Online Appendix: How do commuters adapt to local pollution pricing?

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A   London's ULEZ policy in detail

A.1   Policy overview

The Ultra Low Emission Zone (ULEZ) is an area of London for which an emission-standard based daily levy of £12.50 applies to non-compliant vehicles. The zone operates 24 hours a day, seven days a week. The daily charge currently applies to residents of the ULEZ as well as commuters. This was not always the case. The criteria for charging the levy is based on European emission standards. A penalty charge of £180 is applied for non-compliance. This charge is in addition to the Congestion Charge (CC) and applies to cars, motorcycles, vans, specialist vehicles (up to and including 3.5 tonnes) and minibuses. Vans and minibuses are also be subject to Low Emission Zone (LEZ) charges. Boris Johnson, then Mayor of London, announced the zone (covering the same central area as the Congestion Zone in 2015) would come into effect in September 2020. Sadiq Khan, Johnson's successor, introduced the Toxicity charge or "T-charge", a £10 emissions surcharge for older, more polluting vehicles in October 2017, which covered the same area as the Congestion Zone. The T-charge was replaced by the ULEZ when it came into effect in April 2019, ahead of schedule. The ULEZ was expanded out to the North and South Circular roads in 2021. In November 2022, Sadiq Khan announced the expansion of the zone to cover all 32 London boroughs from August 2023. This matches the existing Low Emissions Zone (LEZ) boundary.

The expanded ULEZ is part of the effort to help improve air quality in and around London and reduce the impact on the health of residents and visitors to the city. The ULEZ is principally aimed at reducing levels of two key air pollutants from vehicle exhausts: nitrogen dioxide (NOx) and fine particle matter (PM). These pollutants have been linked to premature deaths and stunted growth of children's lungs.

A.2   Scrappage and retrofit schemes

A scrappage scheme was introduced to help those on income support or disability benefit to comply with ULEZ standards. The original 2019 scheme offered up to £7,000

compensation for a car or van plus up to £2,500 if it was replaced by an electric vehicle. However, when ULEZ was expanded in 2021, the £61m scrappage scheme reduced the compensation to £2,000 for cars (and for a limited number of vans and £15,000 for heavy vehicles).

The ULEZ schemes also allows some vehicles to retrofit emissions reduction technology to meet Euro VI-equivalent levels of emissions. A vehicle with retrofitted emissions technology needs to be certified by the Government's Clean Vehicle Retrofit Accreditation Scheme (CVRAS). The CVRAS register contains approved and Clean Air Zones (CAZ) compliant companies and emission reduction systems, based on make, model and engine type. The CVRAS certifies emission technologies for black taxis, vans, minibuses, motorhomes, buses, coaches, HGVs and refuse vehicles.

Financial assistance to scrap or retrofit non-compliant vehicles in preparation for the latest expansion of the ULEZ (August 2023) was announced at the end of July 2023, and offers £2,000 for scrapping a car and £1,000 for motorcycles, and £5,000 for wheelchair accessible vehicles. Parts of the scrappage payment is converted to an annual bus and tram pass. Between £5,000 and £9,500 grant is available for scrappage or retrofit of vans and minibuses used by small businesses, sole traders, and charities. It was initially open to people on low incomes, disability benefits and child benefit as well as some businesses but was extended to all Londoners and small businesses on the 21 August 2023.

A.3 Vehicle rules

The vehicle emissions standards are taken from the vehicle logbook data held by the Driver and Vehicle Licensing Agency (DVLA).

Cars. As petrol and diesel engines produce different types of emissions, they require different standards. The ULEZ requires cars to meet minimum 'Euro' emissions standards; the ULEZ standard for passenger cars is Euro 4 (NOx) for petrol cars and Euro 6 (NOx and PM) for diesel cars. Cars featuring older technology are less likely to meet

the Euro 4 standards. Petrol cars that meet ULEZ standards are generally those that were first registered with the DVLA from January 2006 (although some cars registered as early as 2001 may also meet the standards). Diesel cars registered with he DVLA after September 2015 generally meet the ULEZ standards.

Large vans and minibuses.   Euro 6 for diesel engines and Euro 4 for petrol engines. Non-compliant vehicles would be required to pay a daily charge of £12.50.

Motorcycles.   Motorcycles, mopeds, motorised tricycles and quadricycles (L-category) need to meet minimum Euro 3 emissions standards for NOx. Euro 3 engines are those registered with the DVLA after July 2007.

Lorries, coaches and larger vehicles over 3.5 tonnes Gross Vehicle Weight (GVW). Heavy goods vehicles (HGVs), lorries, vans, motor caravans, motorised horseboxes, and other specialist vehicles below 3.5 tonnes.

A.4   Exemptions

- 'Historic vehicles' aged 40 years or older (if registered as historic vehicle tax class).

- Hybrid electric vehicles(HEVs), Plug-in hybrids electric vehicles (PHEVs) and fully battery-powered electric vehicles (EVs or BEVs).

- LPG (Liquefied Petroleum Gas) conversions, depending on the individual model and engine.

- London-licensed taxis.

- Specialist agricultural vehicles or other specialist vehicles (Motorised horseboxes, breakdown and recovery vehicles, snow ploughs, gritters, refuse collection vehicles, road sweepers, concrete mixers, fire engines, tippers, removal lorries, cranes).

- Military vehicles.

- Some showman's vehicles are eligible for 100% discount.

- Residents parked in the zone that do not drive.

- Buses, coaches and minibuses over 5 tonnes GVW.

- NHS patient that are clinically assessed as too ill to travel to an appointment on public transport are eligible to claim back any ULEZ charge.

ULEZ exemptions will be in place until 2025 for community transport vehicles and until 2027 for people receiving certain disability benefits and vehicles for people with disabilities.

A.5 Grace periods

Grace periods covering vehicles for disabled people are in place until 25 October 2027. Some businesses and charities also have a short grace period. Small business (50 employees), micro businesses (up to 10 employees), charities and sole traders with a registered address in London boroughs and city of London fall in this category if they ordered a new minibus or light van or retrofitted their light van or minibus and the delivery is due after 29 August 2023. There will be no exemption from the charges beyond 29 May 2024.

A.6 Full timeline

- 27 October 2014: Mayor and TfL announce consultation on ULEZ.

- 30 December 2014: Reminder of ULEZ consultation ending soon.

- 26 March 2015: Mayor confirms ULEZ.

- 26 October 2015: Mayor and TfL finalise ULEZ requirements for taxi and minicabs.

- 17 February 2017: Mayor confirms £10 T-charge from October 23rd.

- 4 April 2017: Mayor launches consultation for replacing T-charge with ULEZ from 2019.

- 23 October 2017: T-Charge comes into effect.

- 3 November 2017: Mayor announces ULEZ will start in 2019.

- 30 November 2017: Mayor launches ULEZ expansion consultation.

- 8 June 2018: Mayor announces ULEZ to expand up to North and South Circular.

- 29 November 2018: First ULEZ signs go up in London.

- 8 March 2019: TfL reminds of ULEZ one-month countdown London ULEZ.

- 8 April 2019: ULEZ comes into force.

- 16 May 2019: TfL announces that 74 per cent of vehicles comply in first month.

- 15 May 2020: The Congestion Charge, Ultra Low Emission Zone and Low Emission Zone are reinstated.

- 6 August 2020: TfL announces installation of new infrastructure.

- 18 October 2021: TfL urges drivers to check their vehicle ahead of Ultra Low Emission Zone expansion on 25 October.

- 20 May 2022: TfL seeks views on expanding ULEZ.

- 25 November 2022: Mayor announces that ULEZ will be expanded London-wide.

- 30 January 2023: Mayor announces the scrappage scheme.

- 23 March 2023: Tfl data shows over 90% of cars driving in outer London already meet ULEZ standards.

- 21 April 2023: Tfl announces £18m allocated from scrappage scheme ahead of ULEZ expansion.

- 28 July 2023: High Court rules in favour of ULEZ expansion.

- 4 August 2023: Mayor announces expansion of scrappage scheme to all Londoners.

- 23 August 2023: Scrappage scheme becomes open to all Londoners.

- 29 August 2023: ULEZ expands London-wide.

B Data appendix

Table B1: Summary statistics - vehicles (London postcode districts only)

	Mean	N	StDev	Min	p(25)	p(50)	p(75)	Max
All Vehicles	12,587	11,645	8,259	49	7,325	12,007	17,648	66,267
ULE Vehicles	80.77	11,645	179.41	0	6	27	94	7531
Population	29,317	11,645	21,407	0.065	15,284	27,734	40,653	140,711
ULEZ	0.081	11,645	0.22	0	0	0	0	0.91
Taxable ULEZ Share	0.012	11,645	0.0075	0.0034	0.0078	0.0098	0.013	0.068
Share ULEVs	0.010	11,645	0.022	0	0.00056	0.0030	0.010	0.734

Vehicle data from VEH0122 and VEH0134 from the DVLA. Commuting and population data from 2011 Census. Constructed variables computed by authors.

Table B2: Summary statistics - station entry and exit

	Mean	N	StDev	Min	p(25)	p(50)	p(75)	Max
Station entry	0.111	134,955	0.182	0	0.025	0.053	0.115	1.914
Station exit	0.113	134,955	0.189	0	0.023	0.051	0.114	1.868
Distance to boundary	4.51	134,955	3.63	0.099	1.82	3.50	6.48	18.24
ULEZ	0.081	134,955	0.272	0	0	0	0	1
Population	40,701	134,955	24,932	0.065	24,325	40,653	53,032	140,711
Taxable Share ULEZ	0.012	134,955	0.0075	0.0046	0.0079	0.0097	0.013	0.068

2019 daily station entry and exit from Transport for London. Commuting and population data from 2011 Census. Constructed variables computed by authors.

Table B3: Summary statistics - house prices (within 1 mile of ULEZ boundary only)

	Mean	N	StDev	Min	p(25)	p(50)	p(75)	Max
Log house price	13.67	60808	0.96	7.81	13.07	13.46	14.05	20.20
Distance to boundary	0.33	60808	0.41	-0.82	-0.06	0.35	0.70	1.00

For postcodes within 1 mile of ULEZ boundary. House price data from Price Paid Data (PPD). Distance to boundary computed by authors.

Table B4: Summary statistics - firm dynamism for 2019 ULEZ

	Mean	*Median*	*StDev*	*N*
Panel I: outside 2019 ULEZ				
Entry rate	0.069	0.000	0.191	3,764,776
Exit rate	0.068	0.000	0.188	3,764,776
Distance	9.655	8.313	7.034	3,764,776
Panel II: inside 2019 ULEZ				
Entry rate	0.057	0.000	0.151	1,809
Exit rate	0.063	0.000	0.145	1,809
Distance	-0.177	-0.141	0.118	1,809
Panel III: all postcodes				
Entry rate	0.069	0.000	0.191	3,766,585
Exit rate	0.068	0.000	0.188	3,766,585
Distance	9.650	8.310	7.036	3,766,585

Average quarterly postcode-level firm entry and exit rates from 2017 - 2021, for postcodes within and outside the 2019 ULEZ boundary. Distance to boundary in miles, computed by authors.

Table B5: Summary statistics - firm dynamism for 2021 ULEZ

	Mean	Median	StDev	N
Panel I: outside 2021 ULEZ				
Entry rate	0.061	0.000	0.180	2,995,124
Exit rate	0.064	0.000	0.182	2,995,124
Distance	5.528	3.406	6.037	2,995,124
Panel II: inside 2021 ULEZ				
Entry rate	0.059	0.000	0.163	6,403
Exit rate	0.066	0.000	0.172	6,403
Distance	-0.390	-0.400	0.175	6,403
Panel III: all postcodes				
Entry rate	0.061	0.000	0.180	3,001,527
Exit rate	0.064	0.000	0.182	3,001,527
Distance	5.515	3.391	6.037	3,001,527

Average quarterly postcode-level firm entry and exit rates from 2019 - 2023, for postcodes within and outside the 2021 ULEZ boundary. Distance to boundary in miles, computed by authors.

C   CO2 emissions and traffic levels

CO2 emissions.   A tax on high-polluting vehicles should change incentives to purchase vehicles with different levels of emissions. The ULEZ applies to vehicles that do not meet the European emission standards.[1] These standards regulate air pollution from a variety of gases and particulates, but do not directly target CO2 emissions. We do not have data on UK vehicle measures of nitrogen oxides, total hydrocarbon, carbon monoxide or particular matter. But the DVLA provides information on the CO2 band of new vehicles registered in the UK from 2002 to 2024 by local authority district (LAD).[2]

The emissions data is labelled by the UK road tax or Vehicle Excise Duty (VED) band. Until 2025, vehicles with up to 100g/km of CO2 emissions paid no road tax, while cars emitting over 255g/km paid £735.[3] We plot the share of vehicle registrations across five CO2 emissions bands: zero, 1-100, 101 - 150, 151 - 255, 255+. This is shown in Figures C1 to C3, for the whole of the UK, London, and 2019 ULEZ-affected LADs (that is, any LAD which overlaps with a postcode inside the 2019 ULEZ).

Almost two thirds of the vehicles registered in the UK in 2002 emitted more than 150g/km of CO2. This fell to less than one quarter by 2024. Almost no registrations in 2002 emitted below 100g/km of CO2, while this was above 30% of new cars in 2024. However, the fall in the share of high-CO2-emitting vehicles has not been uniform, either over time or across emissions bands.

