

# The Short-Run Effects of Congestion Pricing in New York City

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## Motivation

Economists love congestion pricing, but rare in practice

- ▶ Price the externalities of driving (Vickrey, 1963)
- ▶ Exists in Singapore, London, Stockholm, Milan, ...

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Source: New York Times

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“Second-best” congestion pricing

- ▶ Subset of roads and times with a ~flat price



Source: New York Times

## Motivation

17.6 million fewer vehicles have entered Manhattan since congestion pricing launched this year

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By [Aaron Ginsburg](#)

September 10, 2025



Source: 6sqft / MTA

**NYC's Congestion Toll Raised \$159 Million in the First Quarter**



Source: Bloomberg

## This Project

### Research questions

1. Effects inside the Central Business District (CBD)?
2. Spillover effects outside the CBD?
3. What are the implications for designing congestion pricing programs?

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- ▶ Estimate treatment effects using Generalized Synthetic Control (GSC)
- ▶ Simple model to bound welfare gains
- ▶ Evaluate mechanisms & potential effectiveness in other cities

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3. What are the implications for designing congestion pricing programs?
  - ~ Welfare gains come from the *unpriced trips*.
    - ▶ Trips to CBD only better off if VOTT > \$153/hour.
    - ▶ But aggregate driver welfare positive if VOTT > \$21/hour
  - ~ Mechanisms: *exposure to CBD trips & steepness of density* ↪ speeds relationship

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## Related literature

### ► Empirical evaluations of congestion pricing programs

Existing cordon-based programs in London (2003), Stockholm (2007), and Milan (2008): Leape (2006); Eliasson et al. (2009); Gibson and Carnovale (2015); Green, Heywood and Paniagua (2020); Simeonova et al. (2021); Hierons (2024)

Other existing/potential policies: Hall (2018); Bento, Roth and Waxman (2020); Kreindler (2024); Cook and Li (2024); Almagro et al. (2024); Barwick et al. (2024); Durrmeyer and Martínez (2024); Hierons (2024); Ater et al. (2025)

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### ► First- and second-best congestion pricing, in theory

Vickrey (1963, 1969); Verhoef, Nijkamp and Rietveld (1996); De Palma and Lindsey (2000); Verhoef (2002); Small, Verhoef and Lindsey (2007)

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### ► Evaluating place-based policies

E.g., Glaeser and Gottlieb (2008); Busso, Gregory and Kline (2013); Kline and Moretti (2014); Neumark and Simpson (2015)

~~ Accounting for diffuse effects outside focal region can flip sign on driver welfare

## Data & methodology

## Data

- ▶ Aggregated + anonymized stats from Google Maps trips (Sept. 2024-June 2025)
  - **Segment-level outcomes:** hourly volume-weighted outcomes at the “road” level
    - ▶ traversal speeds
  - **Origin-Destination outcomes:** hourly volume-weighted outcomes at the “trip” level
    - ▶ realized trip travel times and speeds
    - ▶ estimated fuel consumption

## Data

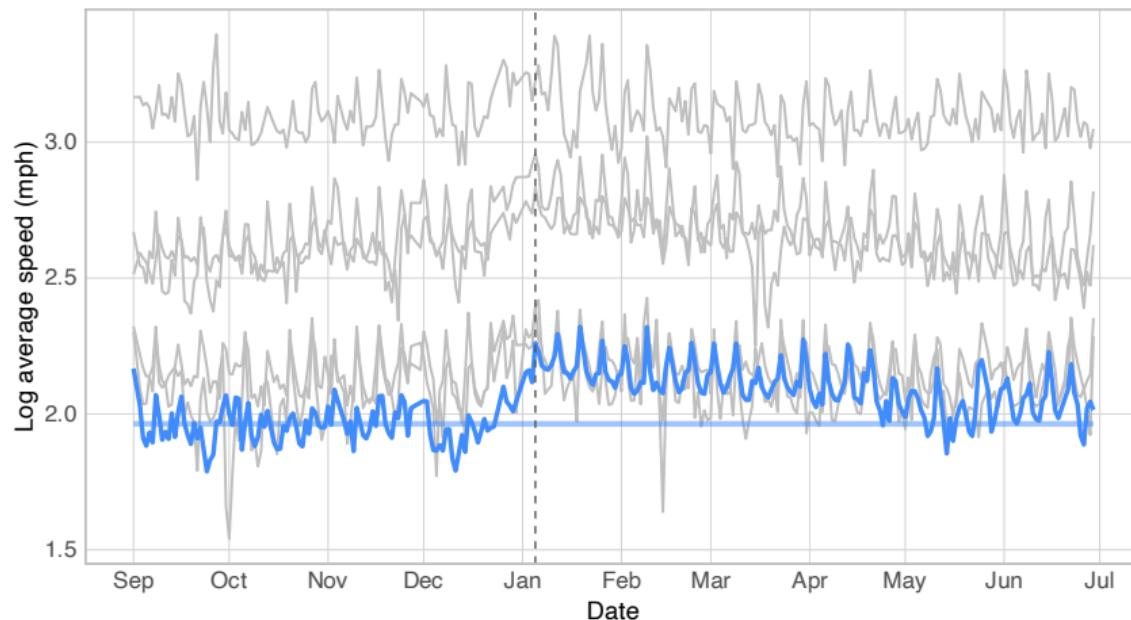
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- ▶ Coverage: NYC metro area + Philadelphia, Chicago, Boston, Atlanta, and Baltimore

## Methodology: Generalized Synthetic Controls

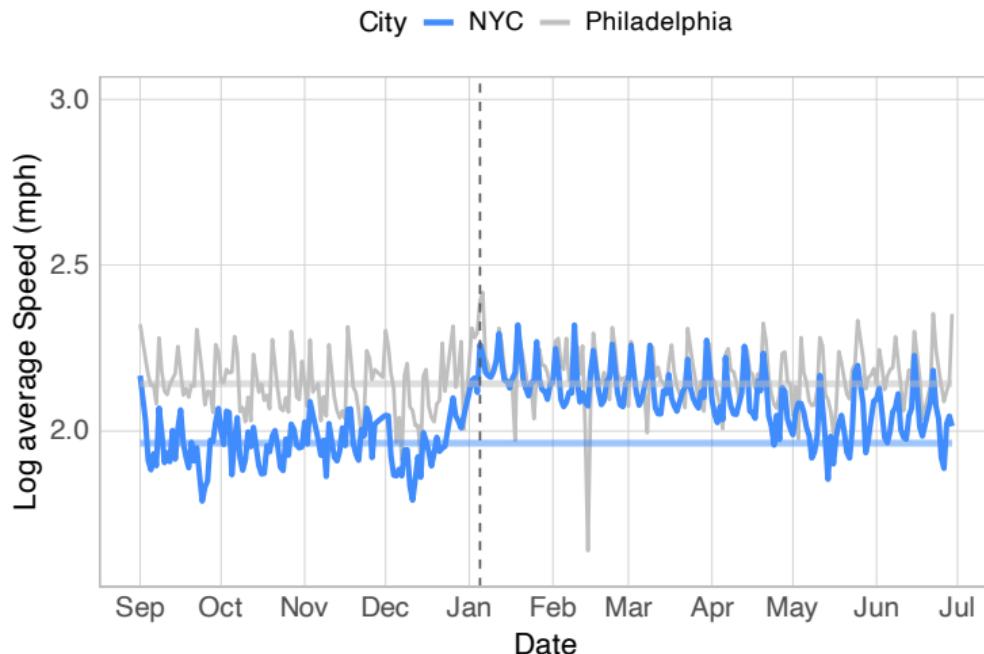
**Key idea: log average speeds on road segments in the CBD of each city**



*Note:* New York City (in blue), Philadelphia, Chicago, Boston, Atlanta, and Baltimore. The blue bar is average speeds pre-policy.

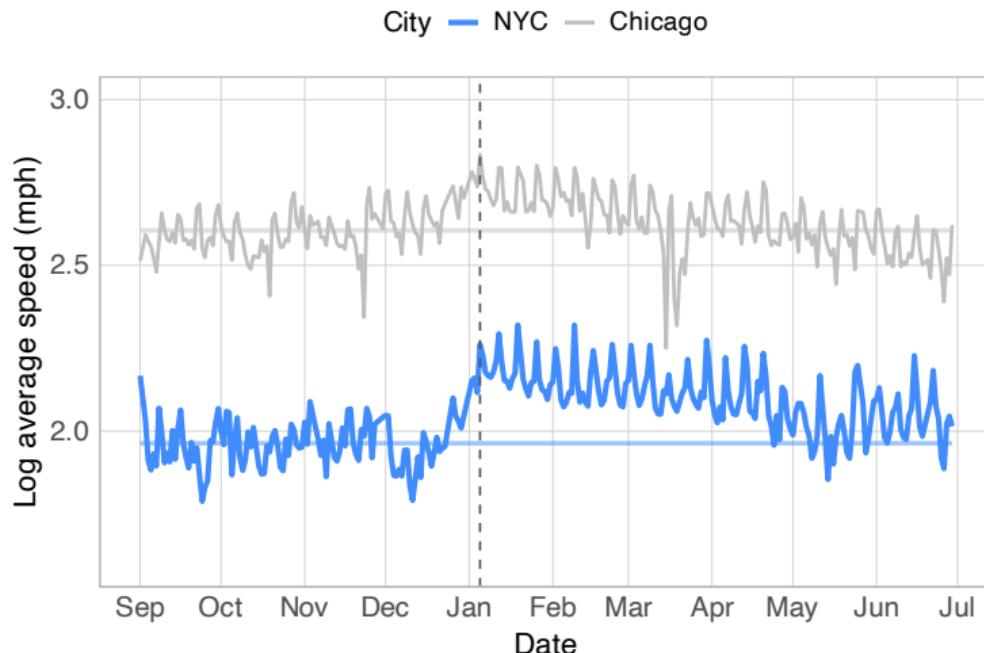
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**Key idea: zoomed in on Philadelphia**



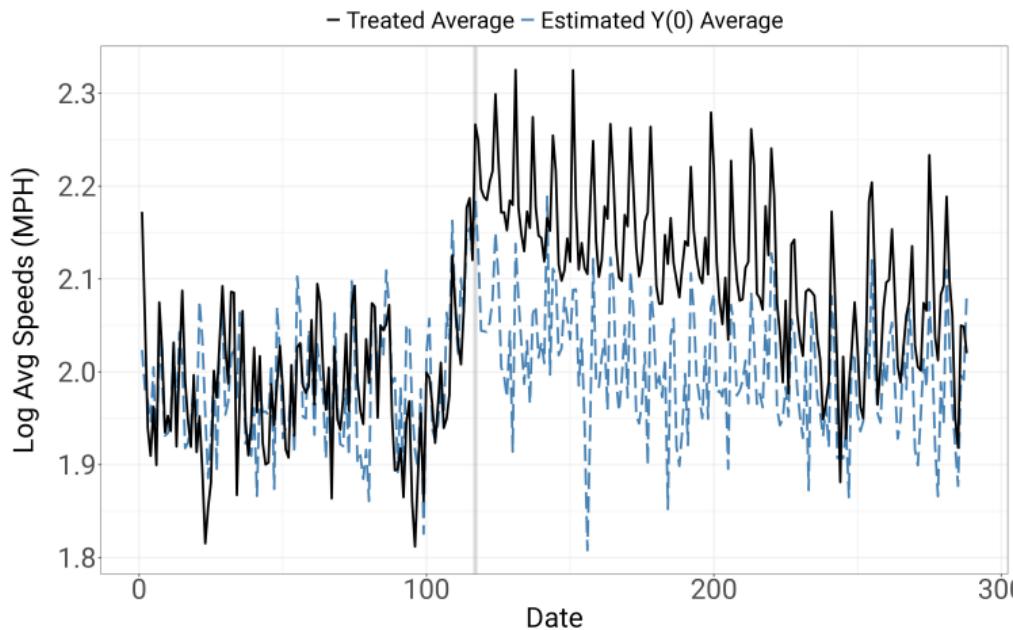
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**Key idea: zoomed in on Chicago**



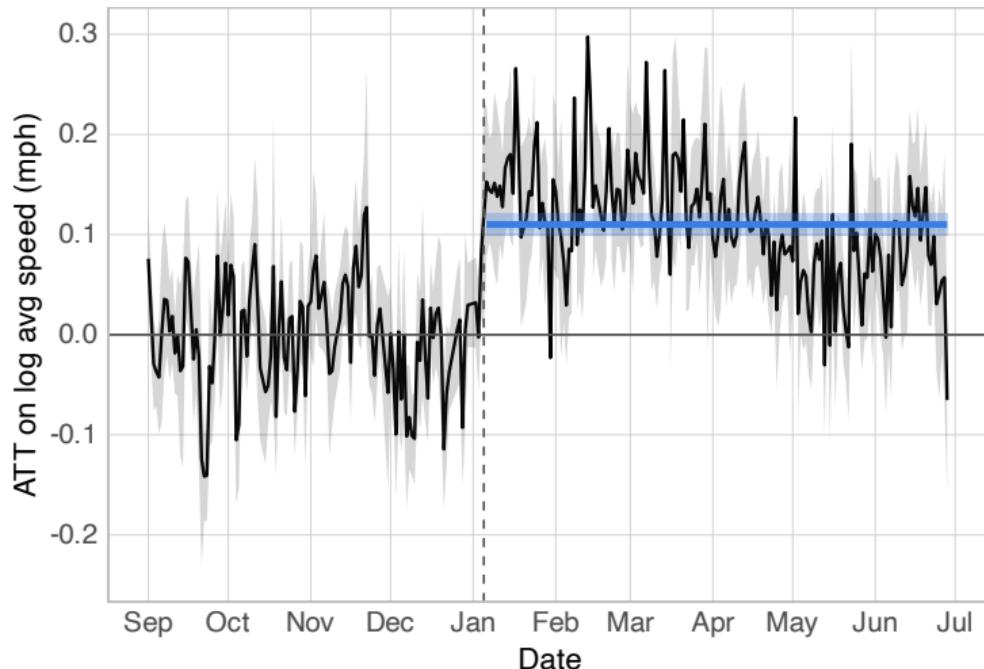
## Methodology: Generalized Synthetic Controls

