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Analysis

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Impacts of micromobility on car displacement with evidence from a natural experiment and geofencing policy

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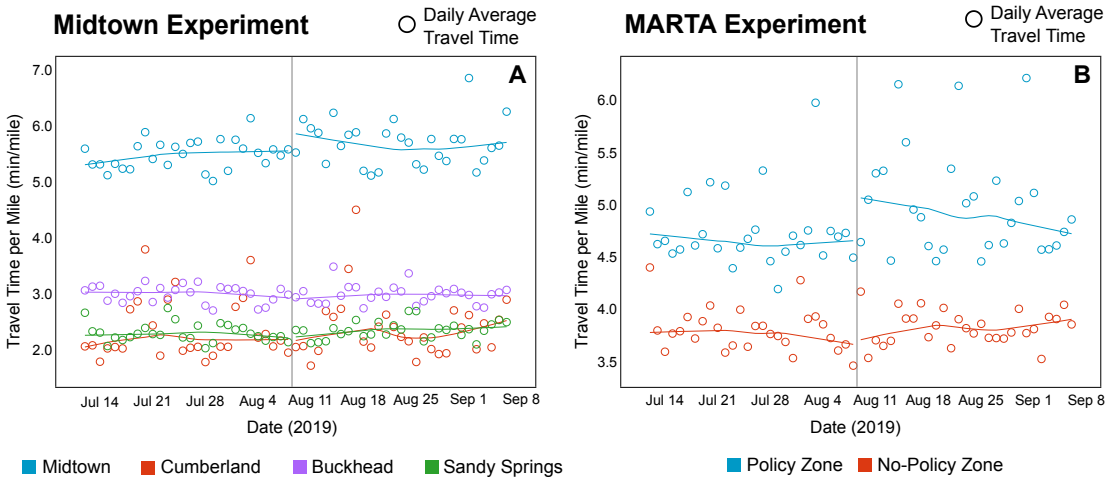
Supplementary Figure 1: Test of parallel time trends assumption.



The figure shows parallel trends of daily evening average travel per mile for 30 days pre and post policy. The unshaded circles correspond to the average travel time for a given day and area. The vertical grey line depicts the start of the micromobility ban, which began on August 9, 2019. The trendlines serve as a visual guide for pre-trends and are created using Locally Weighted Scatterplot Smoothing (LOWESS).

Supplementary Table 1: Dynamic treatment effects in Midtown experiment.

	Days since policy implementation												
	1	2	3	4	5	10	15	20	25	30	35	40	45
Effect size	0.471*	0.703***	0.834***	0.823***	0.569 ***	0.042	0.093	0.191**	0.224***	0.225***	0.268 ***	0.271***	0.239***
Standard error	(0.258)	(0.197)	(0.167)	(0.148)	(0.138)	(0.117)	(0.096)	(0.085)	(0.079)	(0.074)	(0.071)	(0.069)	(0.067)
F-Statistic	611.17	628.64	649.95	668.79	678.95	753.17	818.23	878.41	936.64	52.68	1,010.68	1,083.59	1,135.59
Number of Observations	16,814	17,250	17,630	18,001	18,378	20,459	22,464	24,493	26,569	28,562	30,228	31,968	33,771

*Significant at the level p < *0.1, **0.05, ***0.01*

All models include controls for weather, tract characteristics, time, and traffic alternatives. We adjust for multiple counterfactual comparisons using a triple-differences estimator.

Supplementary Table 2: Dynamic treatment effects in MARTA experiment.

	Days since policy implementation												
	1	2	3	4	5	10	15	20	25	30	35	40	45
Effect size	-0.464	0.057	0.217	0.310	0.213 **	0.278*	0.267 **	0.224 **	0.271 ***	0.223 **	0.209 **	0.247 ***	0.254***
Standard error	(0.424)	(0.286)	(0.233)	(0.204)	(0.183)	(0.136)	(0.116)	(0.104)	(0.096)	(0.091)	(0.086)	(0.083)	(0.081)
F-Statistic	26.80	27.76	28.85	30.11	30.49	35.61	40.61	43.72	49.12	51.75	54.76	60.99	65.29
Number of Observations	6,398	6,544	6,688	6,830	6,974	7,702	8,426	9,157	9,890	10,616	11,336	12,065	12,794

*Significant at the level p < *0.1, **0.05, ***0.01*

All models include controls for weather, tract characteristics, time, and traffic alternatives. We estimate the dynamic effect size using difference-in-differences estimator.