Did the ULEZ play a role in low-emission vehicle registrations? There is not enough variation across LADs to investigate this causally, so we provide descriptive evidence. There is a slight rise in zero-emission vehicle registrations around the ULEZ announcement in 2015, but a sharp increase around the 2019 introduction. This continues after the 2021 ULEZ expansion and accelerates for ULEZ-affected LADs.

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[1] Motorcyles that do not meet Euro 3 standards; petrol cars that do not meet Euro 4 standards; diesel cars that do not meet Euro 6 standards; buses, coaches and heavy goods vehicles that do not meet Euro 6 standards.

[2] VEH9901 table from Gov.uk vehicle licensing statistical tables.

[3] Technically, this only applied to cars first registered between 2001 - 2017. This led to an additional road tax on CO2-emitting cars that were new from 2017 onwards.

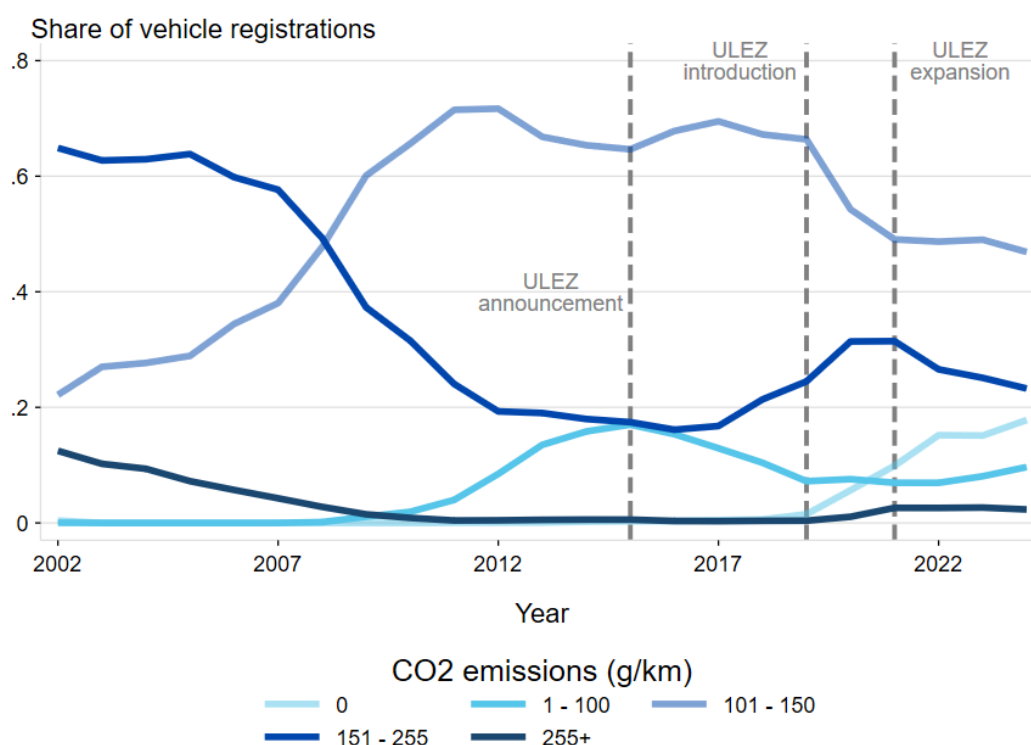**Figure C1:** Share of new vehicle registrations in the UK, by CO2 band, 2002 - 2024.

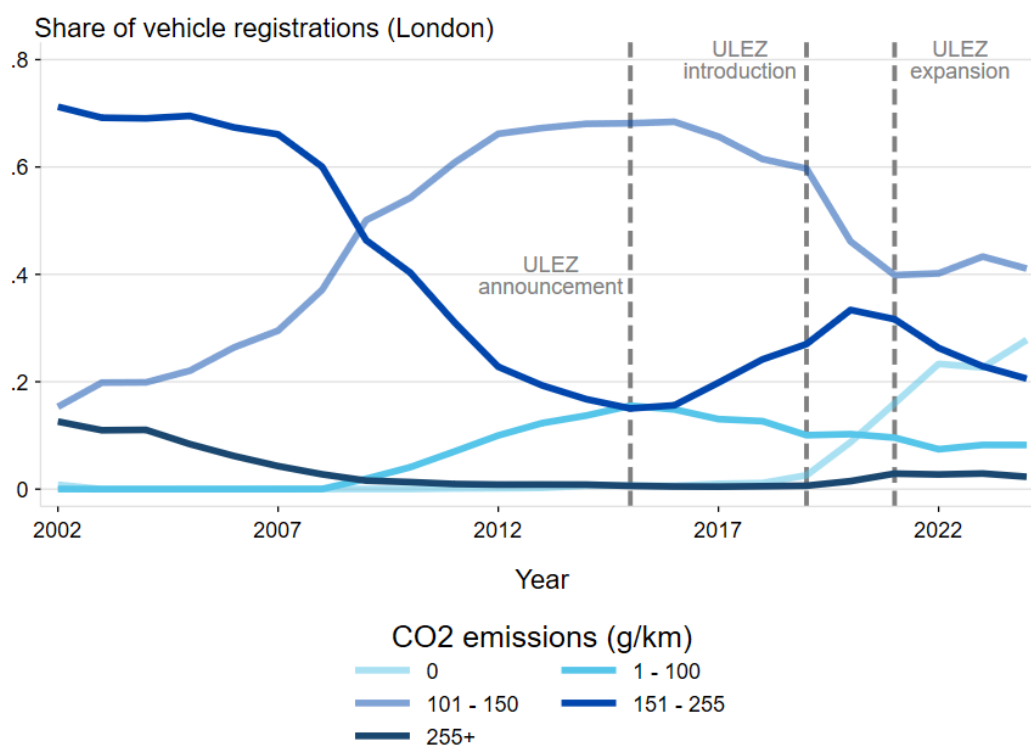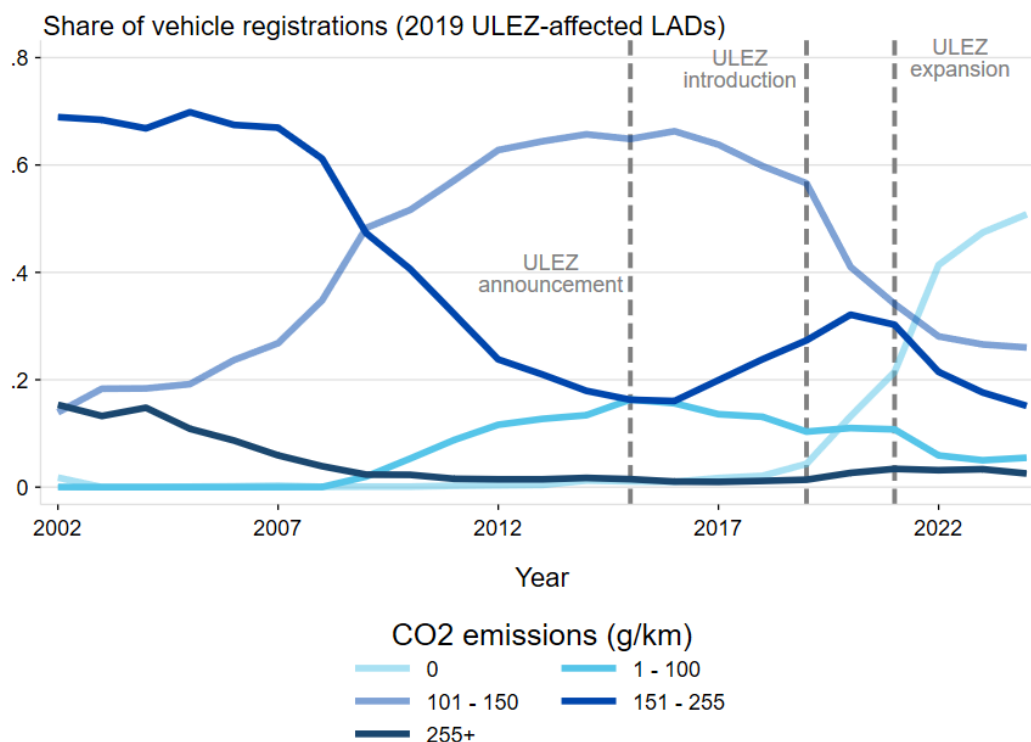**Figure C2:** Share of new vehicle registrations in London, by CO2 band, 2002 - 2024.

Figure C3: Share of new vehicle registrations in 2019 ULEZ-affected local authority districts, by CO2 band, 2002 - 2024.


Traffic. Another likely consequence of the ULEZ is reduced traffic. Traffic data is available from the Department for Transport.[4] These data are counts of different types of vehicles (cycles, buses, cars, buses) at specific survey locations. We have the longitude and latitude, alongside the direction of travel.

We compute annual counts of vehicles (cars, large goods vehicles and heavy goods vehicles) at locations inside the 2019 ULEZ, outside but within 10 miles of the ULEZ, and 10 - 25 miles from the ULEZ. We find a steady decline in the number of vehicles within the ULEZ from 2010 to 2012 (by around 8.5%) and then again from 2015 to 2019 (by over 9.5%). Of course the decline in 2020 due to the pandemic is enormous. Meanwhile, traffic outside the ULEZ increased gradually from 2015 onwards, when the ULEZ was announced. We show the overall trends in Figure C4.

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[4]DfT road traffic data.

Figure C4: Counts of vehicles inside and outside the 2019 ULEZ, from 2010 - 2023.
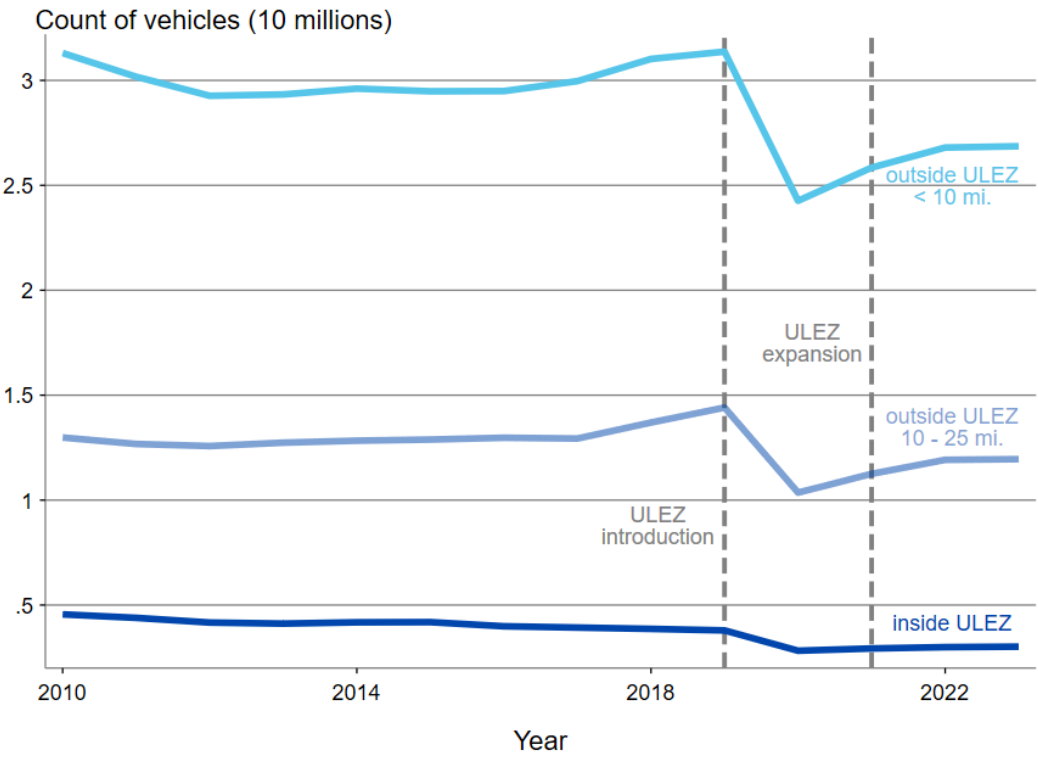
D Additional figures

Figure D1: ULEZ exposure by postcode district

Share of drivers entering ULEZ by Greater London postal district, 2019 Q2

% driving into ULEZ
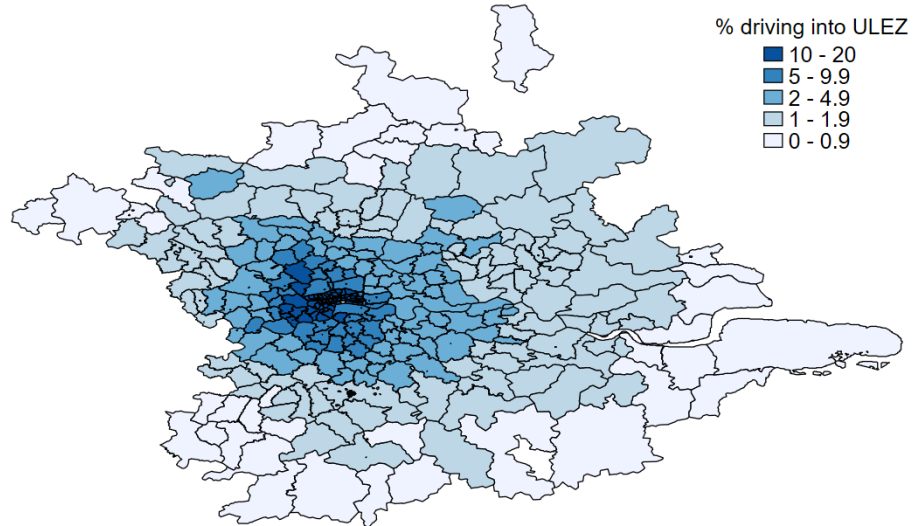- 10 - 20
- 5 - 9.9
- 2 - 4.9
- 1 - 1.9
- 0 - 0.9