**Key idea: combine into ‘synthetic control’**



## Methodology: Generalized Synthetic Controls

**Key idea: difference is the ‘average treatment effect’ (ATT)**



## Methodology: Generalized Synthetic Controls

- ▶ **Challenge:** NYC traffic evolves with many confounders  $\Rightarrow$  simple before/after comparisons not causal
- ▶ **Approach:** Generalized Synthetic Controls (GSC) ([Xu, 2017](#))
  - Compare NYC to a weighted combination of control cities, fit on pre-policy outcomes.
  - For unit  $i$  in time  $t$ , model (untreated) outcome as:

$$Y_{it}(0) = \alpha_i + \gamma_t + \boldsymbol{\lambda}_i^\top \mathbf{f}_t + \epsilon_{it}$$

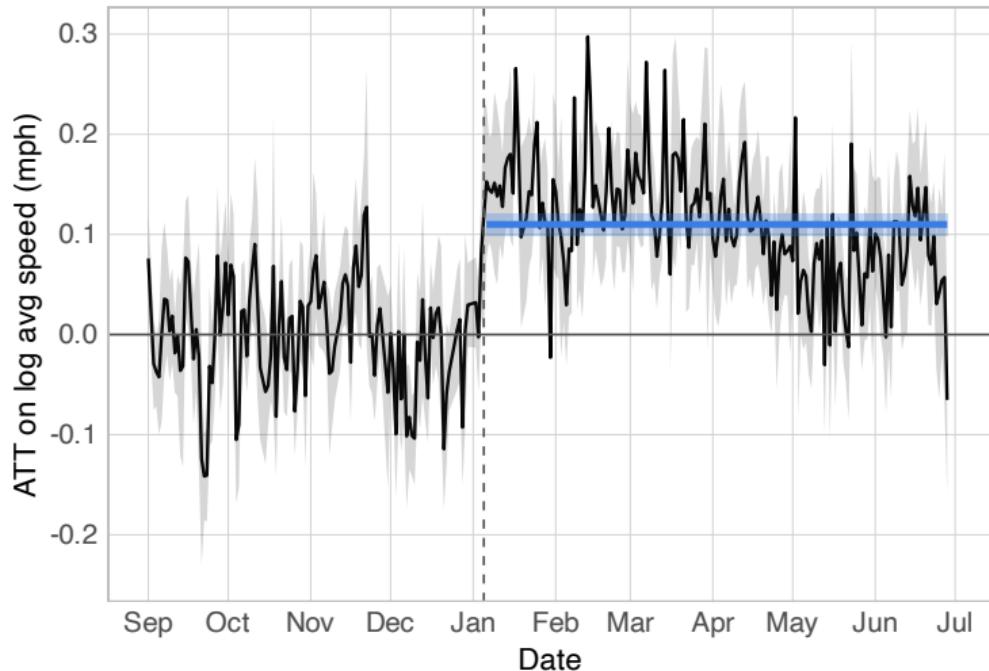
- ▶ **Estimation:**
  - Loadings/factors estimated pre-policy; predict counterfactual  $\hat{Y}_{it}(0)$  post-policy.
  - Treatment effect:

$$\widehat{\text{ATT}}_t = \frac{1}{|\mathcal{I}^{treated}|} \sum_{i \in \mathcal{I}^{treated}} (Y_{it}(1) - \hat{Y}_{it}(0))$$

- ▶ **Key assumptions:**
  - Stable factors/loadings. No spillovers to controls

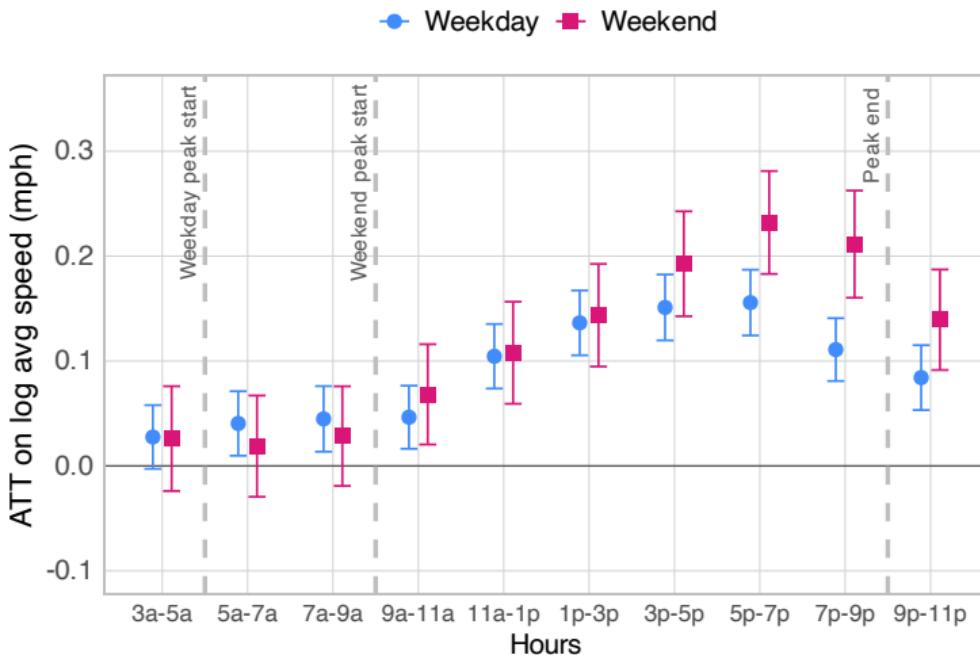
**What happened inside the CBD?**

## Average speeds on CBD road segments increased by 11%



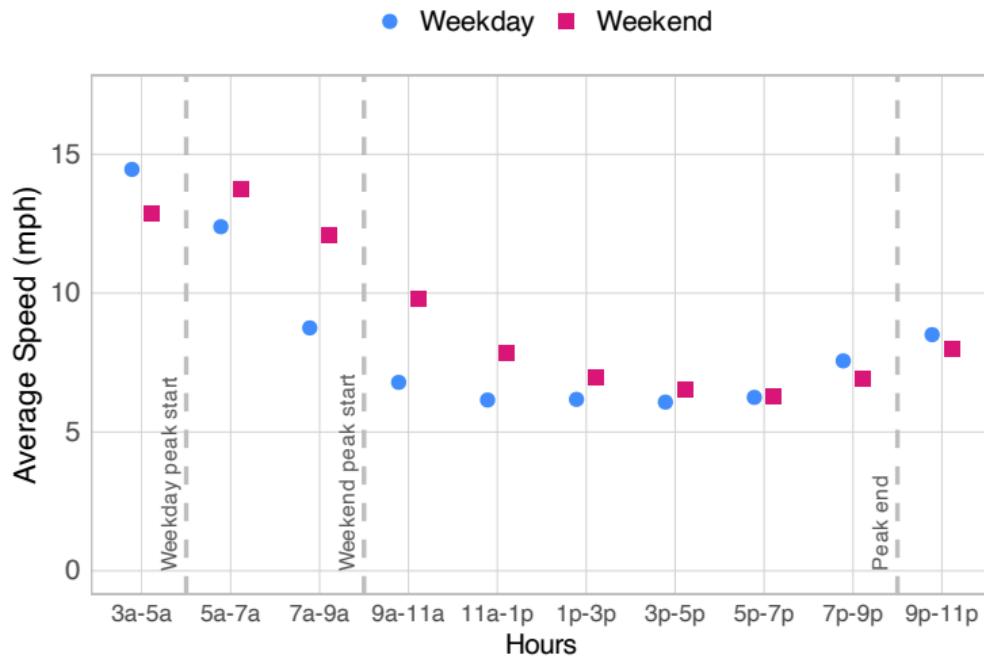
Note: Blue line is estimated ATT for post-period. Shaded areas represent 95% confidence intervals.

## CBD speeds increased the most during the afternoon...



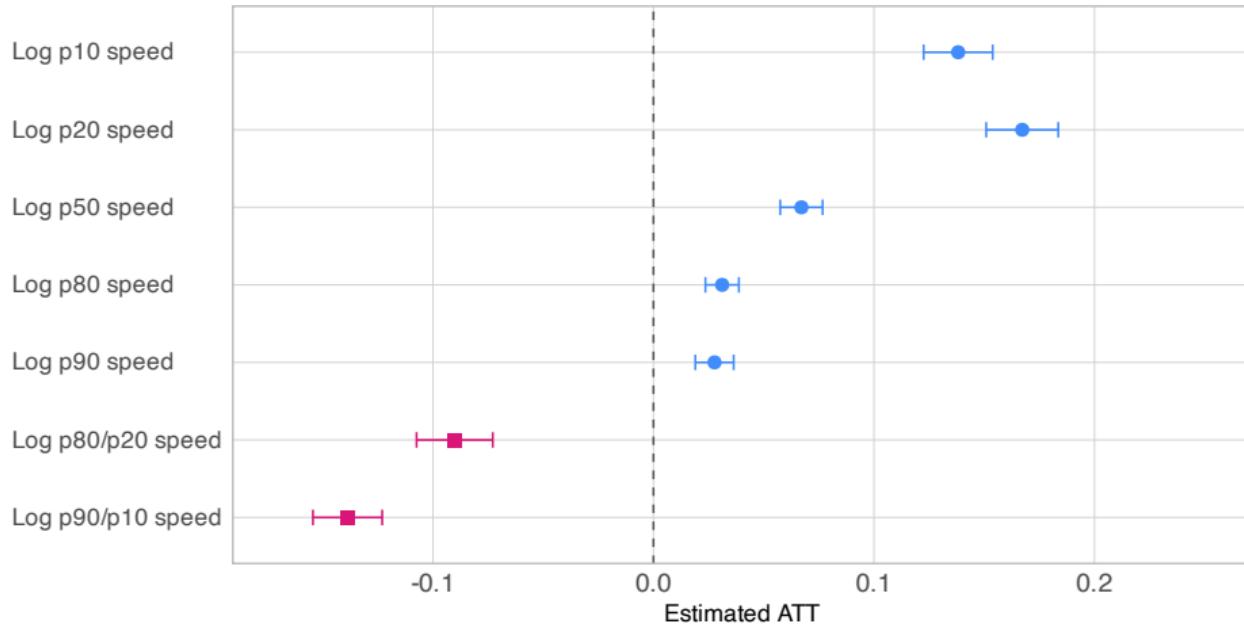
*Note:* Each ATT is separately estimated using traffic conditions from the other CBDs during the same time of day as synthetic controls. Vertical lines represent 95% confidence intervals.

... which is when speeds are usually the slowest



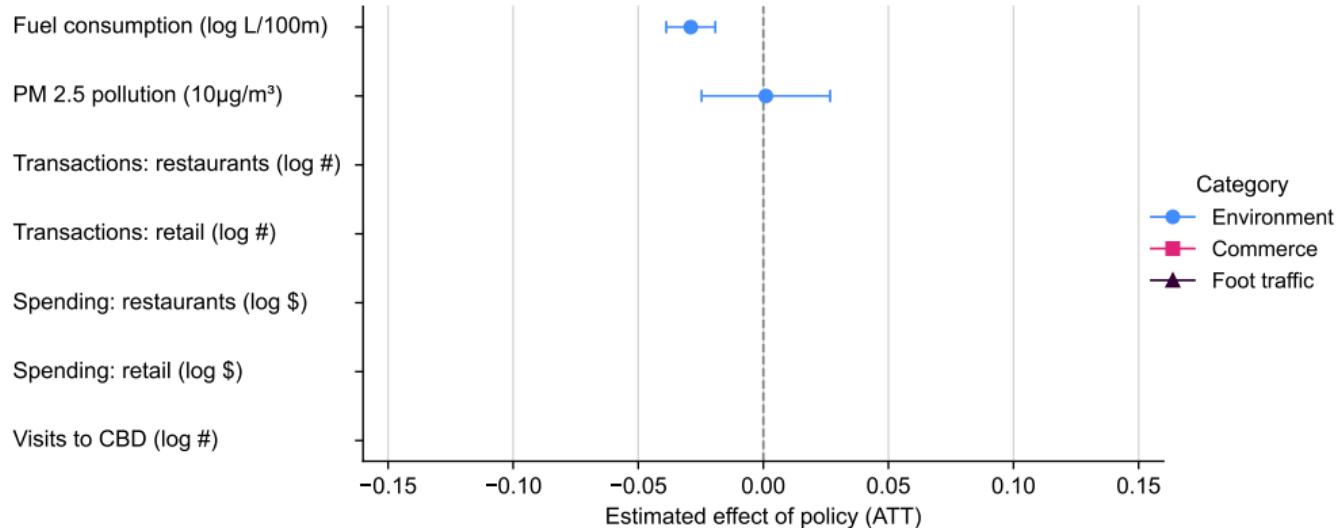
Note: Each ATT is separately estimated using traffic conditions from the other CBDs during the same time of day as synthetic controls. Vertical lines represent 95% confidence intervals. Averages are based on pre-treatment data.

