ of full effect of automation

Thank you!

Appendix

Appendix: Current Electrification Landscape

Appendix: Current Automation Landscape

Appendix: Data Summary Statistics

Appendix: Sample Selection

- 2019 Data only
- Exclude within-MSA trips
- Excluded states: Alaska, Hawaii, Nebraska, Wyoming, Vermont

Appendix: Choice of β

- Given flexible form of common cost shocks ξ_{ij}, it is likely β is not identified (Rust 1994, Magnac-Thesmar 2002).
- The industry sees exit rates of 70-90% annually, which corresponds to a daily discount factor of 0.9937-0.9967.

Appendix: Deterministic Arrival

Given the stochastic arrival probability, with risk-neutral carriers,

$$E[W_{ij}^h] = \frac{\lambda_{ij}}{1 - \beta(1 - \lambda_{ij})} E[V_j^h]$$

In expectation, a carrier arrives in $1/\lambda_{ij}$ days.
Under a deterministic arrival of T_{ij} days,

$$E[W_{ij}^h] = \beta^{T_{ij}} E[V_j^h]$$

For any λ_{ij}, there exists a T_{ij} which is discounts the future equivalently.
In a steady-state equilibrium, the share of travelling carriers arriving will be exactly $1/T_{ij}$ under stochastic and deterministic arrival.

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Appendix: Measurement Details

Appendix: Route Characteristic Construction

- For each (i, j) pair of origin and destination states, I take the centroid of the origin and destination.
- I use roads from the Highway Performance Measurement System and filter for highways on the National Truck Network.
- I compute the shortest distance route from the origin to the destination.
- The route characteristic is the average route characteristic over all intermediate states, weighted by the amount of distance travelled in each state.

$$X_{ij} = \sum_k s_{ijk} X_k$$

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Appendix: Reduced Form Supply Derivation

Recall choice probabilities.

$$s_{ij}^{h} = \frac{\exp\left(\alpha p_{ij} + \gamma X_{ij} + \beta E\left[W_{ij}^{h}\right] + \xi_{ij}\right)}{\sum_k \exp\left(\alpha p_{ik} + \gamma X_{ik} + \beta E\left[W_{ik}^{h}\right] + \xi_{ik}\right)}$$

Factor out common components of RHS, sum over carrier types h, and take logs.

$$\log S_{ij} = \log C_i + \alpha p_{ij} + \gamma X_{ij} + \underbrace{\xi_{ij} + \underbrace{\log \sum_h \frac{C_i^h}{C_i} \frac{\exp\left(\beta E[W]_{ij}^{h}\right)}{\sum_k \exp\left(\alpha p_{i+k} + \gamma X_{ik} + \beta E\left[W_{ik}^{h}\right] + \xi_{i+k}\right)}}_{\text{Error}}}_{} \tag{8}$$

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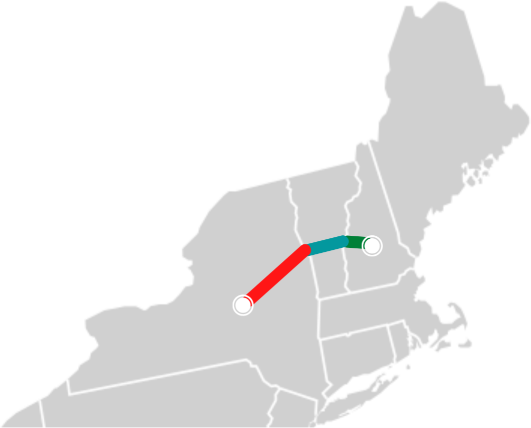
Appendix: Inspection Process



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Appendix: Supply Estimation Details

1. Given a guess for (b, δ), compute value function $E[V_i^h]$.
2. Given $E[V_i^h]$, compute type-specific shares s_{ij}^h
3. Given s_{ij}^h, compute steady-state carrier locations C_i^h
4. Given (s_{ij}^h, C_i^h), compute aggregate shares $s_{ij}(\delta)$
5. Iterate $\delta'_{ij} = \delta_{ij} + \log s_{ij} - \log s_{ij}(\delta)$ until convergence

Back

- In steady-state, conditional on δ, a carrier does not need to know choices of any other carriers.
- Solve for $E[V_i^h]$ using value function iteration.