Figure D2: Histogram of computed ULEZ exposures for London's postcode districts
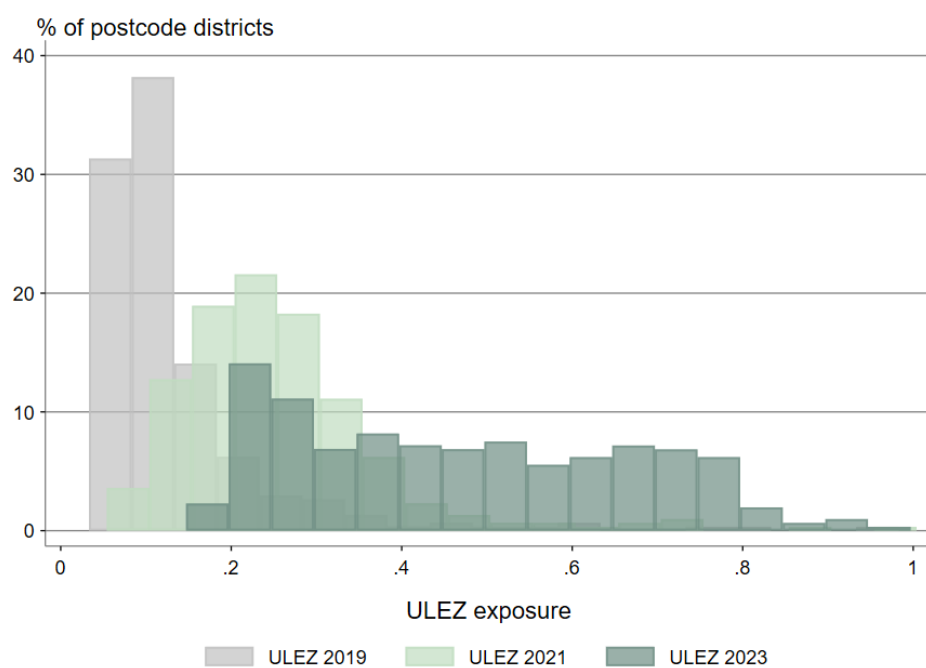
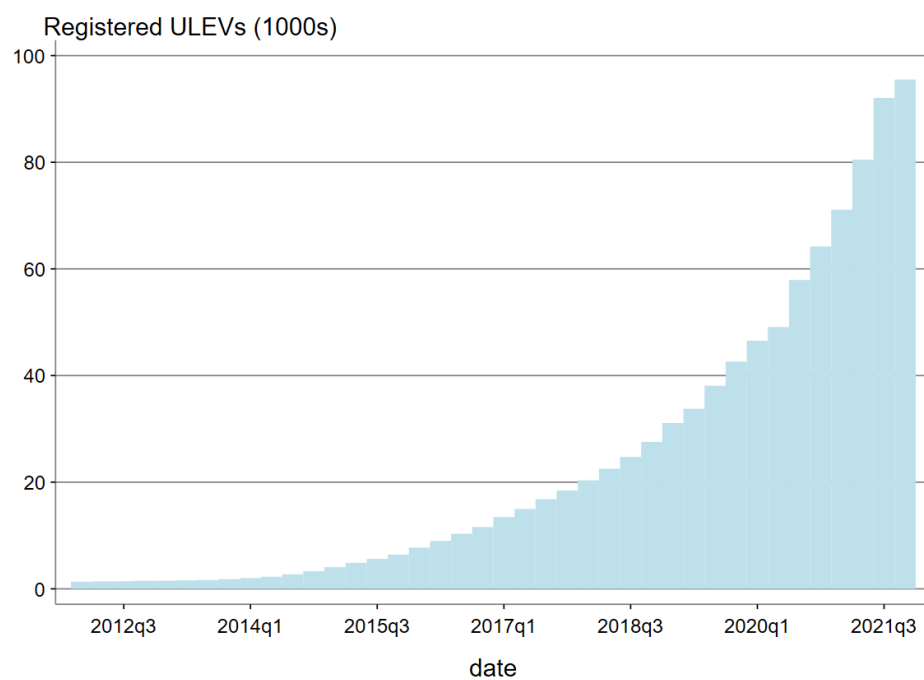**Figure D3:** Adoption of ultra-low emissions vehicles in London

Registered ULEVs (1000s)

Figure D4: Adoption of ultra-low emissions vehicles in London
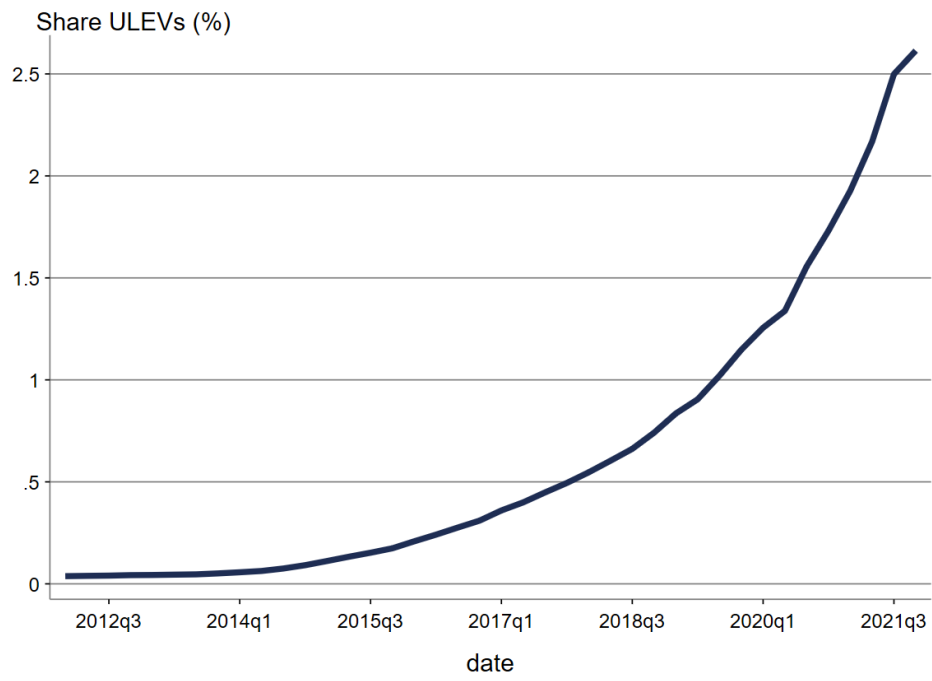
Figure D5: Adoption of ultra-low emissions vehicles in high and low ULEZ exposure postcode districts for the 2021 expansion
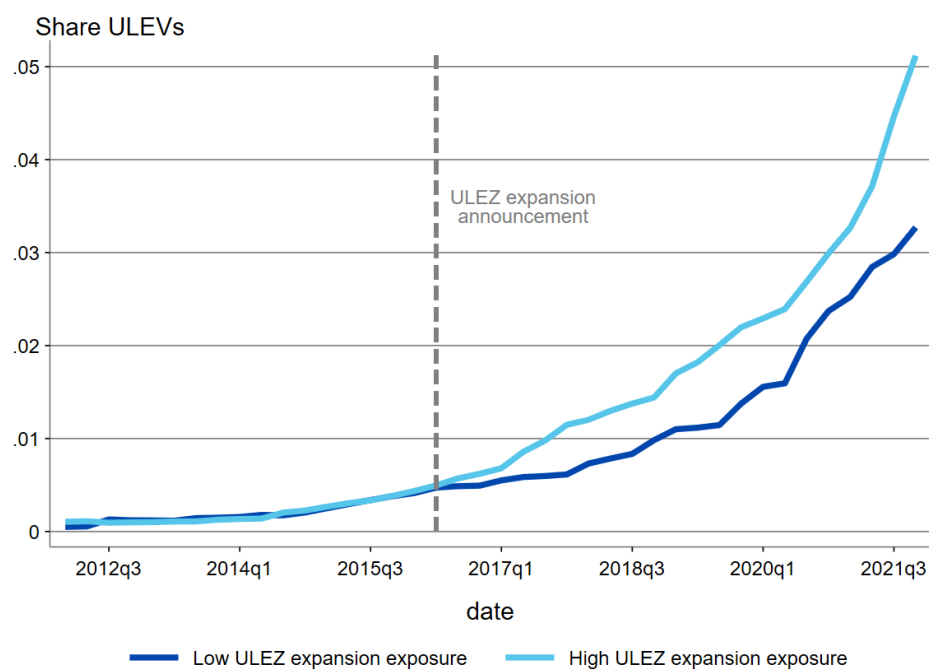
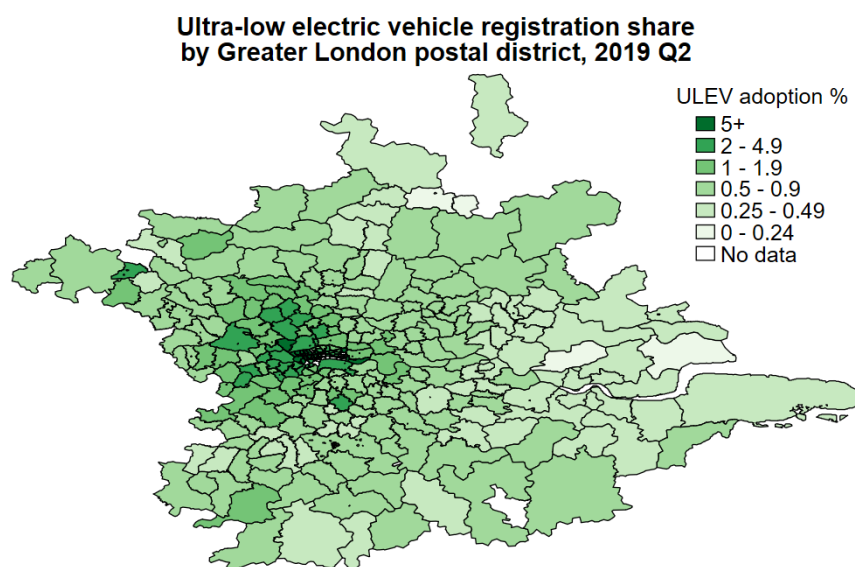**Figure D6:** ULEV adoption by postcode district

**Ultra-low electric vehicle registration share
by Greater London postal district, 2019 Q2**

ULEV adoption %
- 5+
- 2 - 4.9
- 1 - 1.9
- 0.5 - 0.9
- 0.25 - 0.49
- 0 - 0.24
- No data

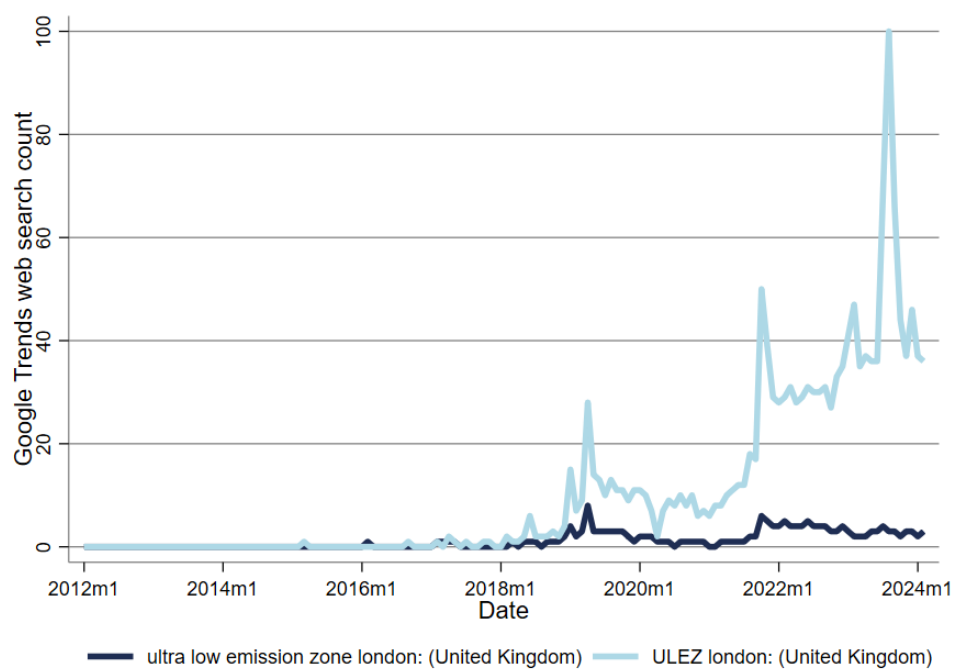**Figure D7:** Google Trends web search for ULEZ London

Figure D8: Relationship between ULEV adoption and ULEZ exposure, 2019 Q2.