## Distribution of speeds compressed → more reliable traffic



*Note:* Each ATT is separately estimated using traffic conditions from the other CBDs during the same time of day as synthetic controls. The underlying data are an hourly panel of traffic conditions in the CBD. Horizontal lines represent 95% confidence intervals, with standard errors clustered by city.

## Little-to-no effects on pollution, commerce, or foot traffic



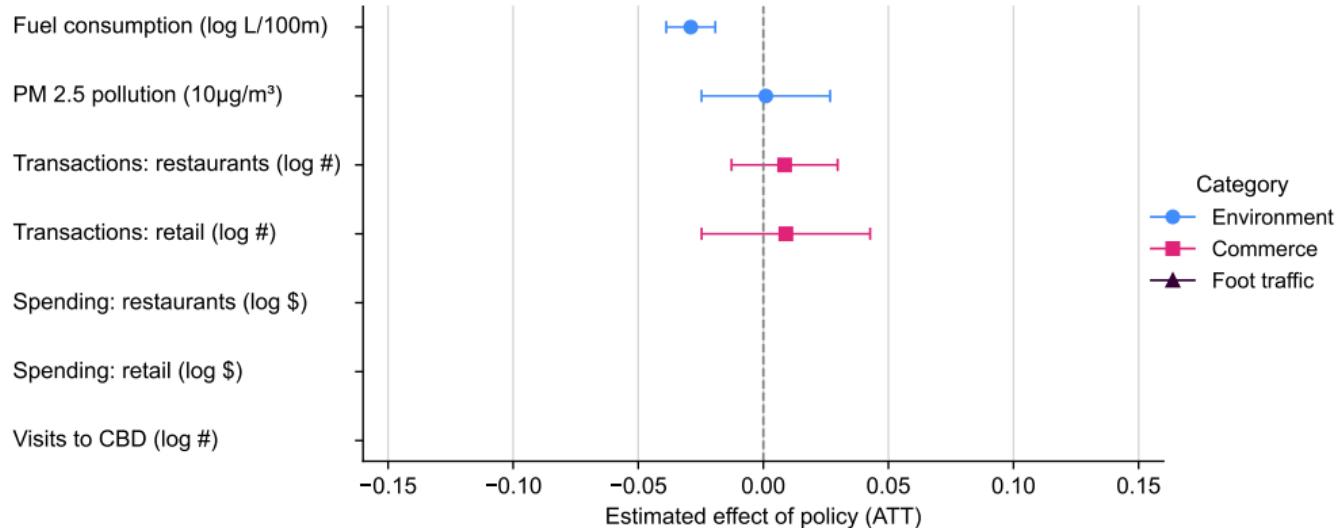
Note: Each point is the estimated ATT using the same five control cities. Fuel consumption is estimated for an average passenger car based on segment characteristics and speed profile. Pollution data from PurpleAir are at day-sensor level, transactions data from MBHS3 are at the zipcode-day level, and foot traffic from Advan are at the tract-day level. All outcomes besides fuel consumption use data from Jan 2024 through June 2025. Horizontal bars represent 95% confidence intervals.

▶ Pollution

▶ Transactions

▶ Foot traffic

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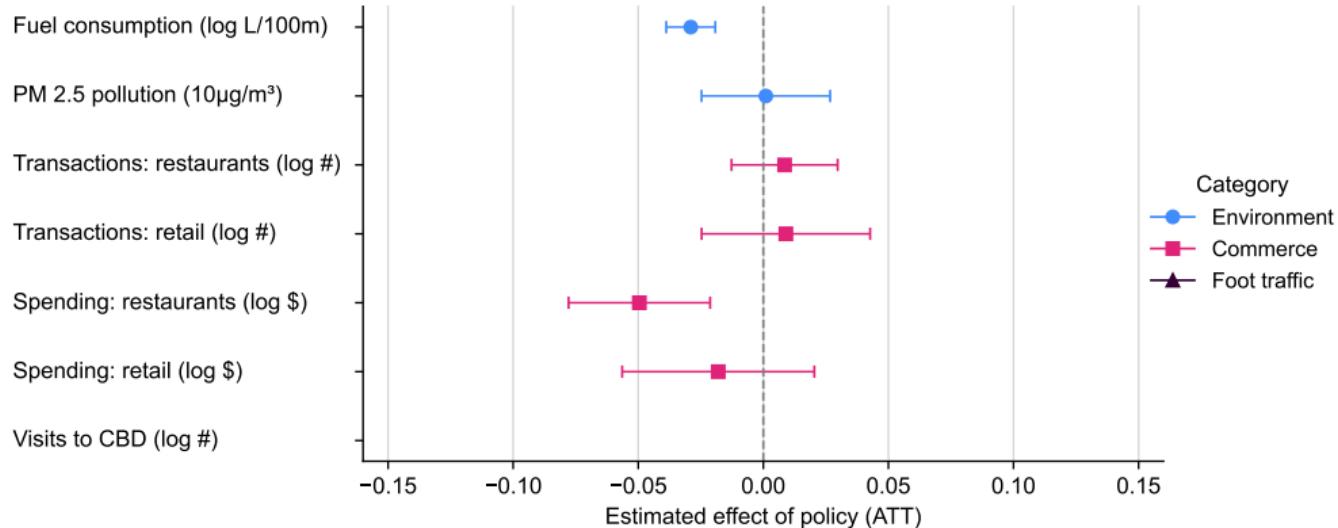
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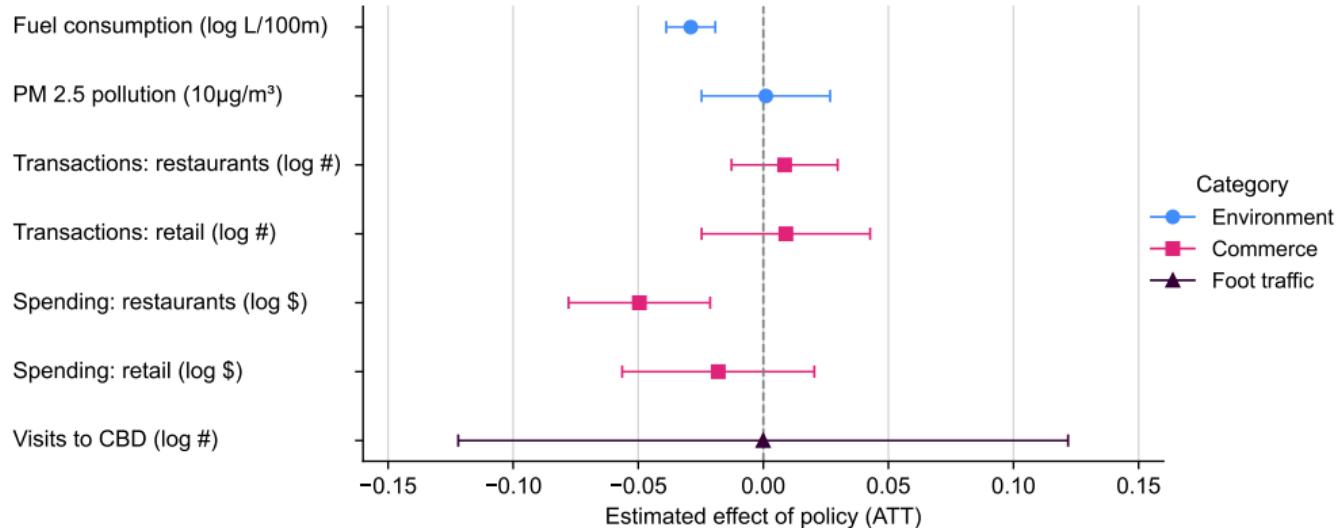
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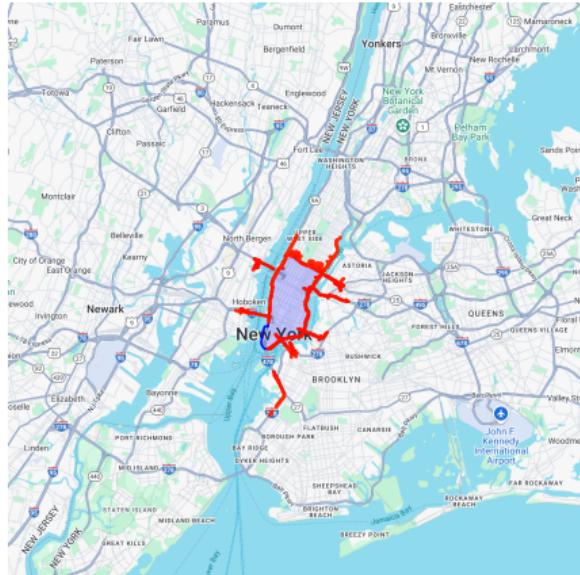
▶ Foot traffic

**What were the spillovers outside the CBD?**

# Measure policy exposure using ‘co-occurrence’

**Road segment co-occurrence:** share of traversals that are CBD trips

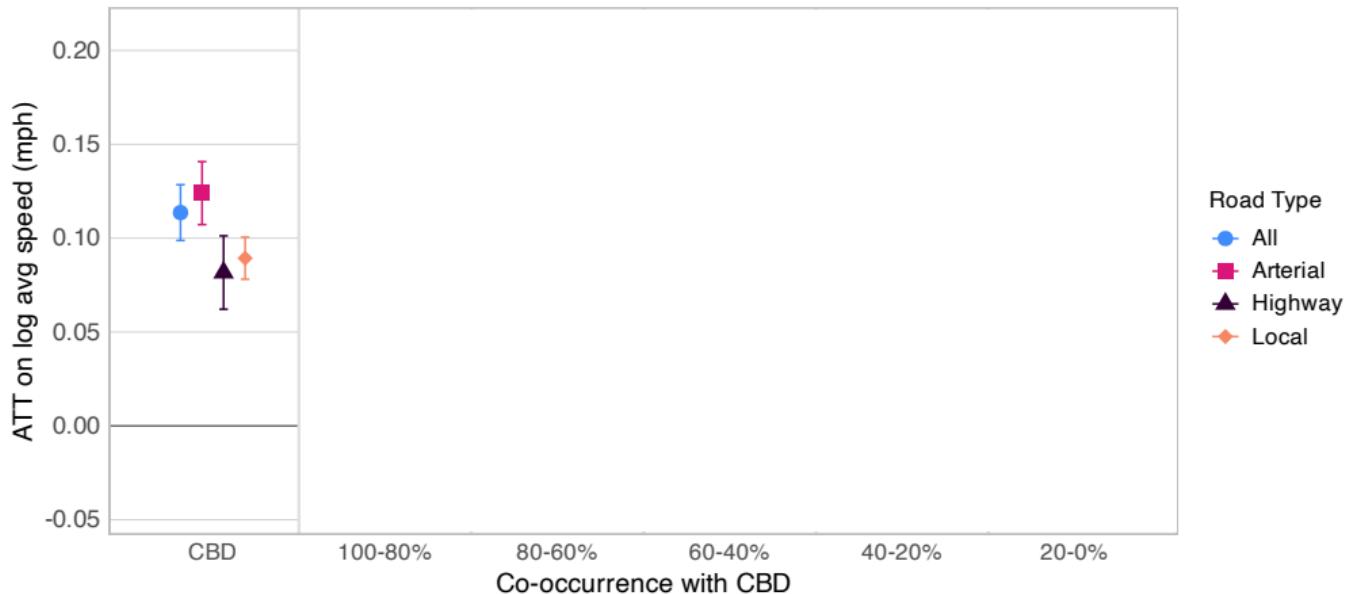
(a) High co-occurrence (80-100%)



(b) Low co-occurrence (10-20%)