Appendix: Supply Estimation Details II

1. Given a guess for (b, δ), compute value function $E[V_i^h]$.
2. Given $E[V_i^h]$, compute type-specific shares s_{ij}^h
3. Given s_{ij}^h, compute steady-state carrier locations C_i^h
4. Given (s_{ij}^h, C_i^h), compute aggregate shares $s_{ij}(\delta)$
5. Iterate $\delta'_{ij} = \delta_{ij} + \log s_{ij} - \log s_{ij}(\delta)$ until convergence

Back

- With value functions, the model implies conditional choice probabilities

$$s_{ij}^h = \frac{\exp(\delta_{ij} + \beta_{ij} E[V_j^h])}{\sum_k \exp(\delta_{ik} + \beta_{ik} E[V_k^h]) + \exp(\beta E[V_i^h$$

- CCPs imply type-specific transition matrices, T^h. The steady-state location of carriers is the solution to

$$\begin{pmatrix} T^h \\ \vec{1} \end{pmatrix} C^h = \begin{pmatrix} C^h \\ \bar{C}^h \end{pmatrix}$$

Appendix: Supply Estimation Details III

1. Given a guess for (b, δ), compute value function $E[V_i^h]$.
2. Given $E[V_i^h]$, compute type-specific shares s_{ij}^h
3. Given s_{ij}^h, compute steady-state carrier locations C_i^h
4. Given (s_{ij}^h, C_i^h), compute aggregate shares $s_{ij}(\delta)$
5. Iterate $\delta'_{ij} = \delta_{ij} + \log s_{ij} - \log s_{ij}(\delta)$ until convergence

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- Aggregate shares are weighted averages of type-specific shares.

$$S_{ij}(\delta) = \sum_h C_i^h s_{ij}^h$$

$$s_{ij}(\delta) = \frac{S_{ij}(\delta)}{\sum_k S_{ik}(\delta)}$$

Appendix: Outside Option

- **Challenge**: I do not observe carriers which take the outside option.
- I observe the number of daily carrier searches for jobs on the DAT spot marketplace app, t_i, for each location i. This includes carriers who accept jobs as well as those who do not.
- I observe the total population of potential carriers C^h using registrations.
- Assume that the number of available carriers is proportional to the number of searches.

$$C_i^h = \frac{t_i}{\sum_j t_j} \times C^h$$

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Appendix: Calibration of λ_{ij}

Appendix: Accounting Cost components

Building to Estimation: δ^*

Given a value of home bias b, I can find a vector of mean payoffs $\delta^*(b)$ which fits observed trip shares s_{ij}^O exactly.

$$\delta^*(b) = \delta \quad \text{s.t.} \quad s_{ij}(b, \delta) = s_{ij}^O \quad \forall (i, j)$$

I can find $\delta_{ij}^*(b)$ by iterating the following until convergence:

$$\delta_{ij}' = \delta_{ij} + \log s_{ij}^O - \log s_{ij}(b, \delta)$$

Following slides: How does model predict aggregate trip shares $s_{ij}(b, \delta)$?

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Computing δ^* I: Solve for value function

- In steady-state, fixing δ, a carrier's problem looks like single-agent optimization.
- Given a guess for (b, δ), compute value function $E[V_i^h]$ using value function iteration.

$$V_i'^h = b \times 1_{h=i} + E_\epsilon[\max(\max_j \delta_{ij} + \beta W_{ij}^h, \beta V_i^h)] \quad (9)$$

$$W_{ij}'^h = \lambda_{ij} V_j^h + (1 - \lambda_{ij}) \beta E[W_i^h j] \quad (10)$$

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Computing δ^* II: Type-specific trip shares

With value functions V_j^h and W_{ij}^h, and δ, the model implies type-specific choice probabilities

$$s_{ij}^h = \frac{\exp(\delta_{ij} + \beta E[W_{ij}^h])}{\sum_k \exp(\delta_{ik} + \beta E[W_{ik}^h]) + \exp(\beta E[V_i^h])} \tag{11}$$

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Computing δ^* III: Steady-state carrier locations

Each period, the number of type h carriers in i is

$$C_i^h = \underbrace{\sum_j C_j^h s_{ji}^h}_{\text{Inflows}} + \underbrace{C_i^h s_{i,OO}^h}_{\text{Outside Option}}$$

L equations and L unknowns $\rightarrow$ solve for C^h for each h.