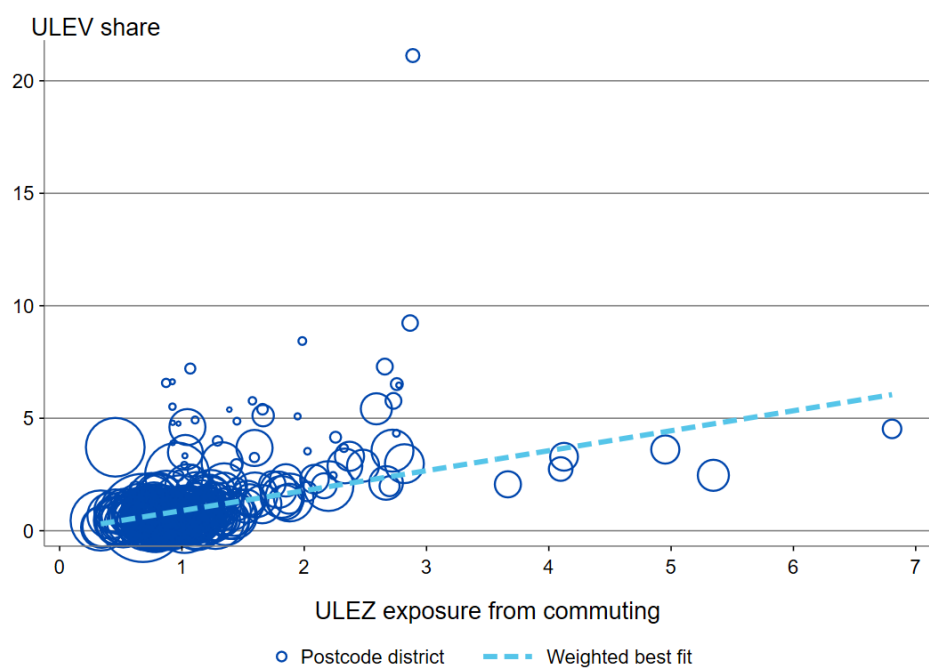**Figure D9:** Chaisemartin and D'Haultfoeuille 2020 event study for ULEV adoption around first ULEZ announcement (Q1 2015)
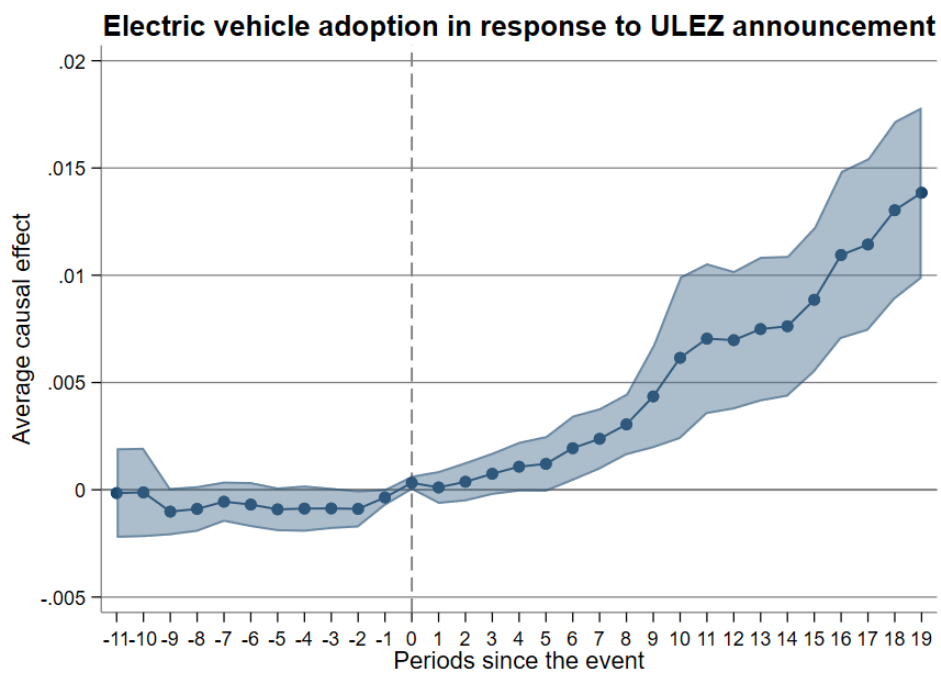

Electric vehicle adoption in response to ULEZ announcement

Figure D10: Callaway and Sant'Anna 2021 event study for ULEV adoption around first ULEZ announcement (Q1 2015)
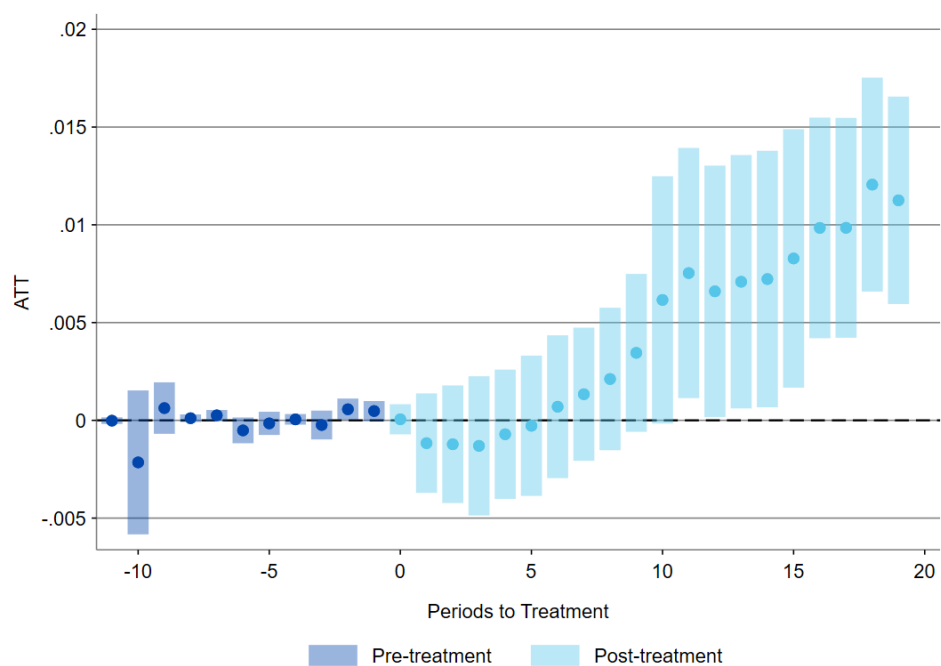
Figure D11: Athey, Bayati, Doudchenko, Imbens, and Khosravi 2021 matrix completion method to estimate event study for ULEV adoption around first ULEZ announcement (Q1 2015)
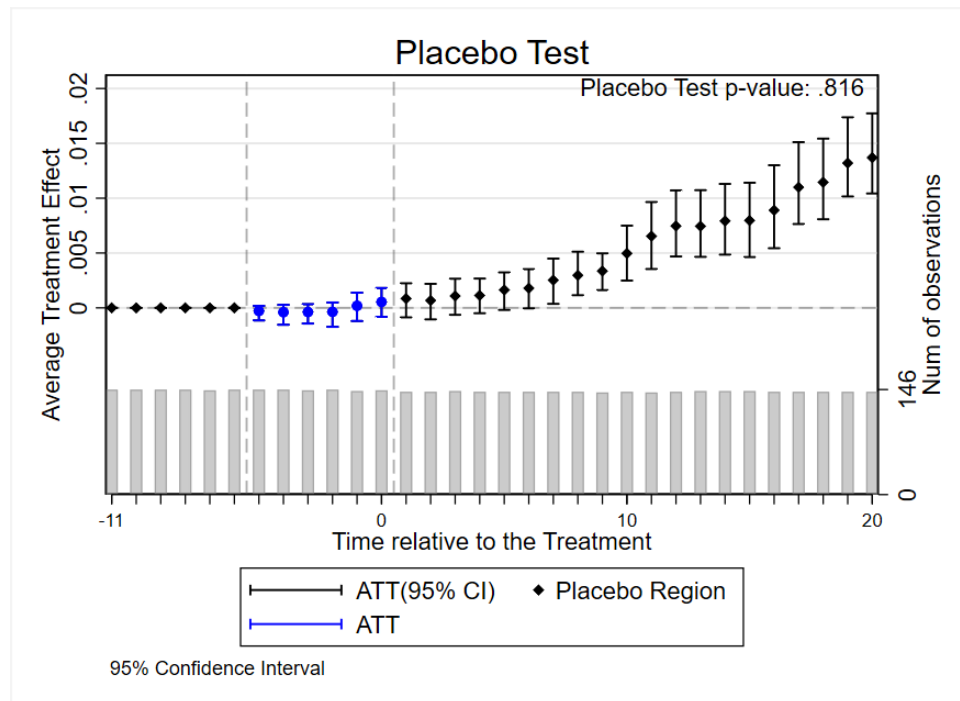
Figure D12: Price of sold houses and number of transactions in London
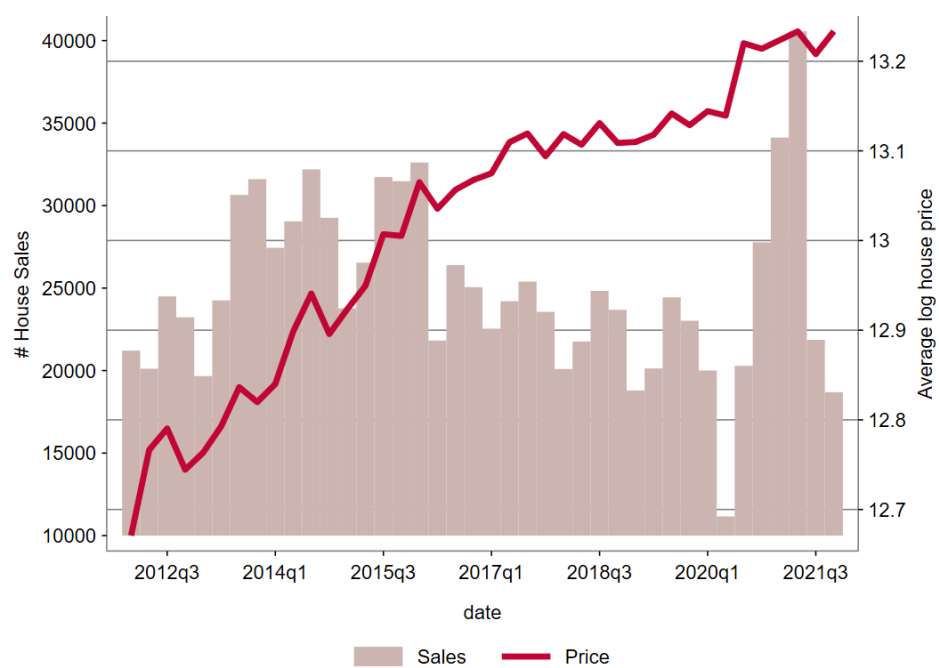
Figure D13: Average log house price in high and low ULEZ exposure postcode districts in London
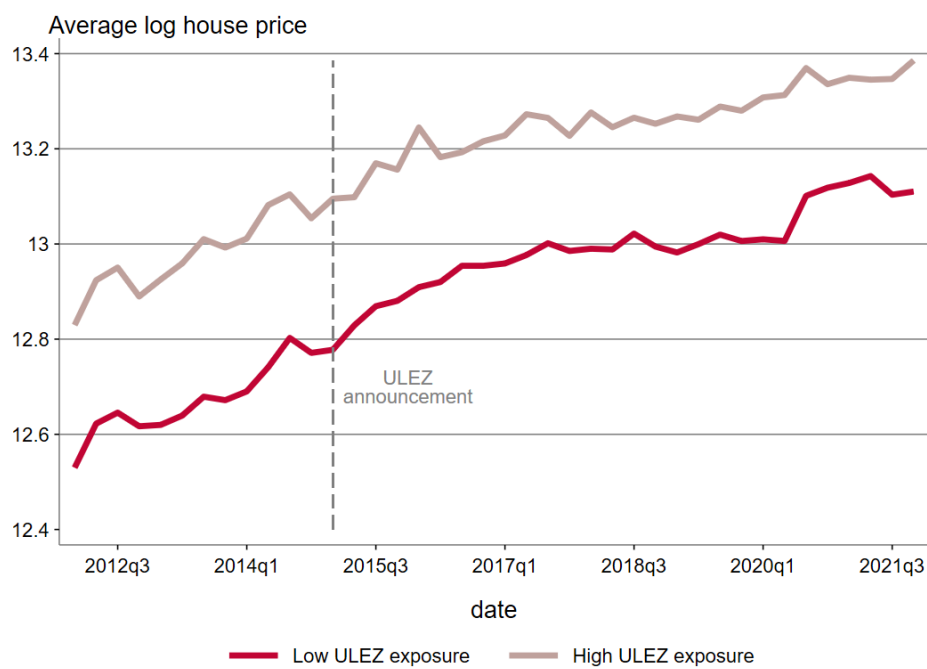
Figure D14: Positive relationship between log house price and ULEZ exposure by postcode districts in London.

Figure D15: Binned average log house prices within 1 mile of the 2019 ULEZ boundary, before and after the policy announcement in March 2015.