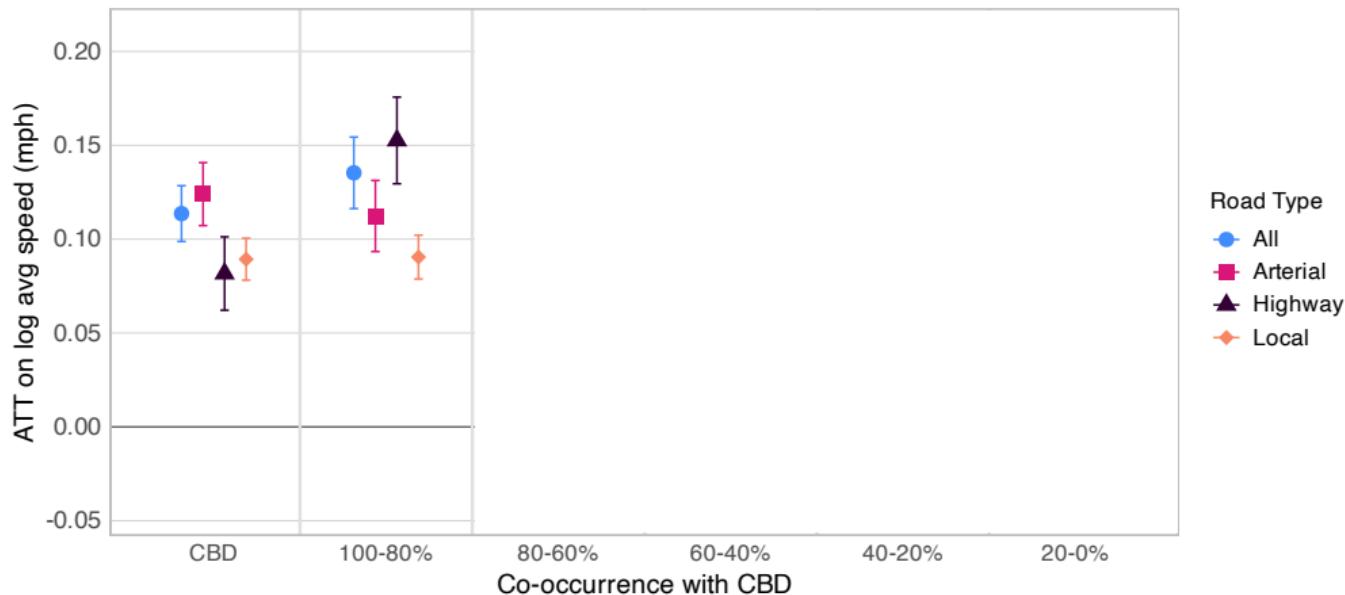


## More exposed segments → larger effect on speeds



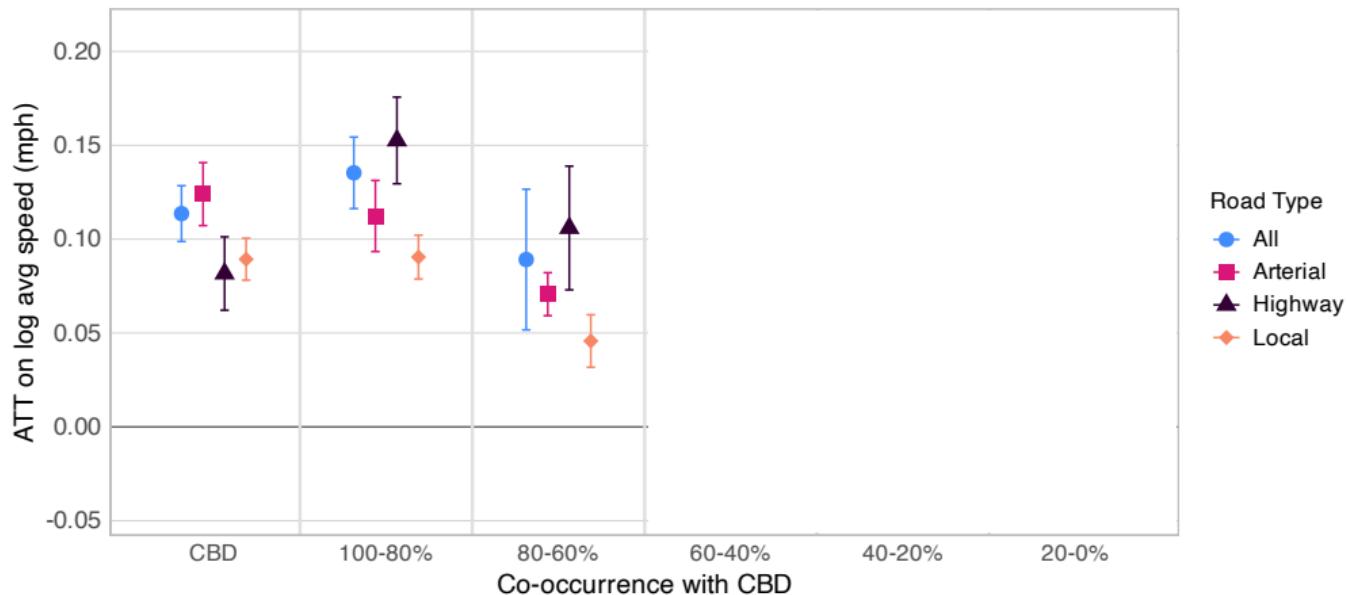
*Note:* Each point is separately estimated using the average speeds in two-hour bins for segments with the corresponding level of co-occurrence and road segment type for both NYC and the comparison cities. Vertical bars represent 95% confidence intervals.

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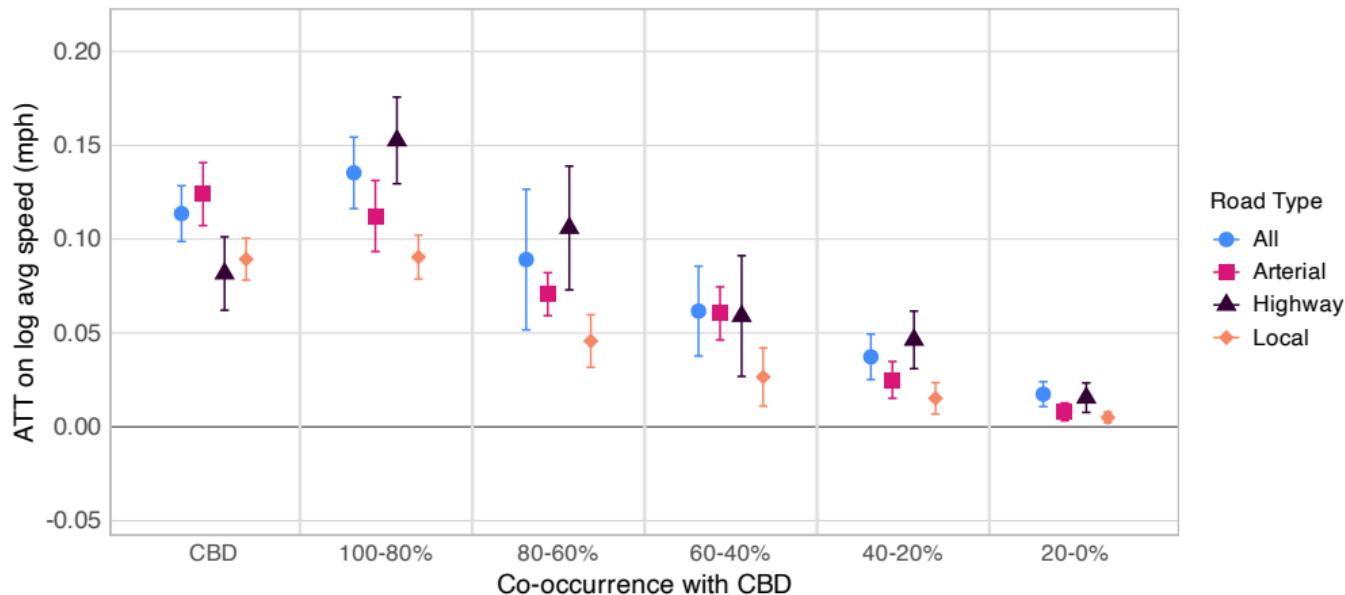
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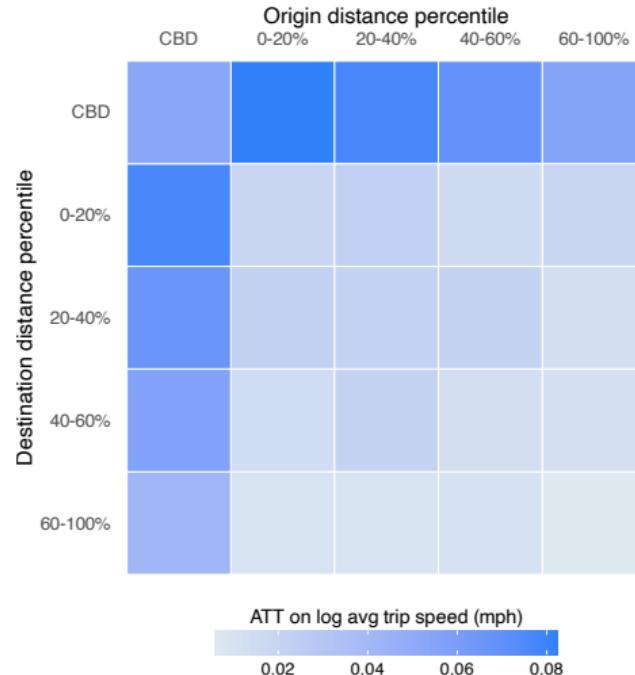
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## Trips to, from, within, and outside the CBD are all faster

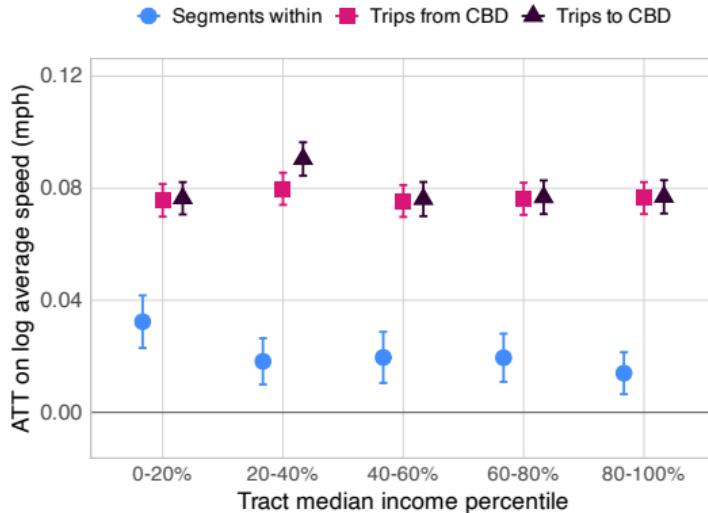
- ▶ Divide origin and destinations (ODs) tracts by percentile of distance to CBD [▶ Map](#)
- ▶ Estimate separate ATTs on log speeds (mph) for all trips between each OD-pair



*Note:* Each cell documents the ATT on log trip speeds for trips that originate in the bin indicated in the column labels and end in the bin indicated in the row labels. All results are significant at 5% level.

# Distributional effects: speeds increased for tracts of all incomes and areas

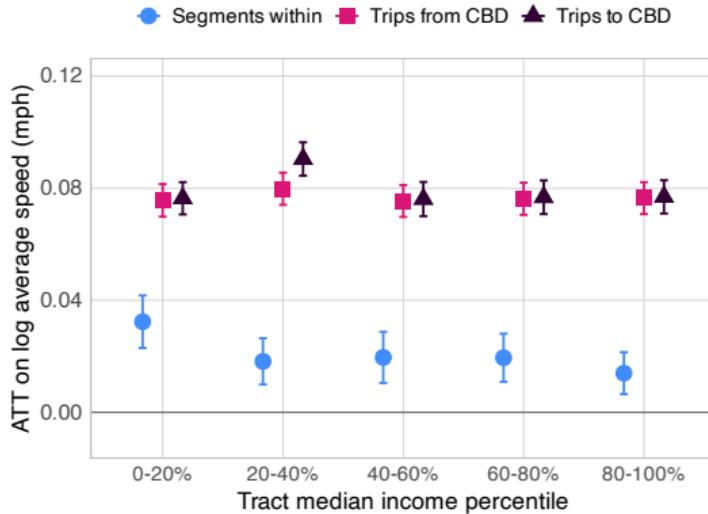
(a) Tract median income



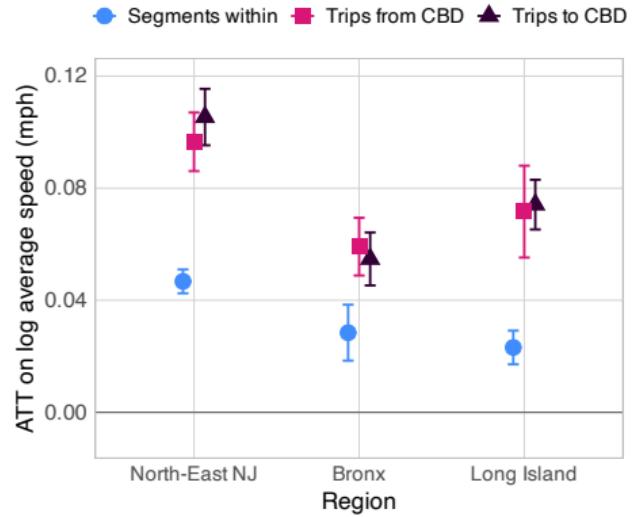
Note: Speeds are for the road segments within given geography. Trips are subset to those starting (ending) in the geography and going to (from) the CBD. Each point is the estimated ATT using the same five control cities. Vertical lines are 95% confidence intervals.

# Distributional effects: speeds increased for tracts of all incomes and areas

(a) Tract median income



(b) Other regions of interest



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**What are the policy implications?**

## Policy implications

- ▶ **Has congestion pricing ‘worked’ in NYC?**
  - Revenue up. Effects on driver welfare?
- ▶ **Would it have similar effects in other cities?**
  - Mechanisms: change in volumes + how volumes propagate to speeds across network

## Evaluating impacts on driver welfare

- ▶ Drivers value time driving and price paid (the toll)
  - For a trip between origin ( $o$ ) and destination ( $d$ ), suppose utility is:

$$u_{od} = \underbrace{\xi_{od}}_{\text{Baseline value}} - \underbrace{p_{od}}_{\text{Price}} - \underbrace{\omega}_{\text{VOTT}} \times \underbrace{t_{od}}_{\text{Travel time}}$$

where VOTT is the Value of Travel Time (\$/hr).