Supplementary Table 3. Descriptive statistics for travel times per mile, 7:00pm to midnight.

Dependent variable		Mean	S.D.	Min	Max	Observations
Recurring mobility						
Midtown experiment	Midtown tracts	5.69	1.68	1.70	22.80	3,552
	Cumberland tracts	2.36	0.96	0.78	9.14	2,550
	Buckhead tracts	3.01	0.66	1.34	5.95	2,550
	Sandy Springs tracts	2.34	0.97	0.59	13.97	25,842
MARTA experiment	Policy zone subway tracts	4.91	2.38	1.16	29.25	10,465
	No-policy zone subway tracts	3.80	1.58	1.34	12.23	2,518
Event-based mobility						
Mercedes Benz experiment	Stadium tract	7.60	2.72	2.43	13.35	120

The table describes the dependent variable for the treatment and control groups used in the three experiments in the study.

Supplementary Table 4: Descriptive statistics for Midtown and counterfactual tracts.

	Midtown tracts				Counterfactual tracts				t-test
	Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	p-value
Demographics									
Population	3,966	1,188.7	1,910	5,317	4,920	1,536	1,920	7,768	0.09
Median age	33.99	5.73	26.0	44.60	38.07	7.67	27.9	55.5	0.14
Median income	53,333	16,797	30,290	84,593	51,673	14,158	29,051	83,800	0.81
Vehicles owned/person	0.42	0.10	0.28	0.52	0.48	0.11	0.30	0.68	0.19
Educational attainment	1,184.4	488.4	493.0	1,633	1,467.2	567.8	690	2,954	0.21
Share of non-white population	0.31	0.09	0.20	0.46	0.32	0.20	0.03	0.75	0.77
Transit Characteristics									
Transit score [1-10]	9.3	0.3	8.9	9.6	5.5	2.1	2.0	9.0	0.00
No. of transit routes	41.9	16.2	11.0	61.0	3.7	2.9	1.0	11.0	0.00
Walk score [1-100]	82.9	11.0	62.0	91.0	28.7	21.4	0.0	73.0	0.00
No. bike share hubs	4.6	1.9	2.0	7.0	0.6	1.8	0.0	9.0	0.00
Travel time to work	53,089	23,256	17,140	79,435	66,672	23,409	17,510	105,910	0.20
School enrollment									
Total	866.3	456.7	347.0	1,498.0	1,020.0	392.3	243.0	1,644.0	0.43
K-12	229.4	197.0	62.0	606.0	625.3	341.6	51.0	1,393.0	0.00
College	605.7	419.7	178.0	1,436.0	320.4	203.8	29.0	966.0	0.13

The table describes demographic, transit characteristics and school enrollment per tract for the treatment and counterfactual areas in the Midtown experiment. The Midtown and counterfactual areas are statistically similar in population size, median age, median income, vehicles owned per person, total school enrollment, and college enrollment. The Midtown area includes 7 census tracts. The counterfactual areas include Cumberland (6 tracts), Buckhead (6 tracts), and Sandy Springs (21 tracts), which were chosen as adjacent urbanized areas with and without scooter deployment (see Figure 1). Demographics and school enrollment are from the 2015 American Community Survey and the transit characteristics are collected from publicly available data provided by transit agencies, available at AllTransit™. Travel time to work is defined as the aggregate travel time to work of all workers 16 and older in minutes. The two-sided t-test p-value comparing Midtown tracts and counterfactual tracts is shown in the final column.

Supplementary Table 5: Data dictionary for urban mobility dataset.