Bin size of 0.005 miles.
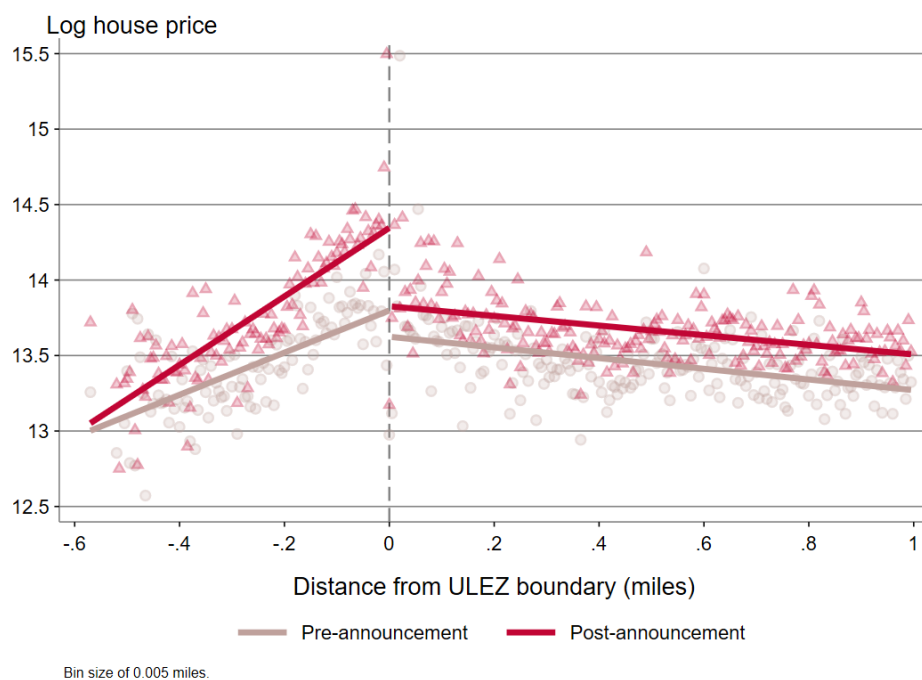
Figure D16: Baseline house price RDD for various distances from 2019 ULEZ boundary.
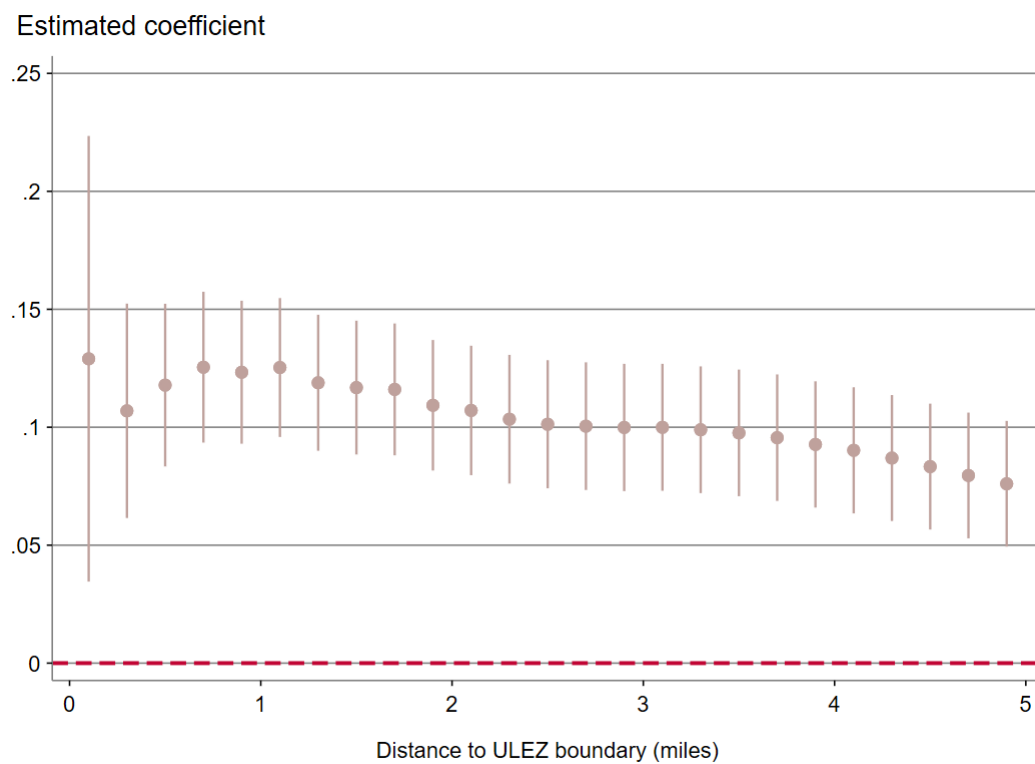
Figure D17: Binned average log house prices within 1 mile of the 2021 ULEZ boundary, before and after the policy announcement in June 2018.

Bin size of 0.005 miles.
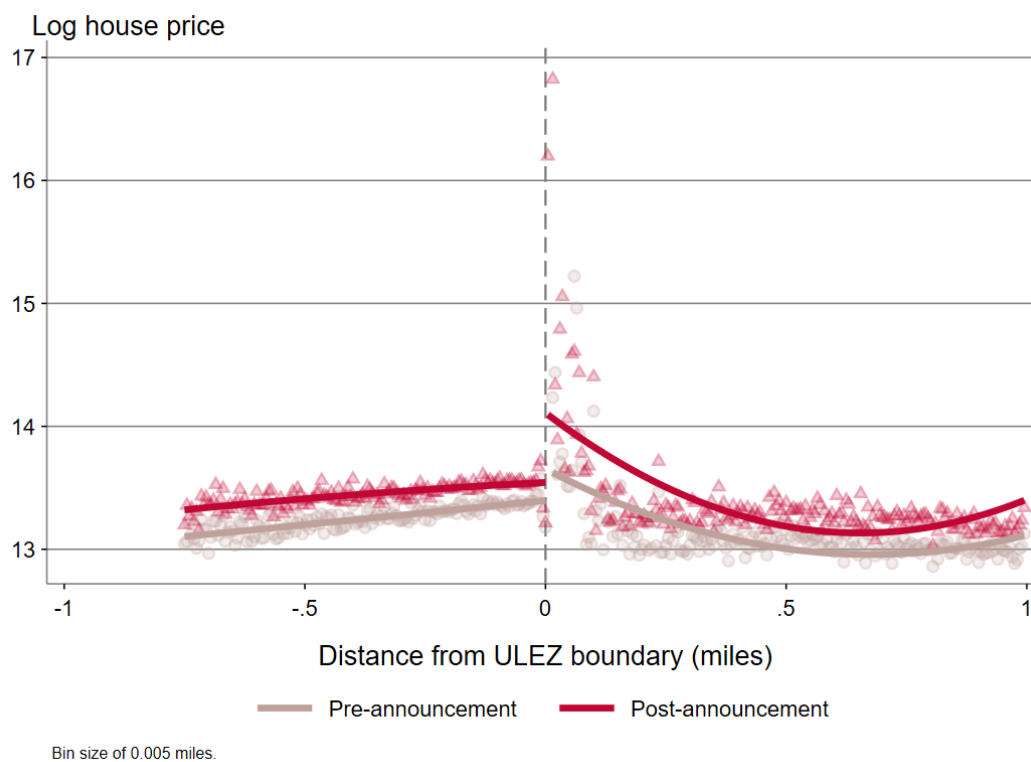
Figure D18: Firm exit rates rose inside the ULEZ boundary (relative to outside) after the announcement
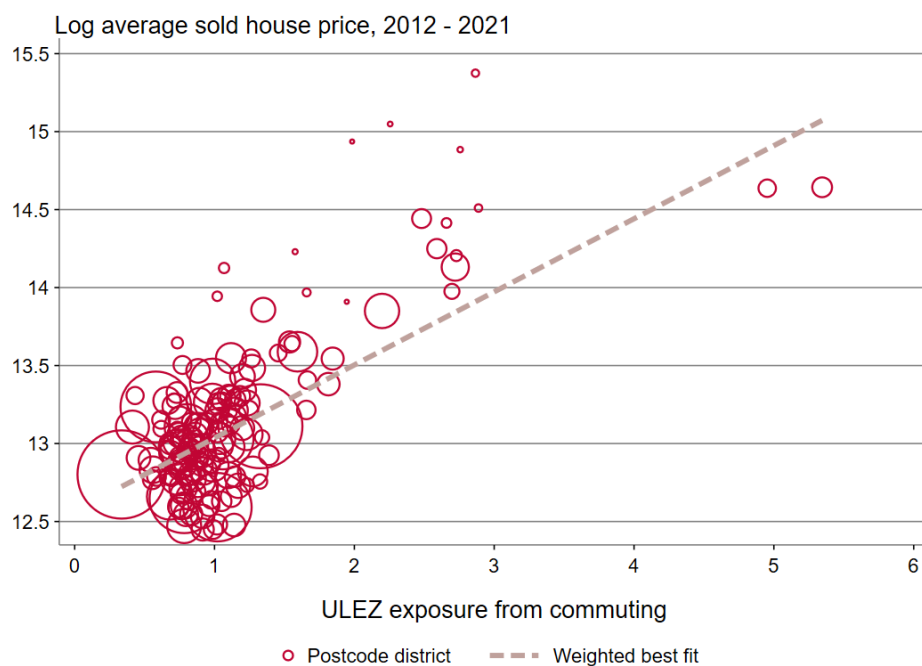

Difference in firm exit rate inside vs outside 2019 ULEZ
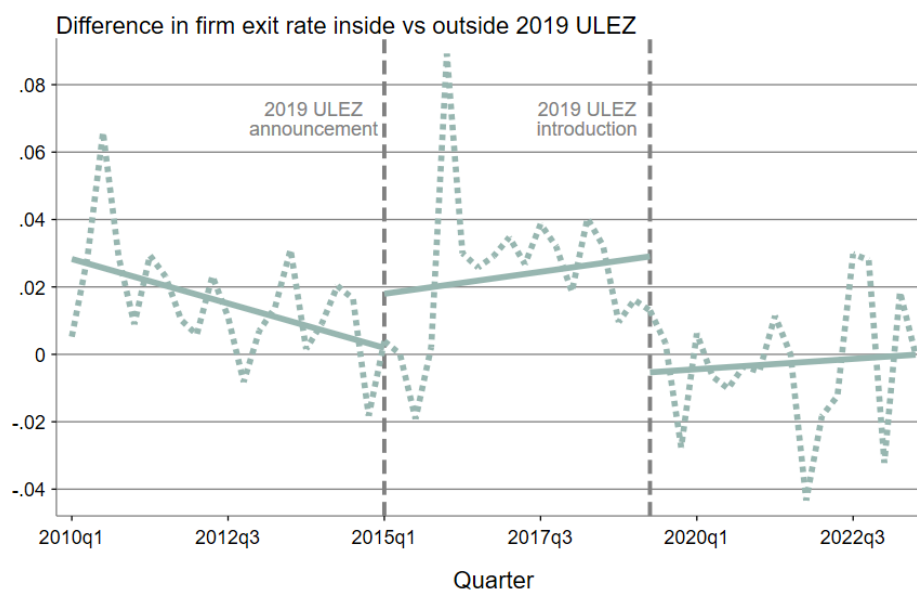
Data from Longitudinal Business Database (LBD). Firm exit rates computed at postcode level, residualised to account for year and quarter fixed effects. Dashed line represents firm exit inside vs outside the zone. Solid line is a linear trend within each time period. Difference computed for postcodes within 1 mile of 2019 ULEZ.

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Figure D19: Firm entry rates fell inside the ULEZ boundary (relative to outside) after the announcement
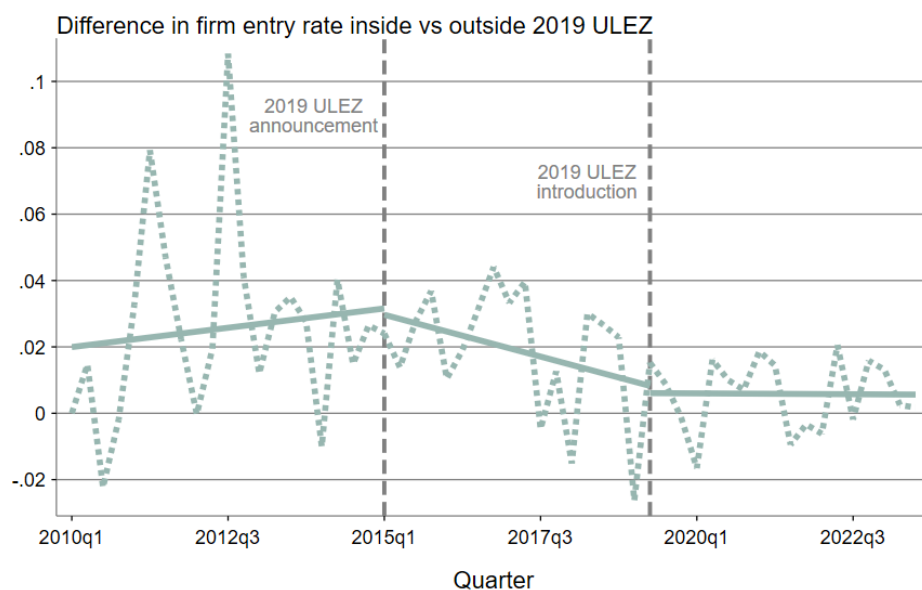
Difference in firm entry rate inside vs outside 2019 ULEZ

Data from Longitudinal Business Database (LBD). Firm entry rates computed at postcode level, residualised to account for year and quarter fixed effects. Dashed line represents firm entry inside vs outside the zone. Solid line is a linear trend within each time period. Difference computed for postcodes within 1 mile of 2019 ULEZ.