- Drivers take trip if  $u_{od}$  above outside option  $\varepsilon_{i,od}$

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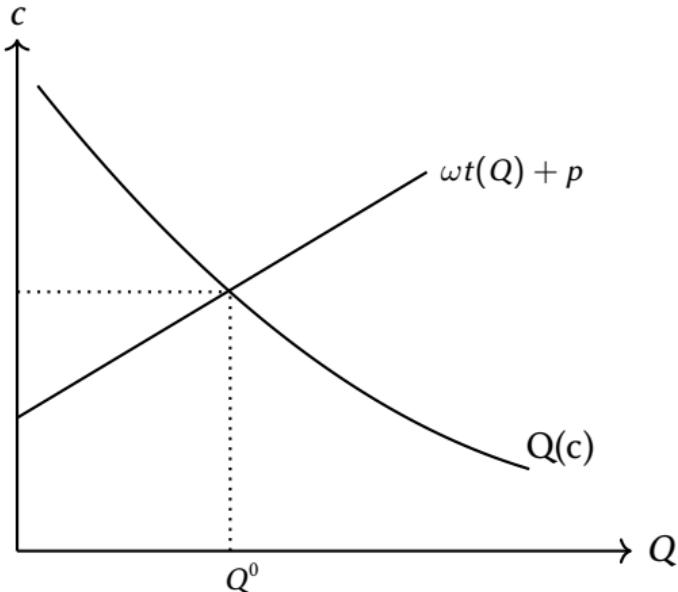
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- Drivers take trip if  $u_{od}$  above outside option  $\varepsilon_{i,od}$
- ▶ We observe  $\Delta p_{od}$  and can use the ATTs to estimate  $\Delta t_{od}$
- ▶ Challenges: we do not observe changes in volumes or Value of Travel Time ( $\omega$ )
  - Assume VOTT of \$40/hour ( $\approx$ avg wage)
  - Use data on estimated tract-to-tract flows in Q4 2024 from Replica as pre-period flows
- ▶ Derive lower bounds for the welfare changes using pre-period flows ▶ Details
  - Similar to ‘social savings’ in [Fogel \(1964\)](#). No GE effects ([Allen and Arkolakis, 2022](#))

## Lower-bounds on change in driver welfare

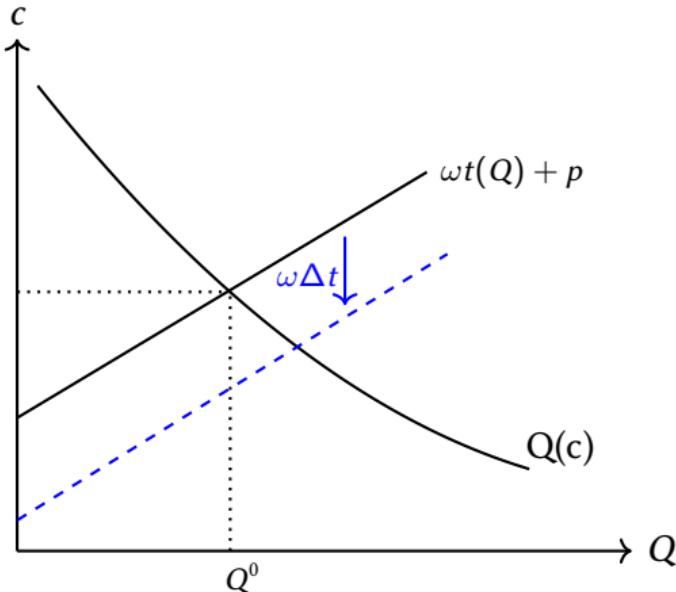
(a) Priced trip



(b) Unpriced trip

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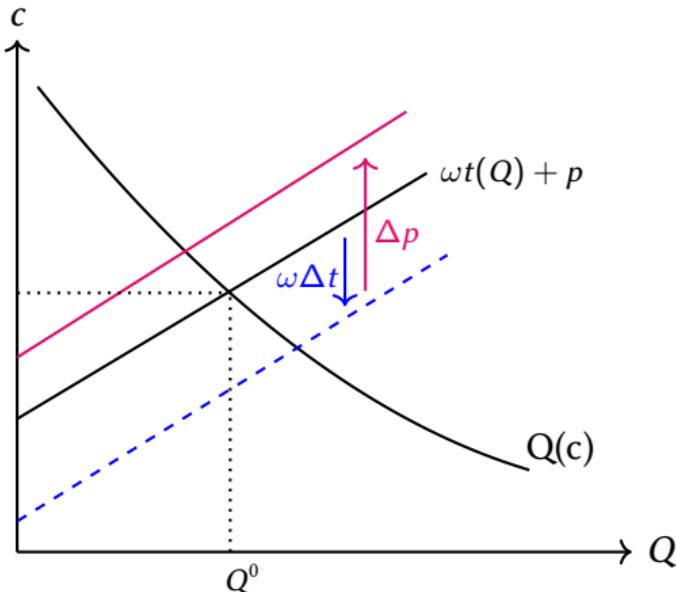
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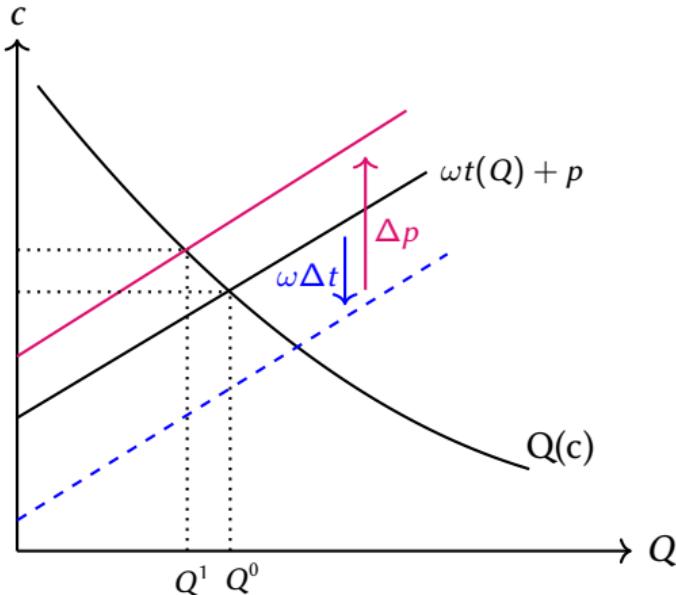
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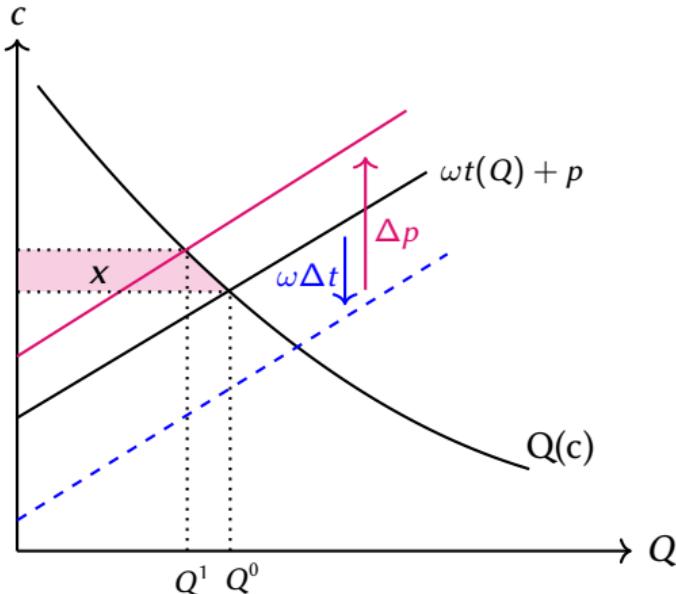
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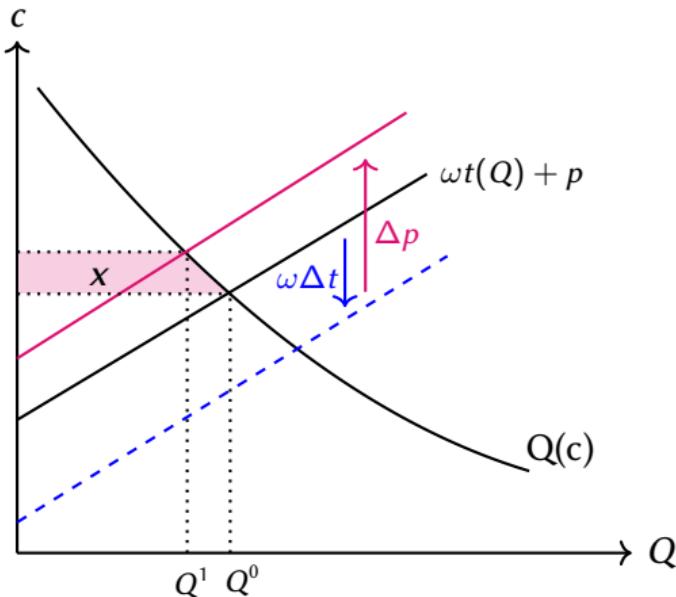
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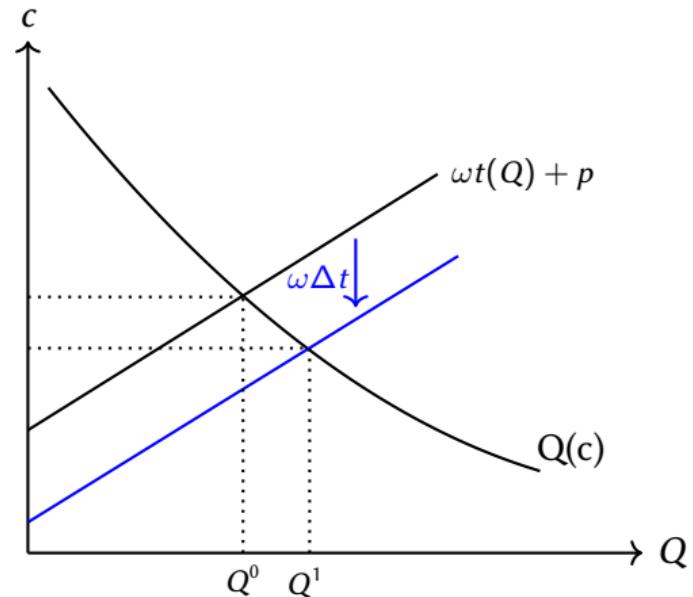
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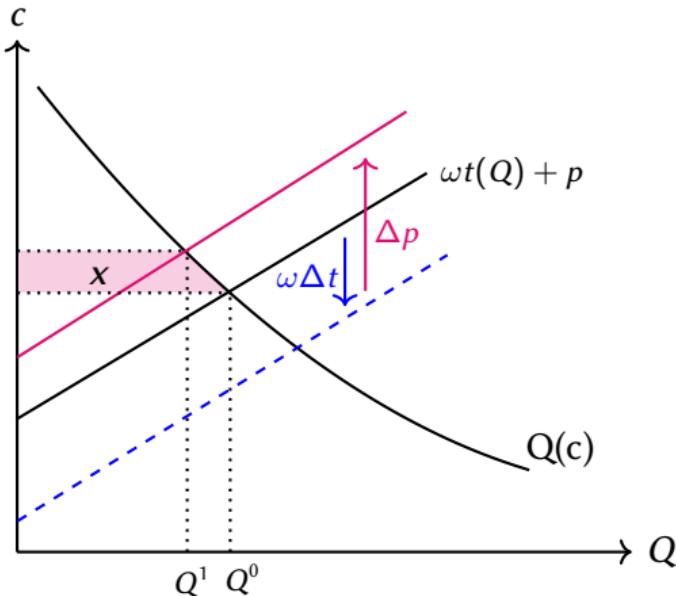


(b) Unpriced trip

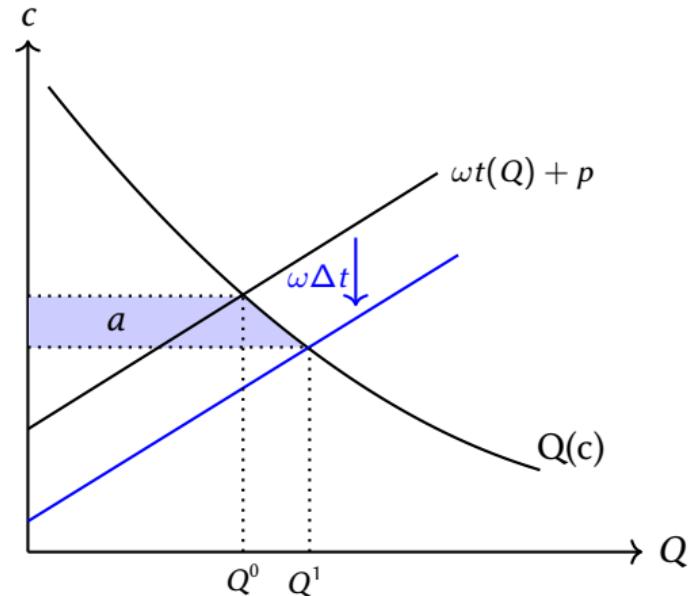


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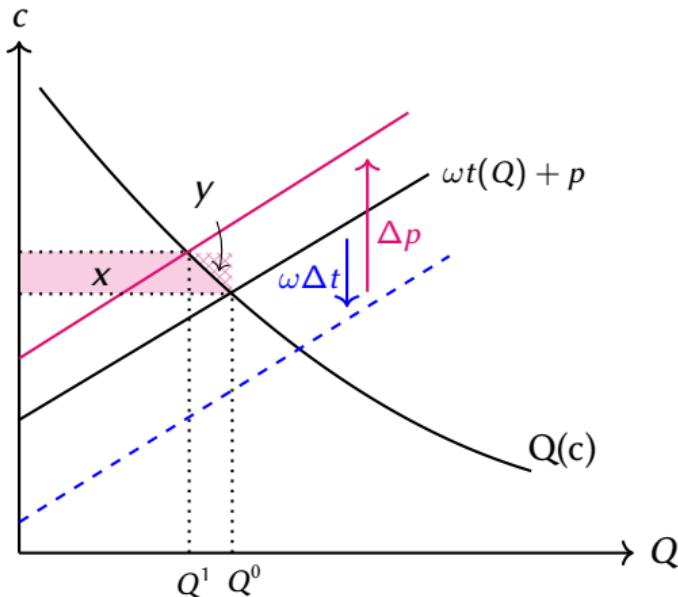