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Computing δ^* IV: Aggregate trip shares

Aggregate shares are carrier-weighted averages of type-specific shares.

$$s_{ij}(\delta) = \sum_h \frac{C_i^h}{\sum_{h'} C_i^{h'}} \times s_{ij}^h$$

I can find $\delta_{ij}^*(b)$ by iterating the following until convergence:

$$\delta_{ij}' = \delta_{ij} + \log s_{ij} - \log s_{ij}(\delta)$$

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Building to Estimation: Inspection Process

- A carrier available in i is inspected at i with probability ρ_i.
- A carrier en-route from i to j is inspected at k with probability $\rho_k m_{ijk}$, where m_{ijk} is the mileage share of the total route from origin i to destination j spent passing through k.
- The share of type h carriers among inspections at k depends on the equilibrium locations of carriers:

$$\iota_k^h(b,\delta) = \iota_k^h(C(b,\delta)) = \frac{C_k^h + \sum_{ij} m_{ijk} C_{ij}^h}{\sum_{h'}(C_k^{h'} + \sum_{ij} m_{ijk} C_{ij}^{h'})}$$

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Price Instrument Construction Details

- Idea: Geographic presence of rivers allows barge freight $\rightarrow$ shifts demand for trucking freight independent of costs
- Construction: Use Army Corps of Engineers' Fuel-Taxed River and Internal Waterway System
- Let $Z_{ij} = 1$ if
  - A fuel-taxed river flows from i to j
  - An internal waterway (Gulf, Atlantic) connects i and j

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Estimation Problem

First stage: Maximize likelihood of inspections I_i^h

$$\max_b LL(s^O \mid b, \delta^*(b)) = \sum_{hi} I_i^h \times \log \iota_i^h(b, \delta)$$

$$\delta^*(b) = \delta \quad s.t. \quad s_{ij}(b, \delta) = s_{ij}^O \quad \forall i, j$$

Second stage:

$$\min_{\alpha,\gamma} E[(\delta_{ij}^* - \alpha p_{ij} - \gamma X_{ij}) Z_{ij}]$$

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Counterfactual III: Electric Trucks (Setup)

Question: What is the effect of electric trucks?

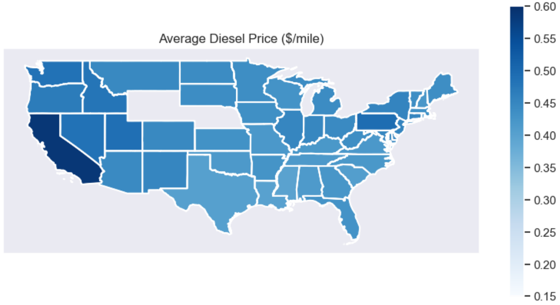
Setup

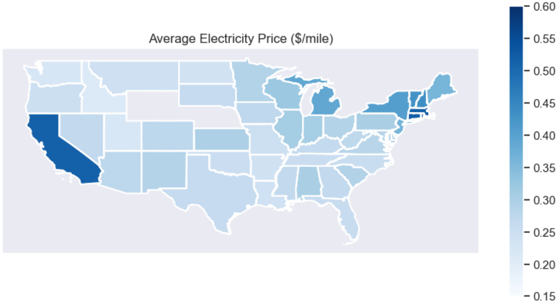
- Replace role of route diesel prices with route electricity prices.
- Agnostic about other cost effects: Keep costs constant, consider dispersion.
  - 3B trucking freight miles $\rightarrow$ 6.6B kWH $\rightarrow$ 0.17% US total electricity usage
- Hold demand and home locations constant.
- Abstract from range (more intense home preference), charging.