Figure D20: Regression discontinuity plot for firm entry around ULEZ boundary, before and after policy introduction
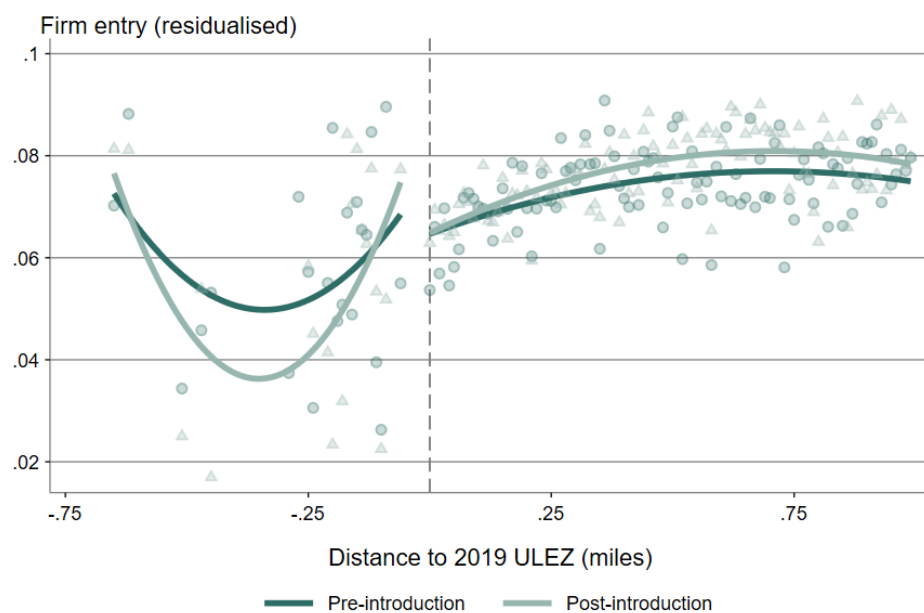
Data from Longitudinal Business Database (LBD). Firm entry rates computed at postcode level, residualised to account for year, quarter and postcode district fixed effects, weighted by the number of firms pre-introduction. Bin size 0.1 miles. Quadratic best-fit lines fitted on either side of the boundary, pre- and post-introduction.

Figure D21: Heterogeneous treatment effects on the firm entry rate for 2019 and 2021 ULEZ boundaries, across pre-policy postcode-level income quartiles.

Standardised coefficients for 2019 ULEZ and 2021 expansion for firm entry rates. Filled symbols are statistically significant at the 95% confidence level.
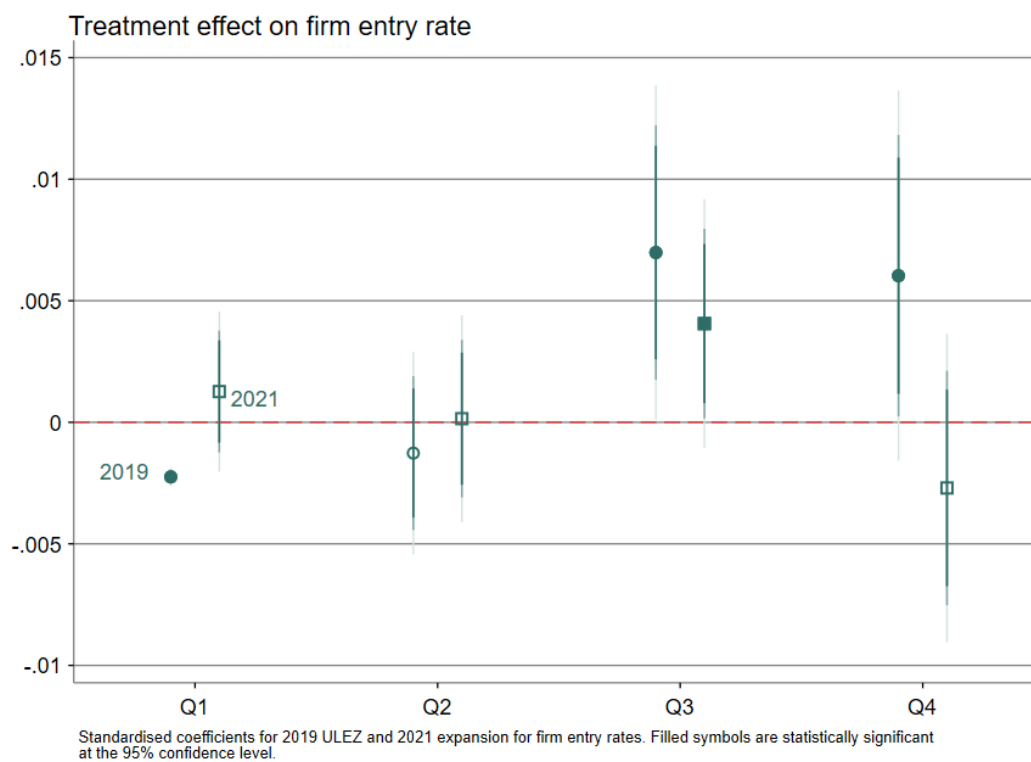
Figure D22: Distribution of true and simulated ULEZ exposure

Distributions of true and simulated ULEZ treatments
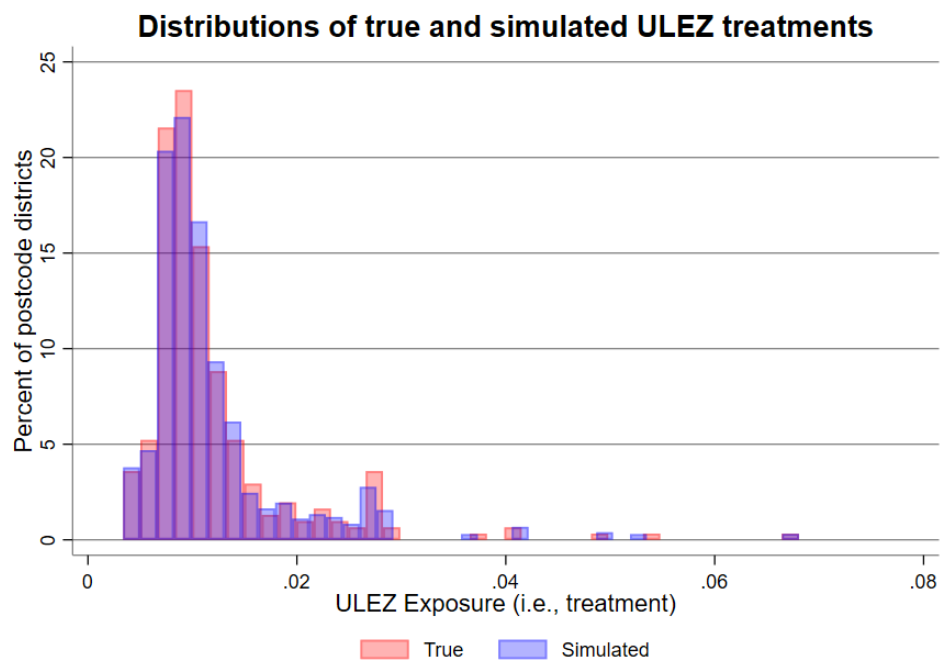
Figure D23: Baseline regression coefficients on ULEV adoption around ULEZ expansion announcement (Q2 2016)
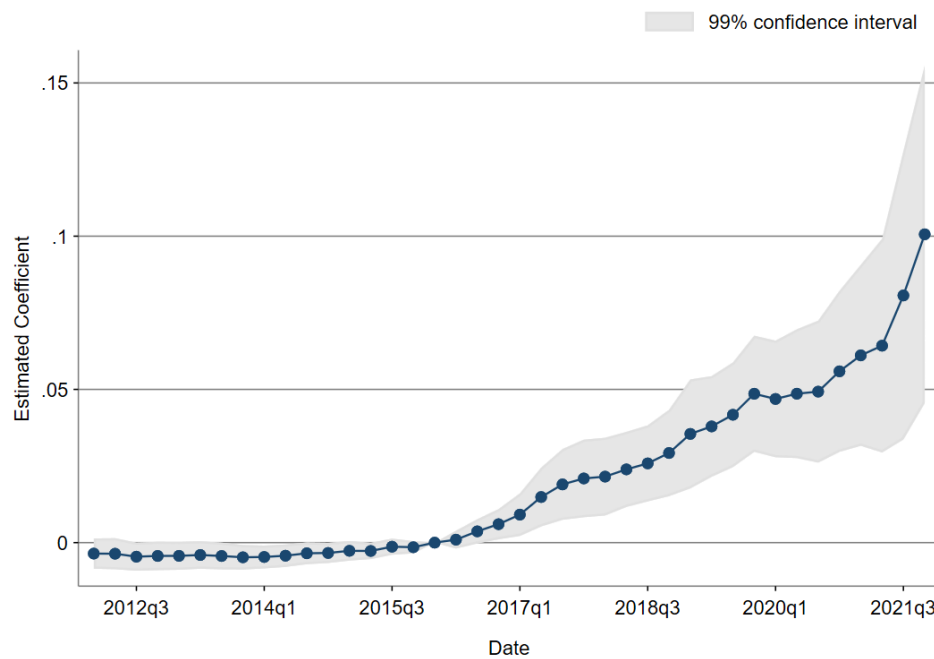
Figure D24: Bootstrapped estimates on the difference in the estimated coefficient on ULEZ indicator for house price RDD regression.
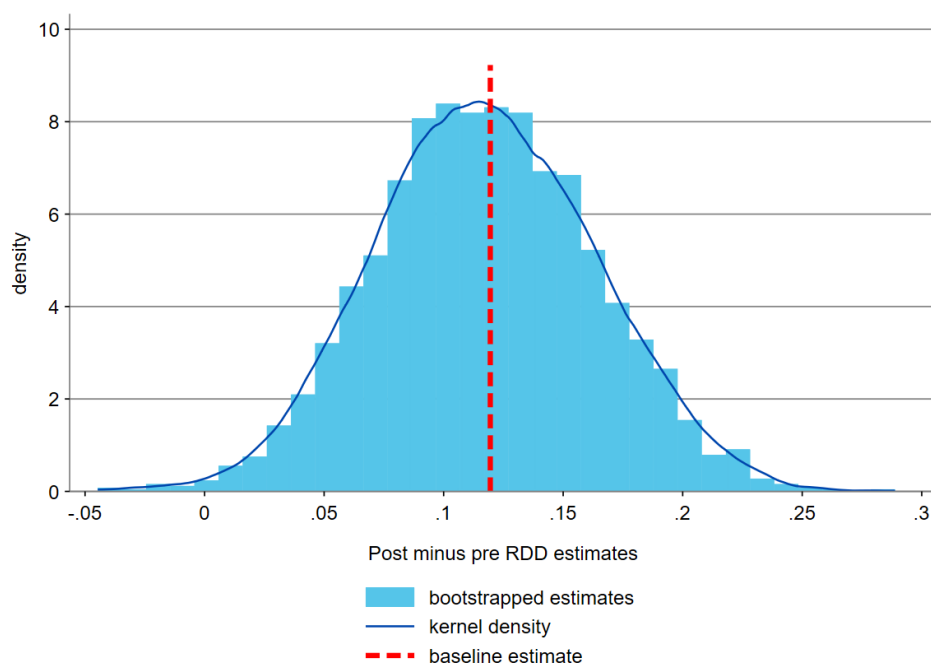
Figure D25: Placebo test on pre-announcement data with fake announcement date.
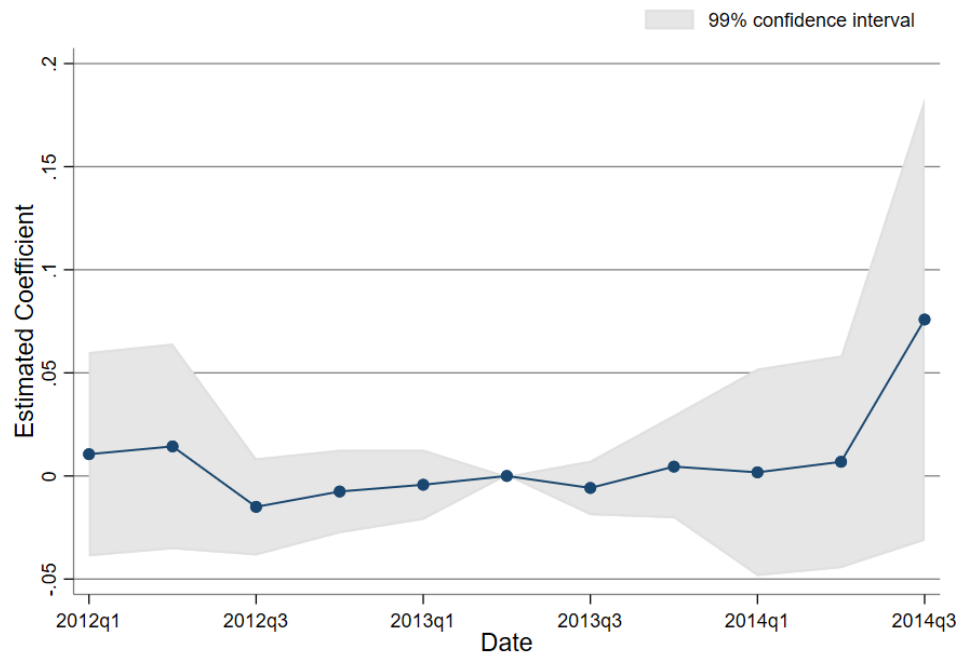
Figure D26: Placebo tests

(a) Placebo test with randomly assigned treatment data.