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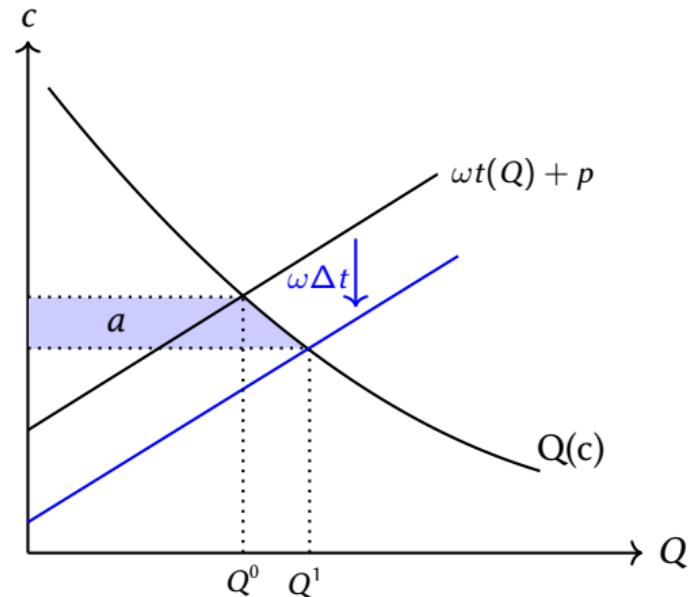


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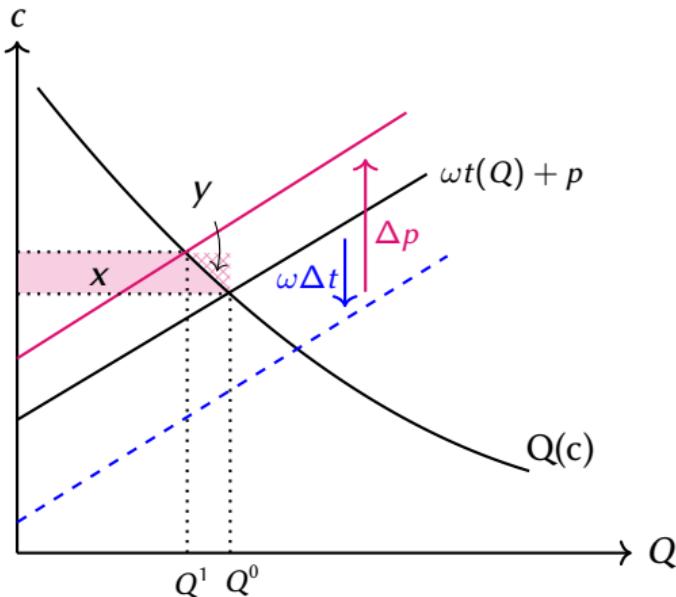


(b) Unpriced trip

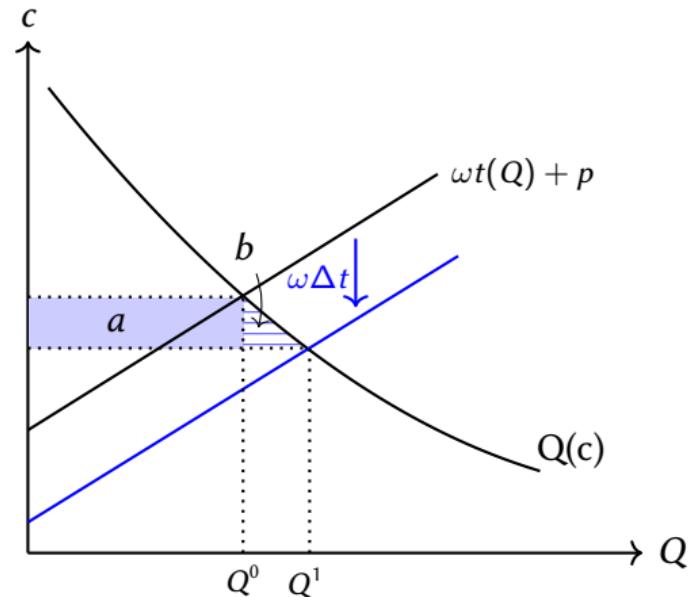


## Lower-bounds on change in driver welfare

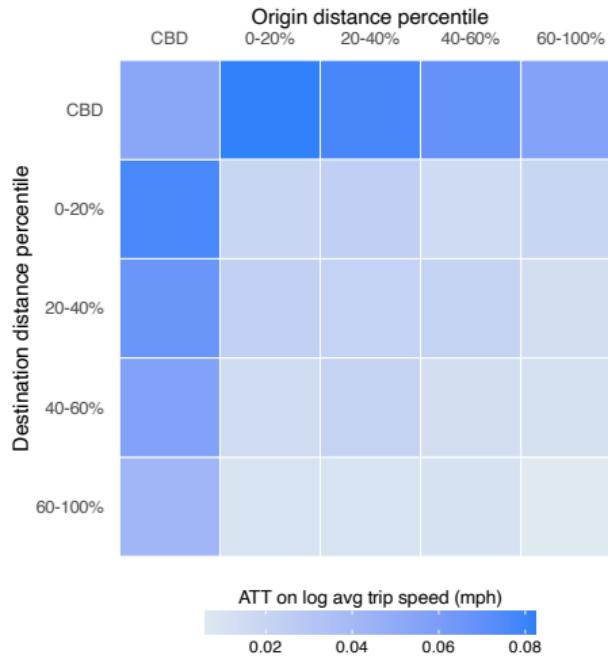
(a) Priced trip



(b) Unpriced trip



## Welfare gains come from *unpriced* trips



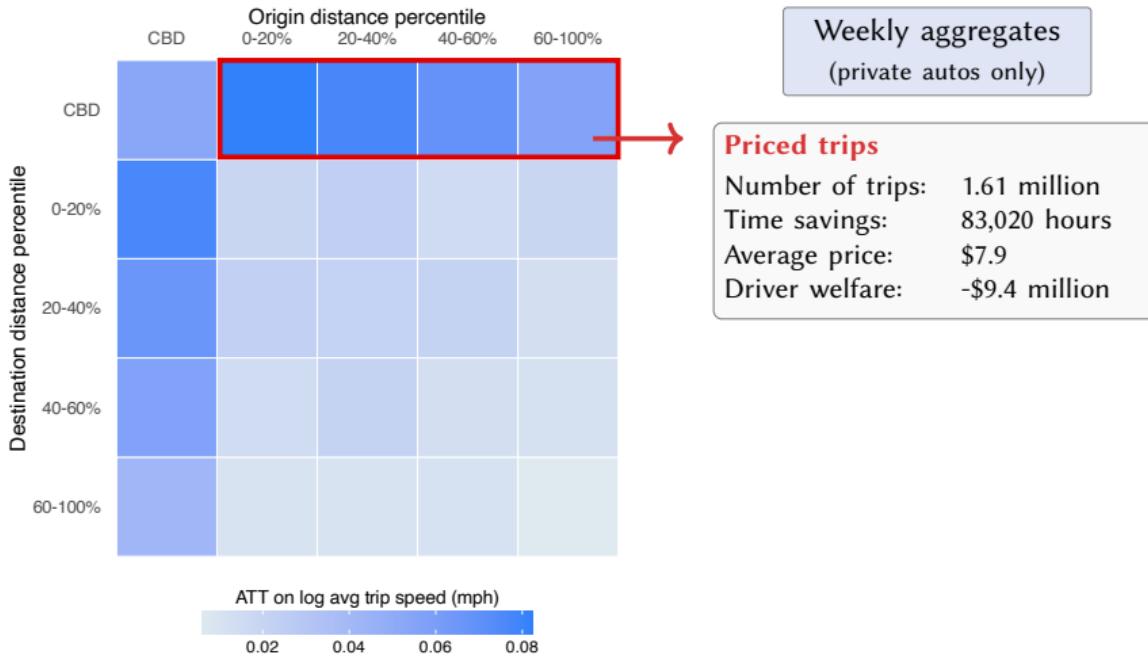
Note: Number of trips is the average tract-to-tract passenger car trips from Replica for 2025. Average price is approximated and is below \$9 because of crossing credits for some entries. The welfare estimates are computed for each cell separately and assume a Value of Travel Time (VOTT) of \$40/hour and no revenue recycling. All ATTs are significant at the 95% level with standard errors clustered by city.

► Map of bins

► Trip counts

► OD welfare

# Welfare gains come from *unpriced* trips



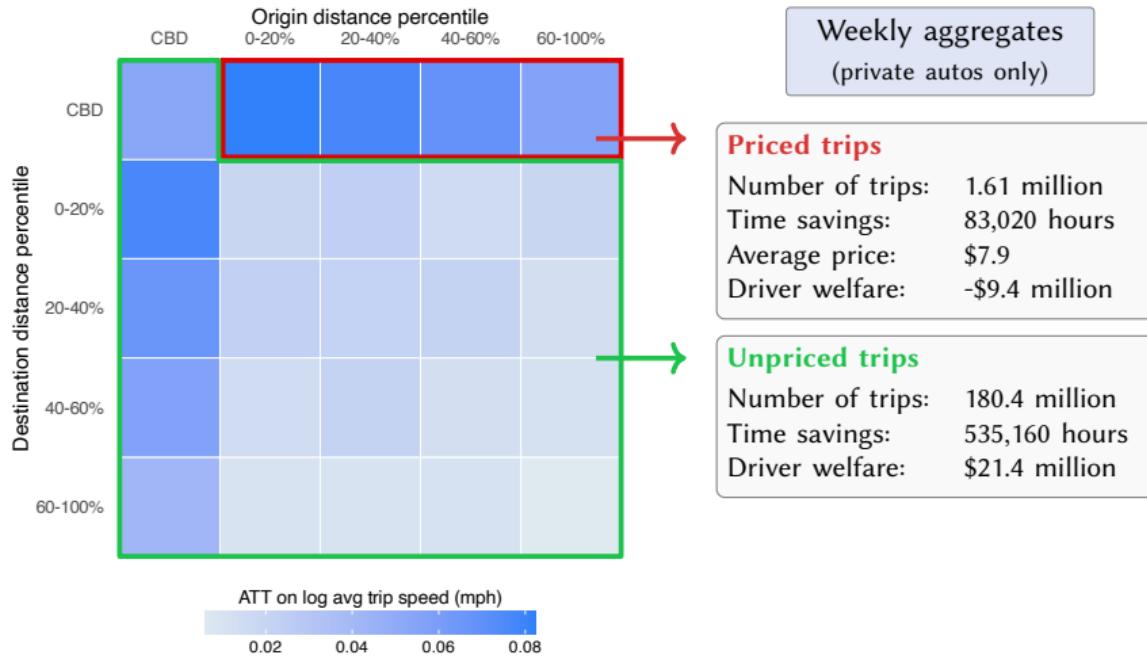
*Note:* Number of trips is the average tract-to-tract passenger car trips from Replica for 2025. Average price is approximated and is below \$9 because of crossing credits for some entries. The welfare estimates are computed for each cell separately and assume a Value of Travel Time (VOTT) of \$40/hour and no revenue recycling. All ATTs are significant at the 95% level with standard errors clustered by city.

► Map of bins

► Trip counts

► OD welfare

# Welfare gains come from *unpriced* trips



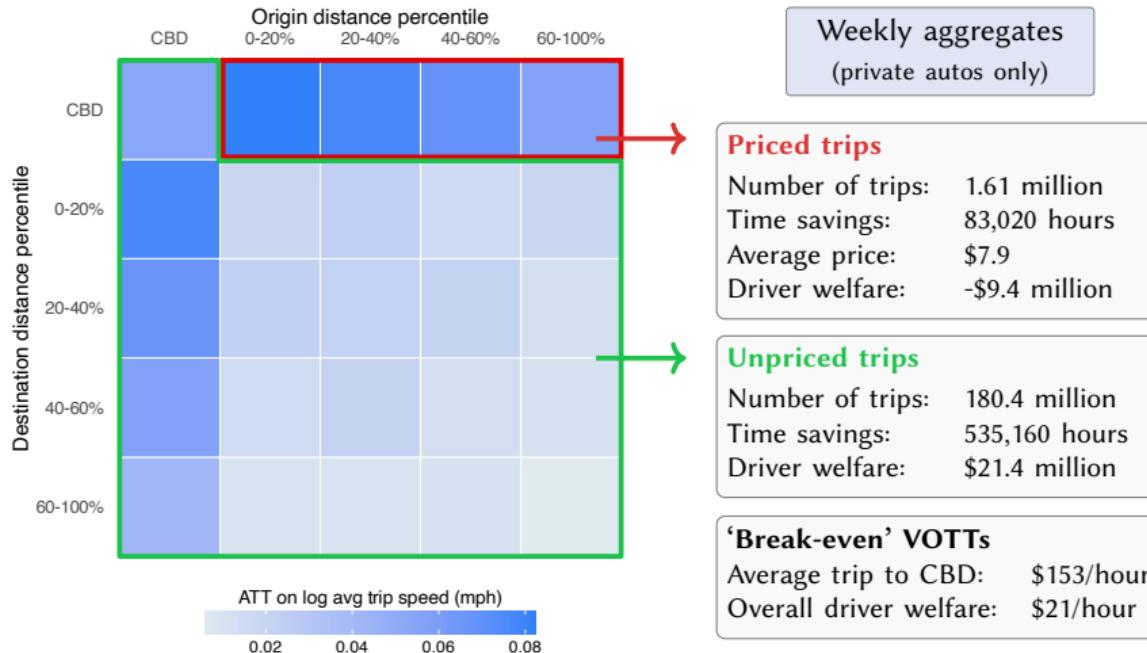
*Note:* Number of trips is the average tract-to-tract passenger car trips from Replica for 2025. Average price is approximated and is below \$9 because of crossing credits for some entries. The welfare estimates are computed for each cell separately and assume a Value of Travel Time (VOTT) of \$40/hour and no revenue recycling. All ATTs are significant at the 95% level with standard errors clustered by city.