Counterfactual II: Input Price Differences

To make prices comparable, I make assumptions:

- Gas mileage: 6 mpg (industry survey of fleets)
- Electricity mileage: 2.2 kWH per mile (Freightliner eCascadia)
- Electricity prices: EIA average residential electricity price





Counterfactual II: Results

Two forces:

- **Level Effect**: Lower costs overall $\rightarrow$ less outside option
- **Dispersion**: Shift toward routes with lower input prices

Counterfactual II: Results

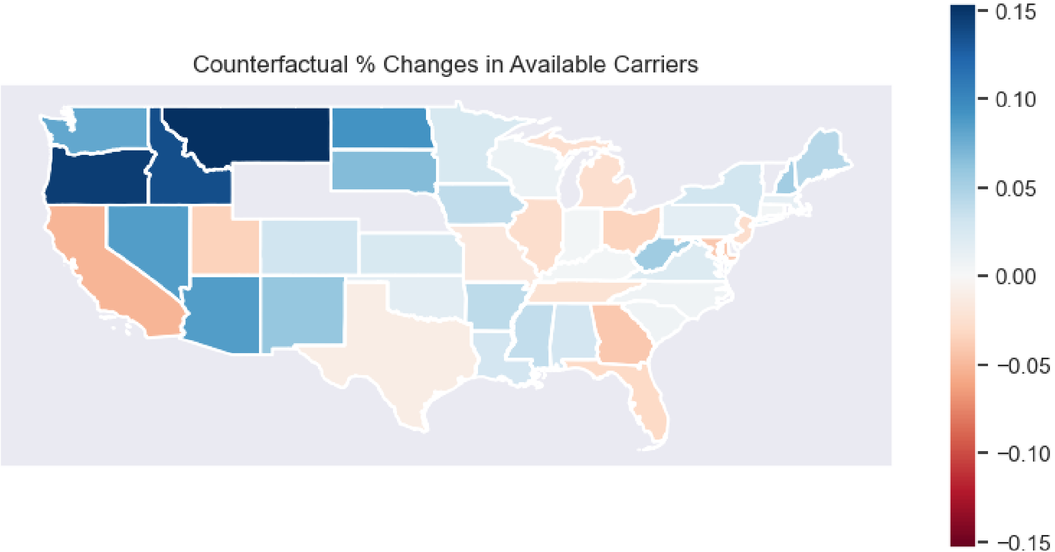
Two forces:

- **Level Effect**: Lower costs overall $\rightarrow$ less outside option
- **Dispersion**: Shift toward routes with lower input prices

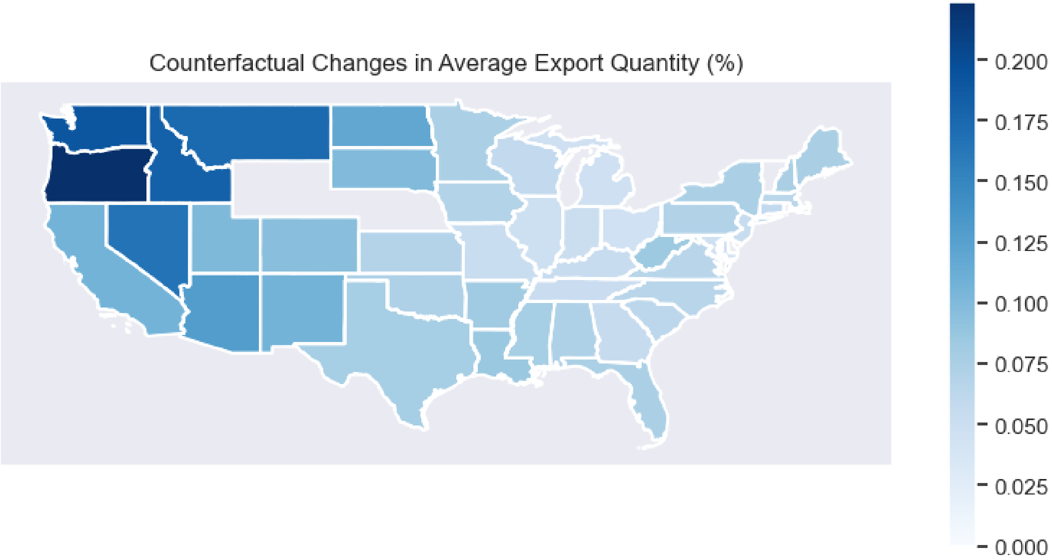
Big picture:

- 17.5% decrease in route prices (Laspeyres Index)
- 7.5% increase in total trucking freight
- 11% increase in distance travelled $\rightarrow$ biased toward longer trips