(b) Placebo test with vehicles per capita as outcome variable.
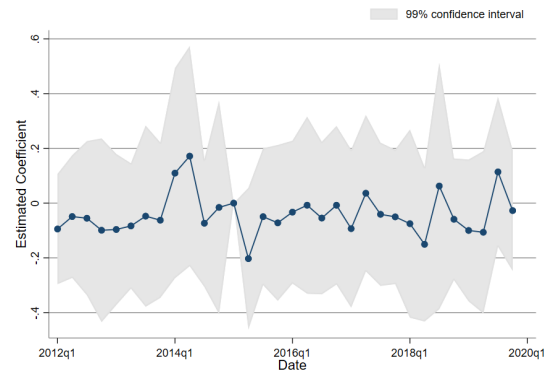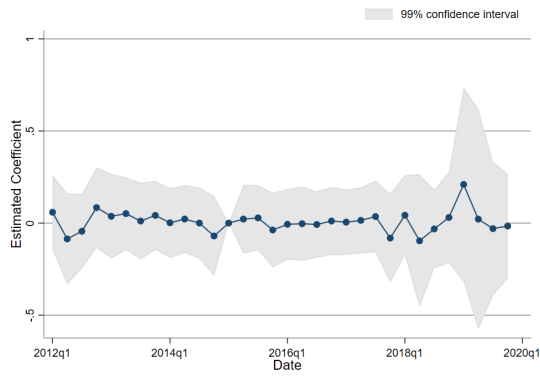
Figure D27: Testing for pre-trends in ULEV adoption prior to initial ULEZ announcement.
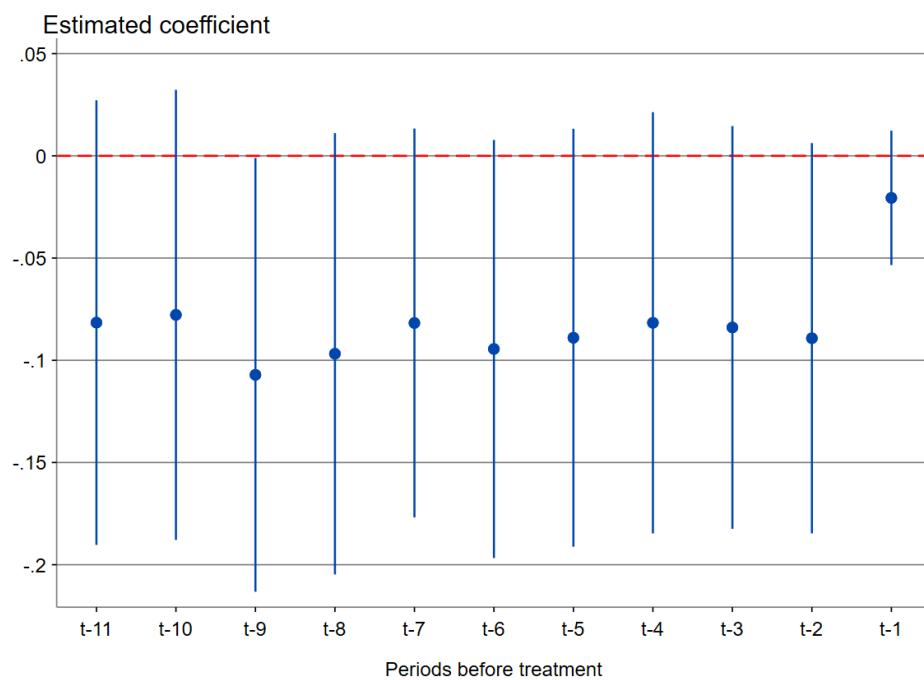
Figure D28: Weekly station entry (detrended) by quartiles of ULEZ exposure
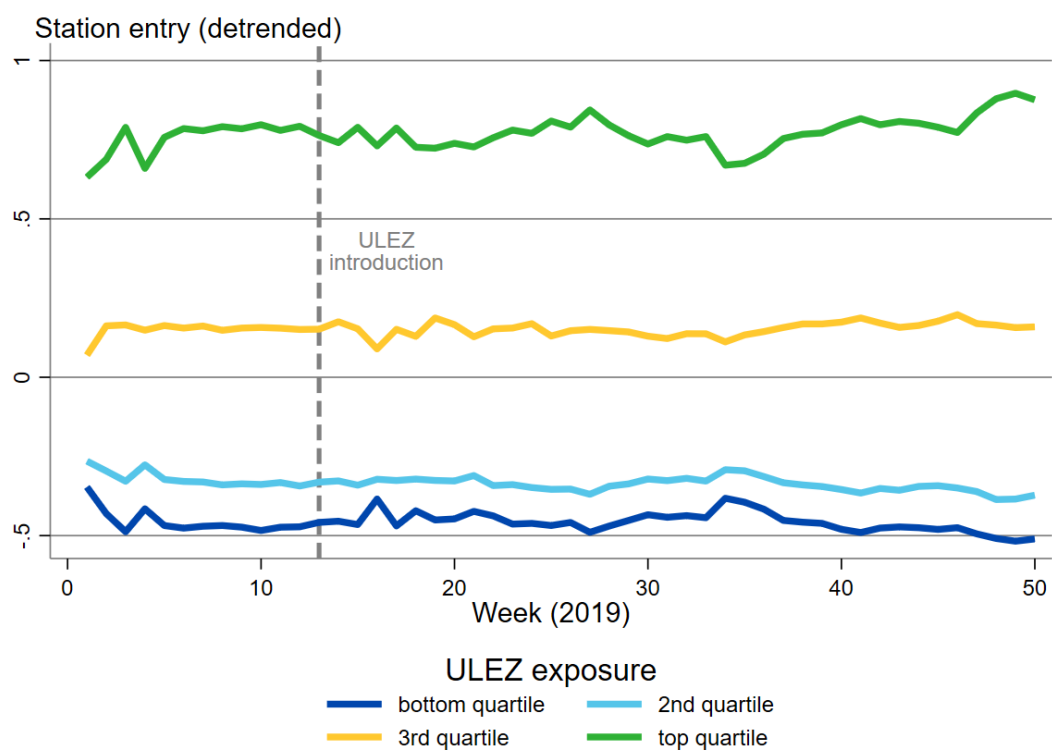
Figure D29: Average change in London underground station entry after the 2019 ULEZ introduction, split by postcodes with above and below median ULEZ exposure.

Difference in average station entry (100,000s) after April 2019 ULEZ introduction
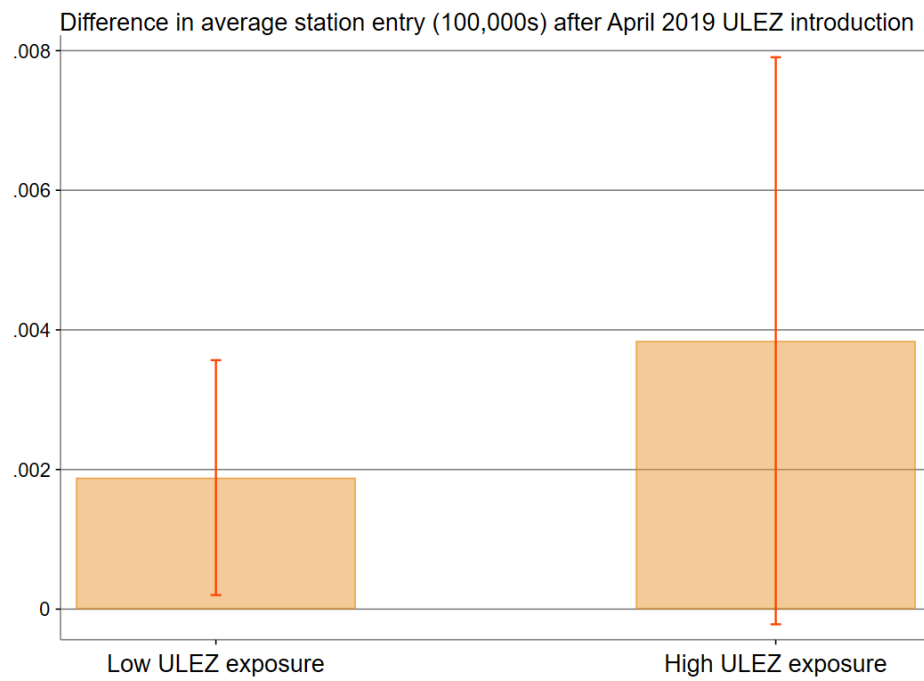
Figure D30: Marginal predicted effect of ULEZ exposure on station entry, pre- and post-policy introduction.
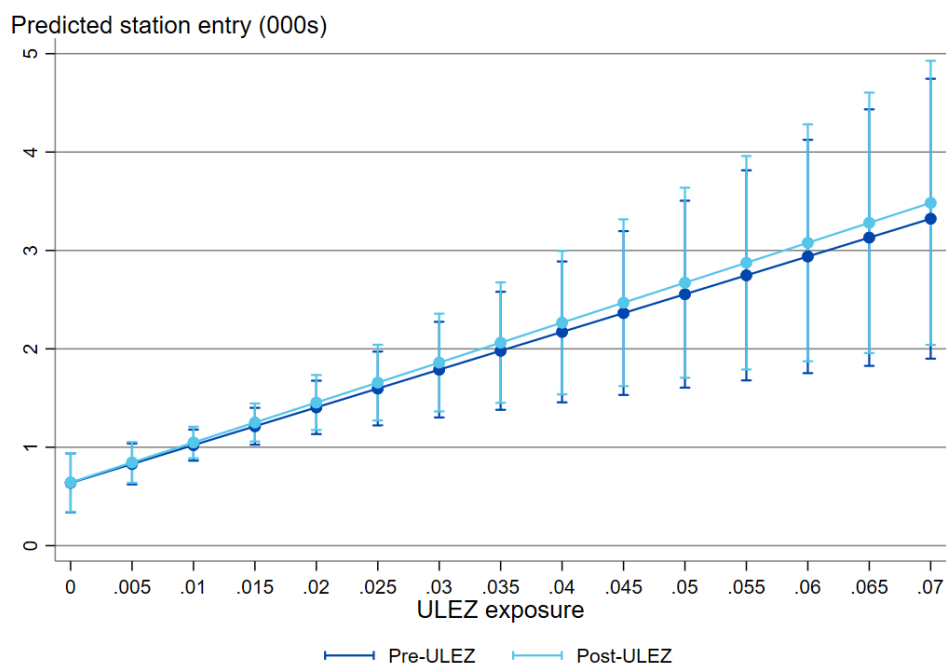
Figure D31: Testing for pre-trends in tube station entry prior to 2019 ULEZ introduction.
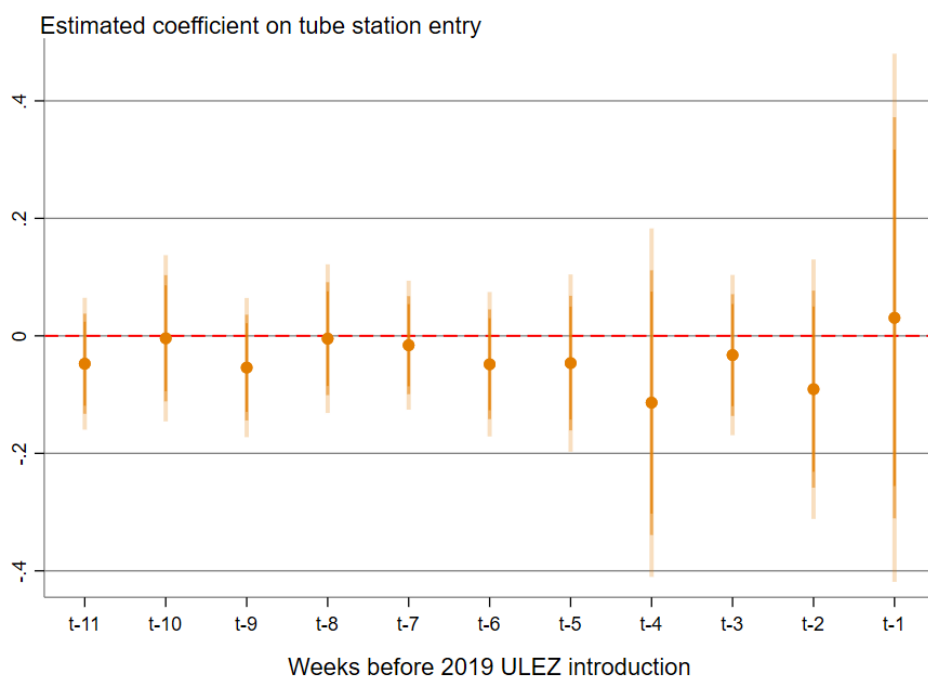
Figure D32: Chaisemartin and D'Haultfoeuille 2020 event study for tube station entry around 2019 ULEZ introduction
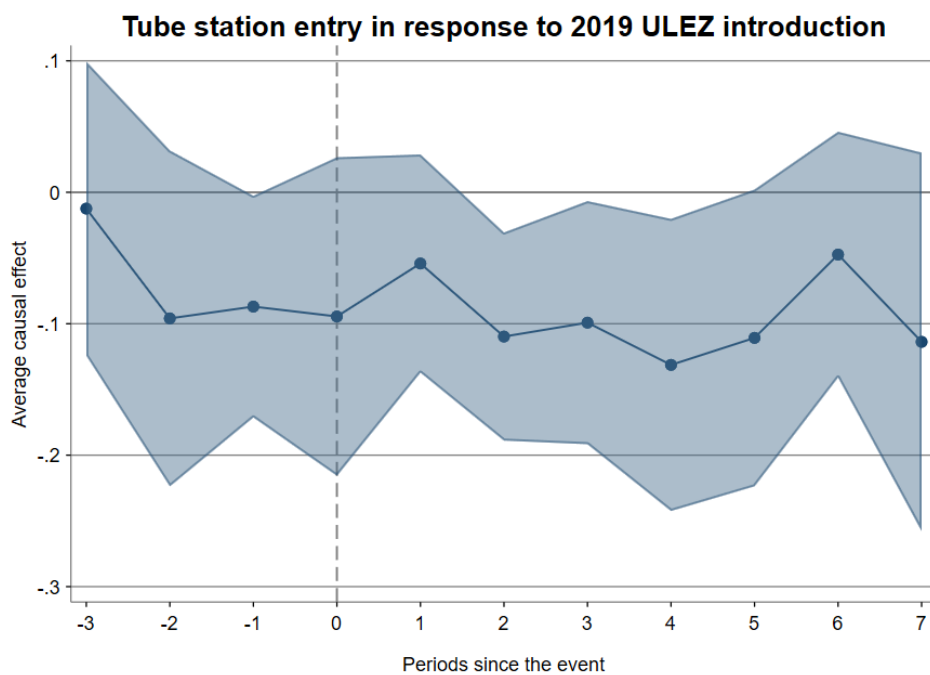
Figure D33: Callaway and Sant'Anna 2021 event study for tube station entry around 2019 ULEZ introduction
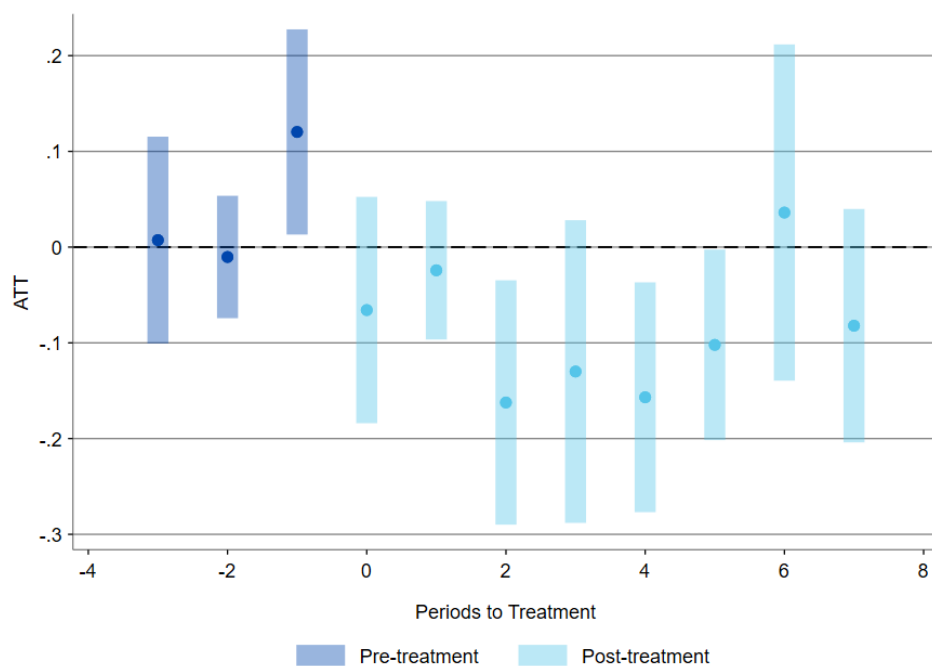
Figure D34: Athey, Bayati, Doudchenko, Imbens, and Khosravi 2021 event study for tube station entry around 2019 ULEZ introduction
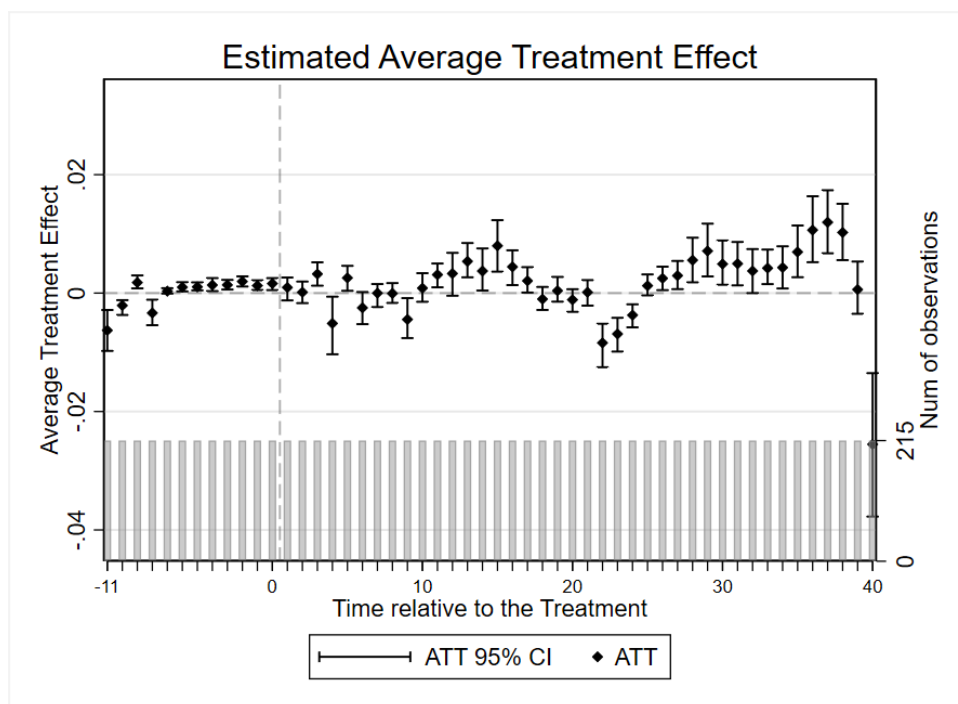
Figure D35: Average change in London underground station entry after September 2021 ULEZ expansion, split by postcodes with above and below median ULEZ exposure.