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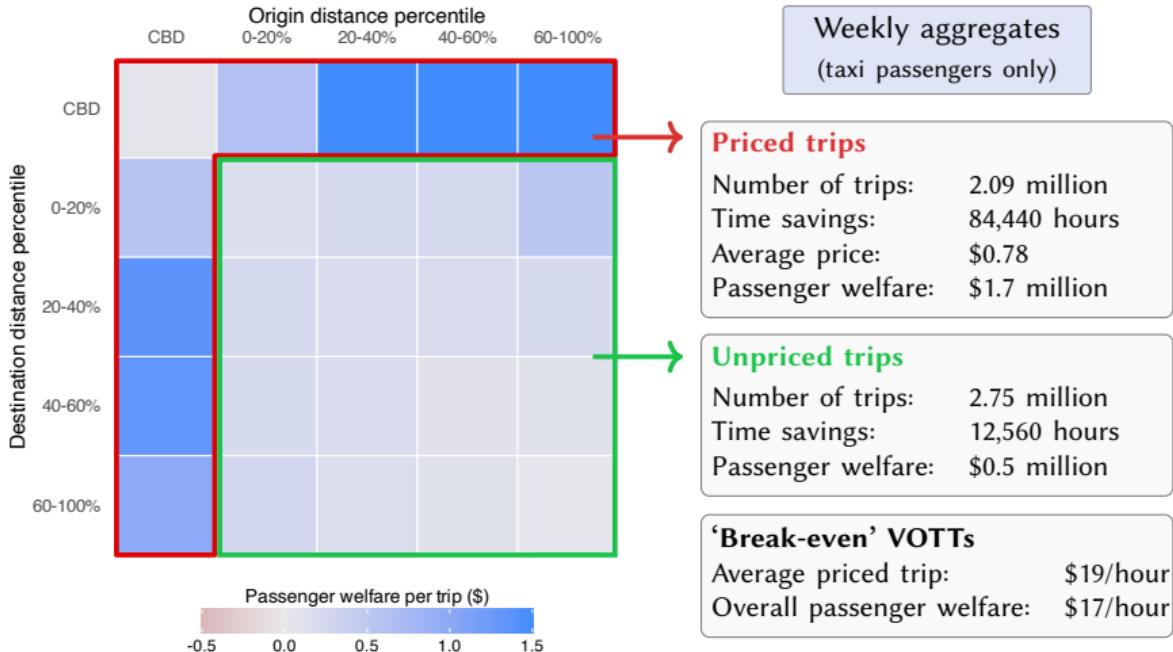
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► Map of bins

► Trip counts

► OD welfare

# Taxi passenger welfare per trip by OD



*Note:* Number of trips is the average tract-to-tract taxi/FHV trips from Replica for 2025. Average price is based on share of taxi trips (\$0.75) and FHV trips (\$1.50). The welfare estimates are computed for each cell separately and assume a Value of Travel Time (VOTT) of \$40/hour and no revenue recycling. All ATTs are significant at the 95% level with standard errors clustered by city.

## Environmental benefits from improved fuel economy

Per-week effects so far:

Passenger vehicle drivers	+\$12 million
Taxi/FHV passengers	+\$2.2 million
Approx revenue	+\$14 million

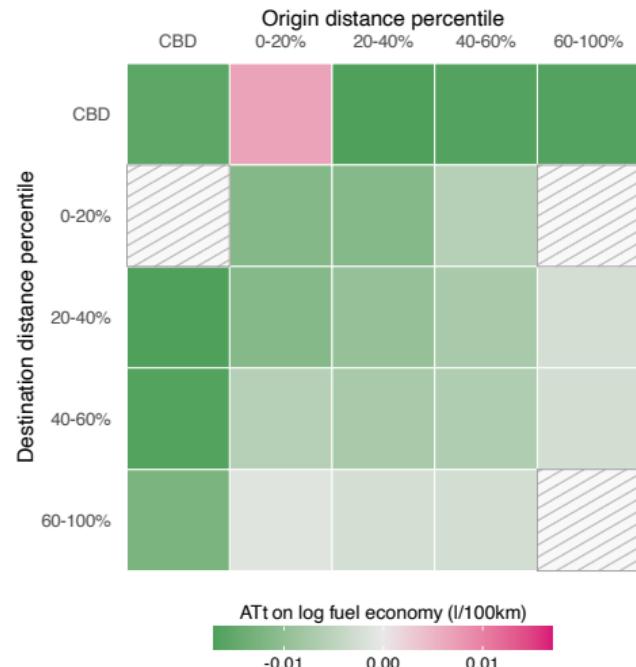
# Environmental benefits from improved fuel economy

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Environmental benefits?

- ▶ Compute ATTs on estimated fuel consumption by origin-destination



Note: This figure documents the ATT on log fuel economy (l/100km) for trips in each OD pair. Grey hash marks represent estimates that are not significantly different from zero at the 95% level, with standard errors clustered at the city-level.

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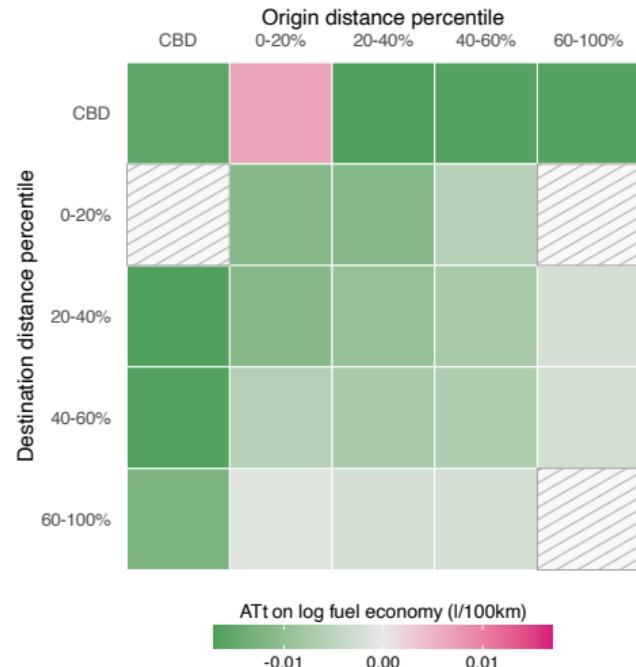
Environmental benefits?

- ▶ Compute ATTs on estimated fuel consumption by origin-destination
- ▶ Implied savings of:

74,700 gallons per week (0.28%)

≈ 653 tonnes of CO<sub>2</sub>

≈ \$120,900 in social cost of CO<sub>2</sub>



Note: This figure documents the ATT on log fuel economy (l/100km) for trips in each OD pair. Grey hash marks represent estimates that are not significantly different from zero at the 95% level, with standard errors clustered at the city-level.

## How well would congesting pricing work in other cities?

Effects of cordon-based congestion pricing depend on:

1. How **prices** affect **volumes**
2. Exposure of other drivers to changes in CBD **volumes**
3. Relationship between **volumes** and **speeds** on different roads

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Consider two extremes:

CBD trips begin just outside CBD zone or traverse roads already at free-flow

- ~> No effect of congestion pricing

CBD trips begin at metro fringe and traverse very congested roads

- ~> Large effects?

## Exposure to CBD trips

### How exposed are drivers in a city to CBD trips?

- ▶ For a given set of trips, compute **duration-weighted average exposure** using our segment-level co-occurrence measures:

$$\bar{e}_l = \frac{1}{|R_l|} \sum_{i \in R_l} \sum_{s \in R_i} \frac{t_{is} \times c_s}{t_i}$$

where  $R_l$  is the set of trips of type  $l$ , each trip  $R_i \in R_{od}$  is composed of segments  $R_i = \{s_1, s_2, \dots, s_j\}$ ,  $t_{is}$  is time on segment  $s$ ,  $t_i$  is the total travel time, and  $c_s$  is the co-occurrence of segment  $s$

- ▶ Compute for each city for trips to, from, and outside the CBD

## Congestion function: road density → speed

### What are the effects of removing marginal drivers on road speeds?

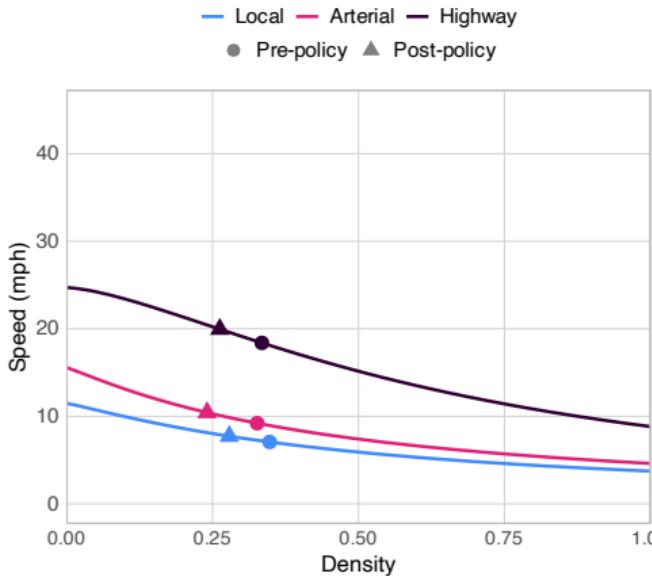
- ▶ Depends on road type & current volumes
  - Smooth highway vs bumpy local road
  - Relationship often convex; no effects at free-flow or past bottleneck
- ▶ Estimate congestion functions for different roads. Functional form from Bureau of Public Roads (BPR):

$$\frac{1}{v_g} = \frac{1}{v_{FF}} \left[ 1 + \alpha \left( \frac{\rho_g}{\kappa} \right)^\beta \right]$$

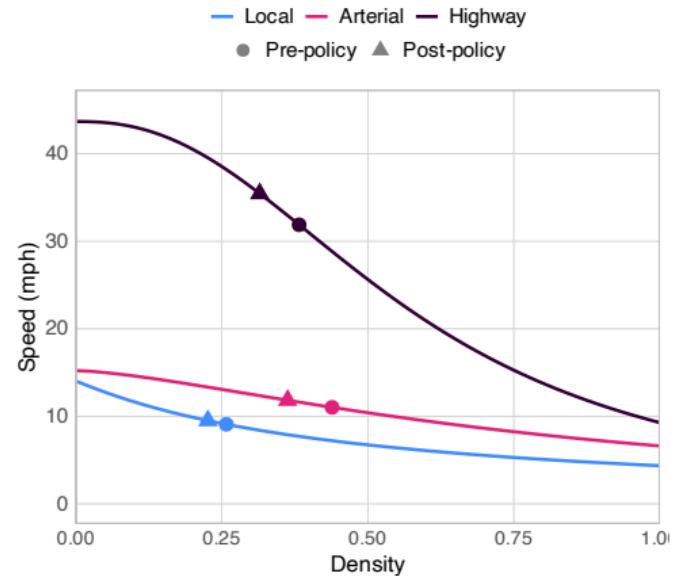
- ▶ Estimate separately for each road type ( $r$ )  $\times$  co-occurrence bin ( $c$ )
  - Data: hourly average speeds and pseudo-density (based on partial flows)
- ▶ Compute duration-weighted average local elasticity for trips to, from, and outside the CBD

## Example congestion functions

(a) CBD roads (NYC)



(b) 80-60% co-occurrence (NYC)



Note: This figure plots estimated congestion functions for roads in NYC. Circles are added to each line based on the raw average speed before the policy's implementation. Triangles are based on the post-period speed, which is computed as the pre-period speed plus the estimated ATT on speeds.

## Potential for effects in other cities

City	Avg. exposure ( $\bar{e}_l$ )			Avg. elasticity of CF ( $\bar{\eta}_l$ )		
	To CBD	From CBD	Outside CBD	To CBD	From CBD	Outside CBD
NYC	57.6%	58.7%	3.0%			
Philadelphia	54.6%	54.9%	3.2%			
Chicago	62.2%	62.7%	7.1%			
Boston	55.4%	55.5%	7.6%			
Atlanta	51.1%	51.8%	7.4%			
Baltimore	49.6%	49.8%	5.3%			

Note: The first three columns document the average exposure to the policy for trips to, from, and outside the CBD, measured as the weighted average co-occurrence of segments traversed with weights corresponding to the average duration on each segment. The latter three columns document the average elasticity of the congestion functions (CF) of roads traversed on each trip type, again weighting by the average duration spent on a given segment type. In each case, we compute averages for each OD pair then aggregate to trip type using pre-period flows as weights.

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Philadelphia	54.6%	54.9%	3.2%	-0.254	-0.250	-0.215
Chicago	62.2%	62.7%	7.1%	-0.325	-0.320	-0.170
Boston	55.4%	55.5%	7.6%	-0.387	-0.384	-0.205
Atlanta	51.1%	51.8%	7.4%	-0.336	-0.334	-0.239
Baltimore	49.6%	49.8%	5.3%	-0.255	-0.254	-0.214

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## Conclusion

- ▶ Policy improved speeds in the CBD roads by 11% over first six months
  - Little-to-no effects on air quality, visits to shops/restaurants, and foot traffic
- ▶ Spillovers throughout the metro area
  - Higher co-occurrence with CBD trips  $\implies$  larger speed increases
  - Welfare gains come from the *unpriced* trips
    - ▶ The “losses” are concentrated on CBD-bound trips, the “gains” are diffuse
- ▶ Mechanisms: volume response + exposure + congestion functions
  - NYC outside the CBD: low average exposure but steep congestion functions
  - Boston more promising than Philadelphia or Baltimore

**Thank you!**

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## Pollution data from PurpleAir

We use day-sensor level measures of PM2.5 from PurpleAir. There are 22 outdoor sensors in the NYC CBD. There are few sensors in our control city CBDs, so we use data from 800 sensors throughout the control metro areas when computing ATTs.