Counterfactual II: California carriers shift to work in NW



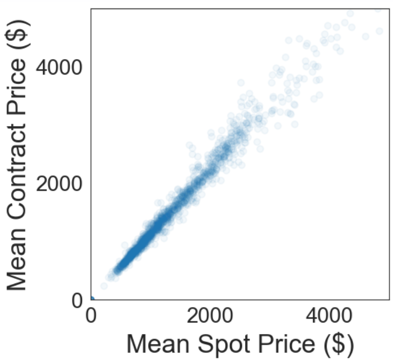
Counterfactual II: Pacific Northwest sees greatest increase in exports



Appendix: Spot vs Contract Prices

Spot + Contract Price Correlation (2016)

- Monthly average prices: 0.9804
- Annual average prices: 0.9909
- For more details, see literature: *Masten 2009, Scott et al 2016, Aemireddy et al 2019, Acocella et al 2020, Harris and Nguyen 2021*.



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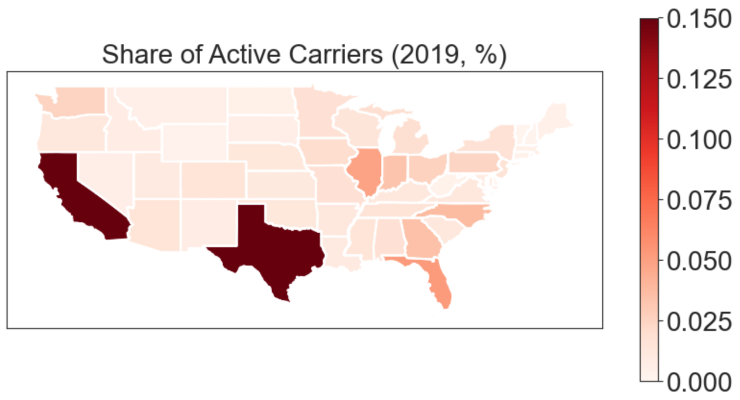
Active Carriers



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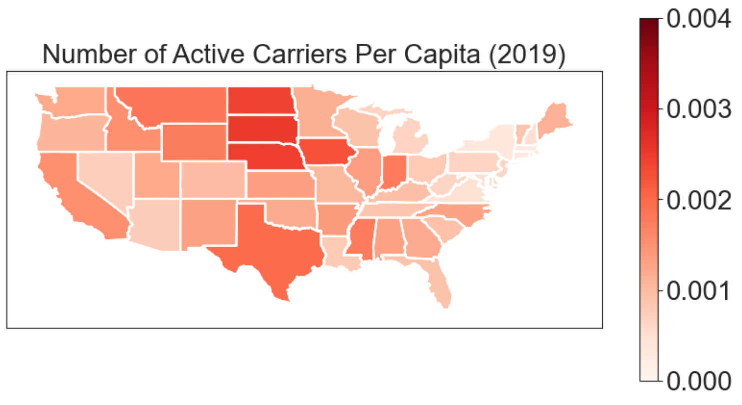
Activer Carriers per Capita



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Estimation Details

Parameters

- Demand Parameters
  - σ: Price sensitivity
- Supply Parameters
  - b: Home preference
  - α: Price sensitivity
  - γ: Route observables
- Calibrated Parameters
  - β: Discount factor (0.995)
  - λ_{ij}: Arrival probabilities

Estimation Details

Parameters

- Demand Parameters
  - σ: Price sensitivity
- Supply Parameters
  - b: Home preference
  - α: Price sensitivity
  - γ: Route observables
- Calibrated Parameters
  - β: Discount factor (0.995)
  - λ_{ij}: Arrival probabilities

Data

- Q_{ij}: Quantity (DAT RateView)
- N_{ij}: Total Shippers (CFS - Total Shipping)
- p_{ij}: Average Price (DAT RateView)
- ι_{hi}: Inspection Shares (Highway Inspections)

Route Characteristics:

- $Dist_{ij}$: Distance (PC-Miler miles)
- $Diesel_{ij} \times Dist_{ij}$: Avg diesel price (\$/gal) $\times$ Distance (demeaned)
- $Cracking_{ij}, Faulting_{ij}, Rutting_{ij}$: Road quality measures (std mean zero, std dev 1)

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Inspection (Boston Globe 2020)

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