Variable	Description	Data Type	Source
Origin Tract	Origin census tract for trip.	Integer	Uber Movement
Destination Tract	Destination census tract for trip.	Integer	Uber Movement
Date	Date in which trip occurred.	String	Uber Movement
Origin Area	Origin area for trip (Midtown, Buckhead, Cumberland, Sandy Springs).	String	Uber Movement
Destination Area	Destination area for trip (Midtown, Buckhead, Cumberland, Sandy Springs).	String	Uber Movement
Distance	Straight line distance from the centroid between census tracts (miles).	Float	Author derived
Travel Time	Trip duration (min).	Float	Uber Movement
Post	Binary variable indicating whether trip occurred after the ban.	Boolean	Author derived
Treated	Binary variable indicating whether trip began in census tract affected by the ban.	Boolean	Author derived
Scooter	Binary variable indicating whether trip began in census tract with scooters available.	Boolean	Author derived
Month	Month in which trip occurred.	Integer	Uber Movement
Day of Week	Day of week in which trip occurred.	String	Uber Movement
Vehicles	Aggregate number of vehicles used in commuting by workers whose means of transportation is car, truck, or van within a census tract.	Integer	All Transit
Transit Routes	Number of transit routes within half a mile of an average block group.	Integer	All Transit
Bike Hubs	Number of bike shares within half a mile of transit.	Integer	All Transit
Walk Score	Integer between 0-100 measuring the walkability of a census tract.	Integer	All Transit
Total School	Count of students enrolled in school by Census tract.	Integer	2015 American Community Survey
Event	Binary variable indicating whether trip occurred on the day of a large event at the Mercedes Benz Station or State Farm Arena.	Integer	Author derived
Festival	Binary variable indicating whether a highly attended music festival occurred in Midtown tracts on a given day.	Integer	Author derived
Precipitation	Binary variable indicating whether there was evening precipitation in a tract on a given day.	Integer	NOAA, National Centers for Environmental Information

Supplementary Table 6: Robustness to additional controls for tract populations with high-variability summer travel.

	School Enrollment Controls? †	I Diff-in-diff Estimator	II Triple-differences Estimator
Midtown Experiment	No	0.202***	0.234***
		(0.025)	(0.036)
	Yes	0.201***	0.241***
		(0.025)	(0.035)
MARTA Experiment	No	0.253***	--
		(0.051)	
	Yes	0.255***	--
		(0.051)	

*Significant at the level p < *0.1, **0.05, ***0.01. Standard errors are clustered at the origin tract level and are shown in parentheses.*

† Total school enrollment is used as a proxy for households with children. The source data is from the 2015 American Community Survey and is aggregated at the tract-level. In the Midtown Experiment, we also adjust for multiple counterfactual comparisons using a triple-differences estimator.

Supplementary Table 7: Robustness of model estimates to various clustering levels for the Midtown experiment.

I Clustering Levels	II No. of Spatial Clusters	III No. of Temporal Clusters	IV DD Estimator	V DDD Estimator†
One-way (origin tract)	13 (DD), 40 (DDD)	--	0.191*** (0.024)	0.238*** (0.035)
Two-way (origin tract and day of week)	13 (DD), 40 (DDD)	7 (DD), 7 (DDD)	0.191** (0.053)	0.238*** (0.039)
Two-way (origin tract and week number)	13 (DD), 40 (DDD)	12 (DD), 9 (DDD)	0.191* (0.107)	0.238*** (0.064)

*Significant at the level p < *0.1, **0.05, ***0.01. Standard errors are shown in parentheses.*

† We use procedures for multiway clustering described in Cameron, Gelbach, and Miller (2011). The secondary counterfactuals used for the triple-differences estimator include tracts from the Buckhead and Sandy Springs communities.

Supplementary Table 8: Placebo test with data 12 months prior to the natural experiment (Midtown tracts, July through September 2018).

Experiment Number	I Clustering Levels	II DDD Estimator	III Number of Observations
1	Origin tract	0.047 (0.064)	20,189
2	Origin tract + month	0.048 (0.053)	20,189
3	Origin tract + day of week	0.052 (0.091)	20,189

*Significant at the level p < *0.1, **0.05, ***0.01. Standard errors are shown in parentheses.*
We adjust for multiple counterfactual comparisons using a triple-differences estimator.

Supplementary Table 9: Placebo test with data up to 2 months prior to the ban.

Clustering Levels	I Midtown (DD Estimator)	II Midtown (DDD Estimator)	III MARTA (DD Estimator)
Origin tract	-0.038	-0.036	0.041
	(0.047)	(0.054)	(0.051)
Origin tract + month	-0.038	-0.036	0.041
	(0.152)	(0.068)	(0.052)
Origin tract + day of week	-0.038	-0.036	0.041
	(0.097)	(0.148)	(0.081)
Observations	2,931	16,406	6,255

*Significant at the level p < *0.1, **0.05, ***0.01. Standard errors are shown in parentheses.*
We adjust for multiple counterfactual comparisons using a triple-differences estimator in Column II.