We follow EPA's recommended calibration method for PurpleAir data ([Barkjohn et al., 2022](#)) to clean the data:

1. Drop records where difference between A and B channels is over  $5\mu\text{g}/\text{m}^3$  or relative difference is over 70%
2. Calibrate adjusted PM2.5 measures using EPA's formula and the relative humidity measurement
3. Aggregate to the day level, dropping any that have fewer than 18 hours of observations
4. Impute missing sensor-date PM2.5 values using a regression with interacted sensor, month, and day of week fixed effects.

## Transactions data from MBHS3 (Jan 2024-April 2025)

The data are at the day-zipcode level. Category is defined using 3-digit NAICS. We weight ATTs by the outcome total (transactions or spend) in the pre-period

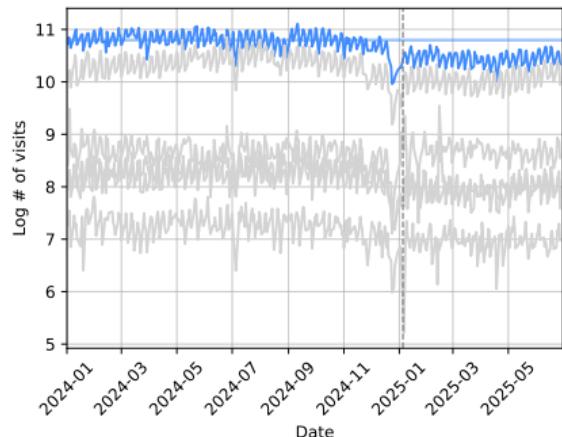
City	Category	All			CBD-only		
		Count (millions)	Amount (millions \$)	Avg. size (\$/trans.)	Count (millions)	Amount (millions \$)	Avg. size (\$/trans.)
NYC	Restaurant	164.7	4613.2	28.0	26.1	941.7	36.0
	Retail	286.1	13247.0	46.3	39.6	2196.0	55.4
PHL	Restaurant	88.5	2291.9	25.9	3.9	125.3	32.1
	Retail	168.6	7549.0	44.8	3.2	115.0	35.5
CHI	Restaurant	114.2	2773.8	24.3	5.8	172.5	29.7
	Retail	148.2	7425.8	50.1	3.7	137.5	37.3
BOS	Restaurant	59.2	1433.1	24.2	0.8	25.6	32.4
	Retail	68.4	3390.8	49.6	0.2	15.9	79.2
BAL	Restaurant	61.7	1066.6	17.3	—	—	—
	Retail	58.4	2644.8	45.3	—	—	—
ATL	Restaurant	141.7	3368.8	23.8	3.6	90.3	25.2
	Retail	190.0	8995.0	47.3	1.2	43.2	37.2
Total	Restaurant	629.9	15547.4	24.7	40.2	1355.6	33.7
	Retail	919.7	43252.4	47.0	47.9	2507.5	52.3

Note: This table documents the aggregate number of transactions and total spending in the MBHS3 data for zipcodes within each of the sample cities. The Baltimore CBD is small and there are no zipcodes whose centroids lie within it.

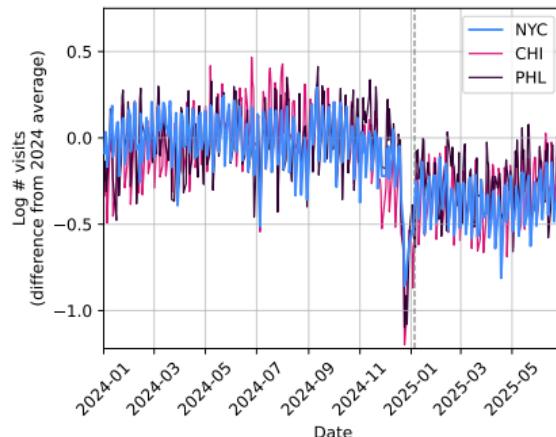
# Foot traffic data from Advan Neighborhood Patterns (Jan 2024-June 2025)

We use data at the day-tract level, aggregating foot traffic across all peak hours that day. We weight the ATTs by the number of pre-period stops in a tract

(a) Log average stops per day

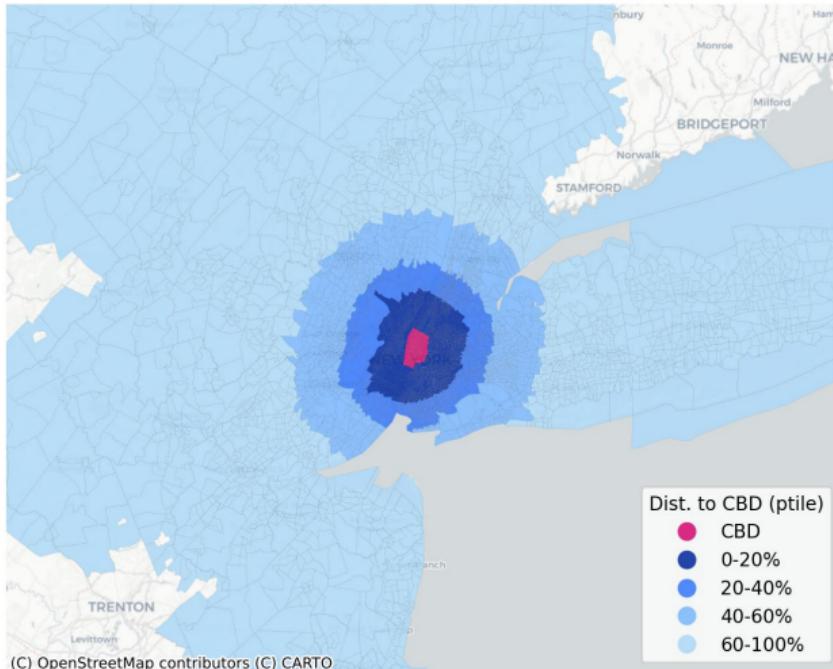


(b) Log stops relative to 2024 average



Note: These figures plot daily CBD foot traffic, restricted to weekday peak hours (5am to 9pm). The first panel plots the log total number of visits. The blue horizontal line is the pre-period average for the NYC CBD. The second panel restricts attention to the three largest cities and plots the difference in log trips between a given date and the 2024 average.

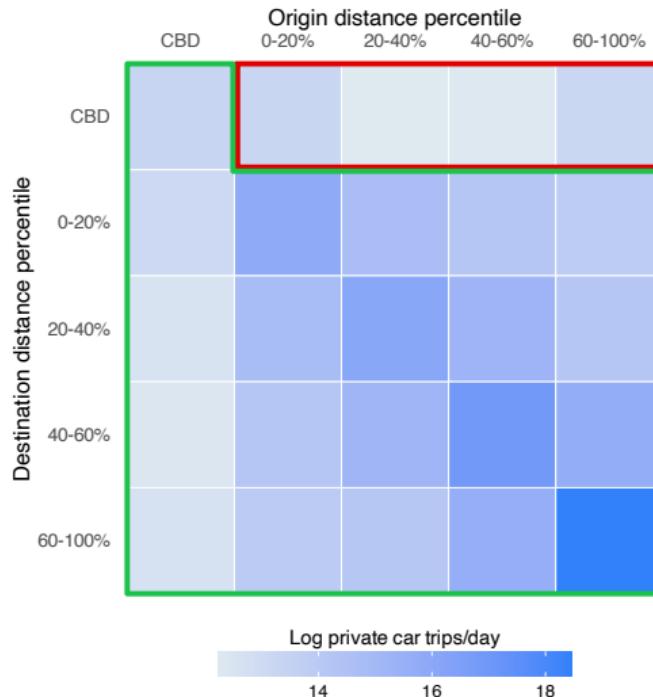
## Distance from CBD for NYC metro area



Note: The boundaries are based on the Core Based Statistical Area boundaries. The map is zoomed in slightly to make the CBD more visible; the CBSA extends further in each direction, especially east down Long Island. Distance to CBD is based on the distance between centroid and the closest point of the CBD.

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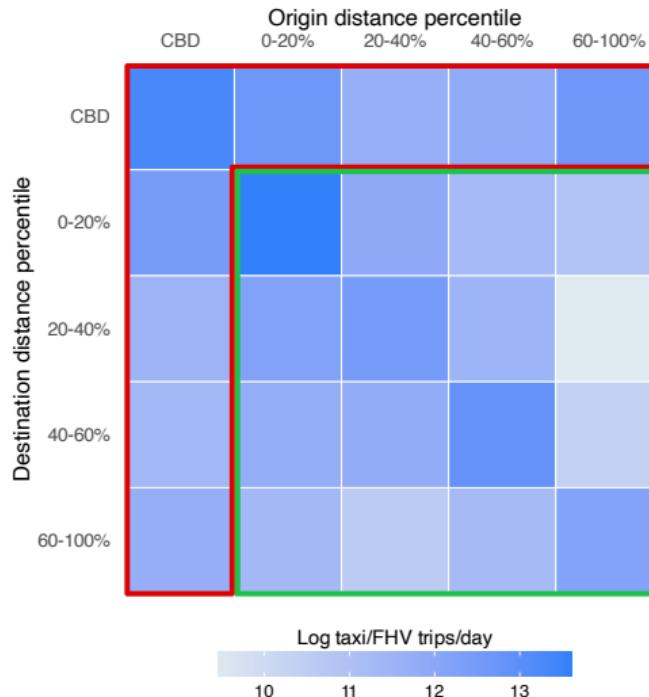
## Private auto trips by origin/destination



*Note:* We compute trips between each OD using a combination of data from Replica and MTA. Replica estimates are used for all trips that do not end in the CBD. For trips to the CBD, we scale the Replica estimates to match the total number of personal auto entries from the MTA. All data are for Jan-June 2025.

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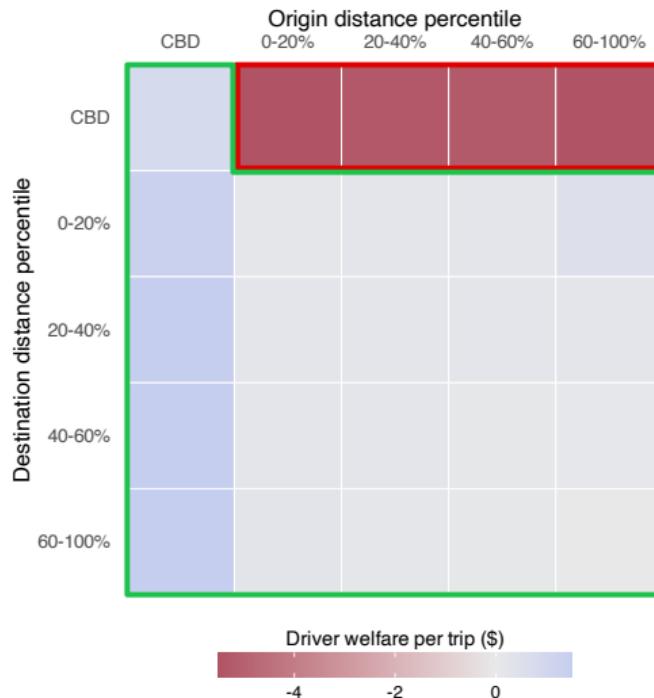
## Taxi/FHV trips by origin/destination



*Note:* We compute trips between each OD using a combination of data from Replica and MTA. Replica estimates are used for all trips that do not end in the CBD. For trips to the CBD, we scale the Replica estimates to match the total number of taxi/FHV from the MTA. All data are for Jan-June 2025.

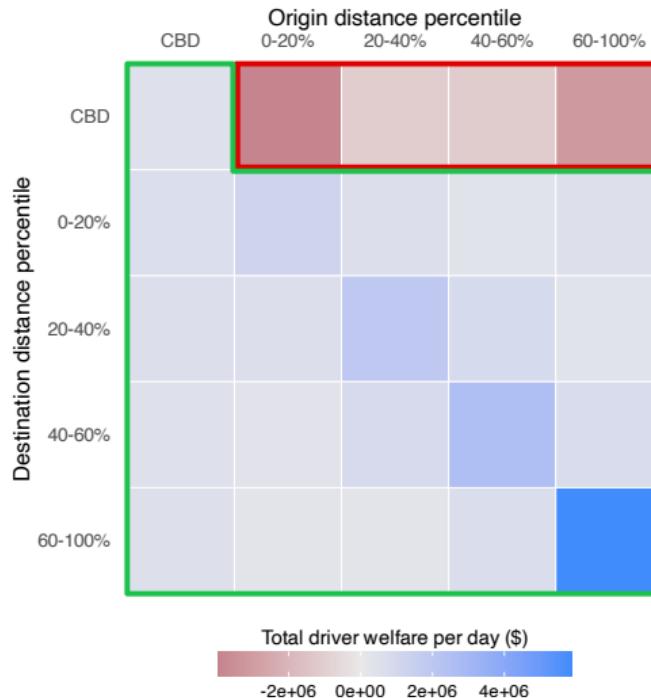
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## Driver welfare per trip by OD



*Note:* Grey hashes indicate results that are not statistically different from zero, which are not used for the aggregate effects. The welfare estimates are computed for each cell separately and assume a Value of Travel Time (VOTT) of \$40/hour and no revenue recycling.

## Total driver welfare by OD



*Note:* Grey hashes indicate results that are not statistically different from zero, which are not used for the aggregate effects. The welfare estimates are computed for each cell separately and assume a Value of Travel Time (VOTT) of \$40/hour and no revenue recycling.

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