Difference in average station entry (100,000s) after October 2021 ULEZ expansion
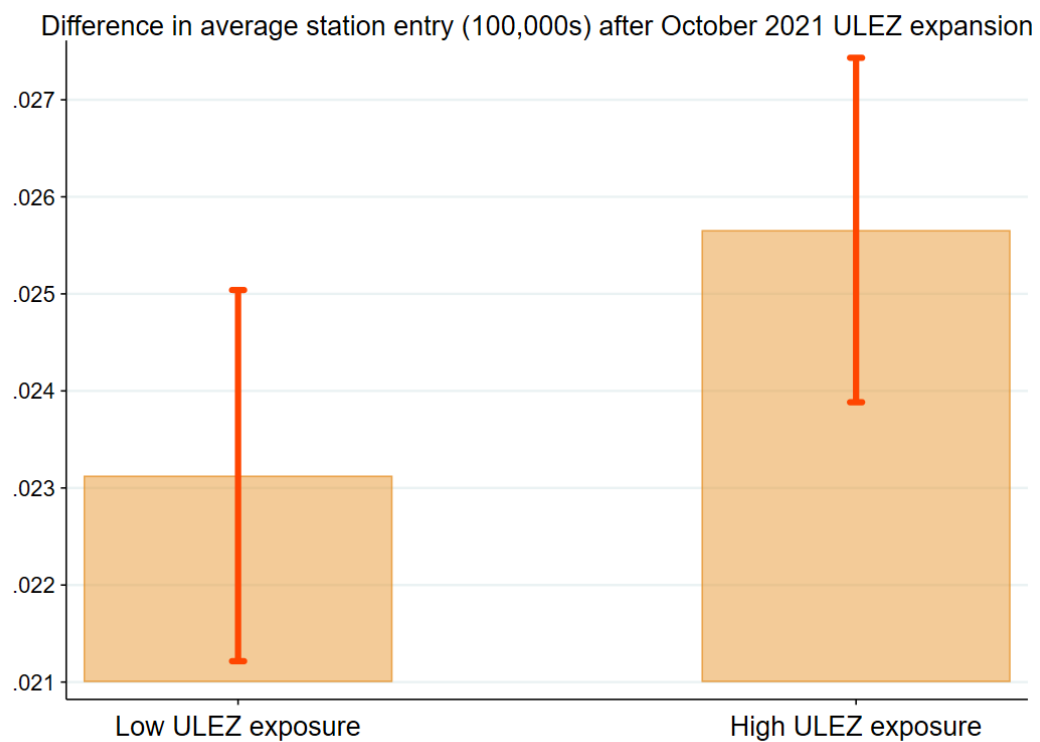
Figure D36: Average working from home share over NUTS3 regions inside and outside the 2019 ULEZ, 2018 - 2020.

Work from home share

Working from home data from De Fraja et al. (2021)
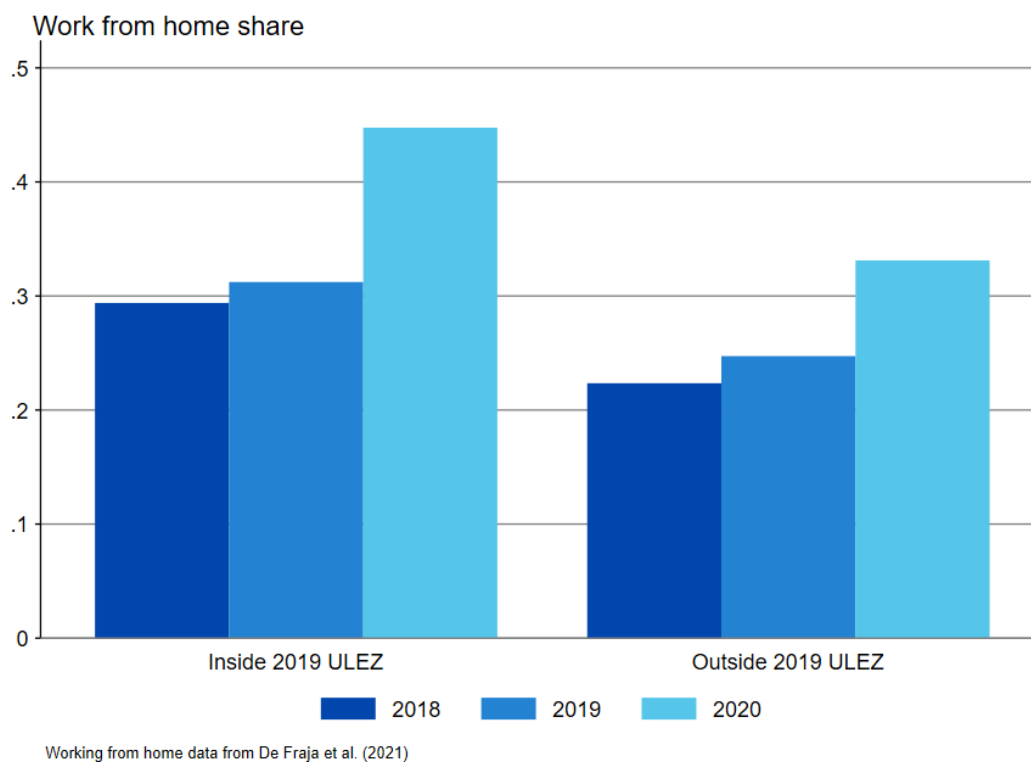
Figure D37: Working from home share (2018) against 2019 ULEZ exposure over NUTS3 regions.

Work from home share (2018)

Working from home data from De Fraja et al. (2021) Best fit line weighted by NUTS3 population.
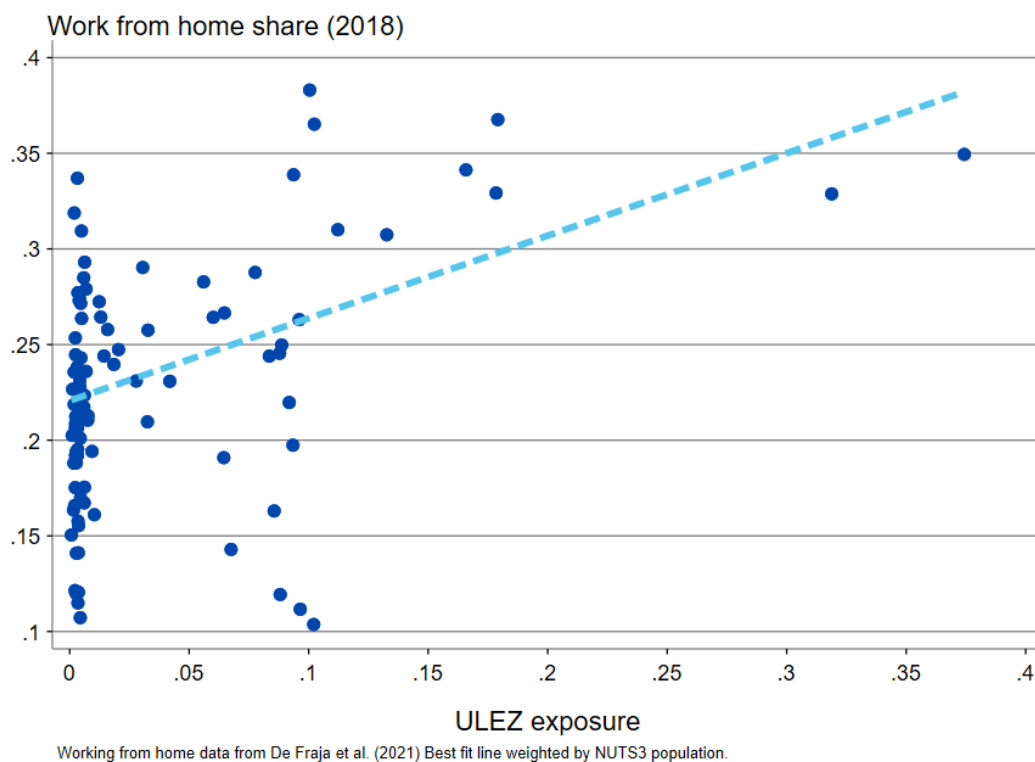
Figure D38: Distribution of ULEZ exposure over London postcode districts, split across four income quartiles
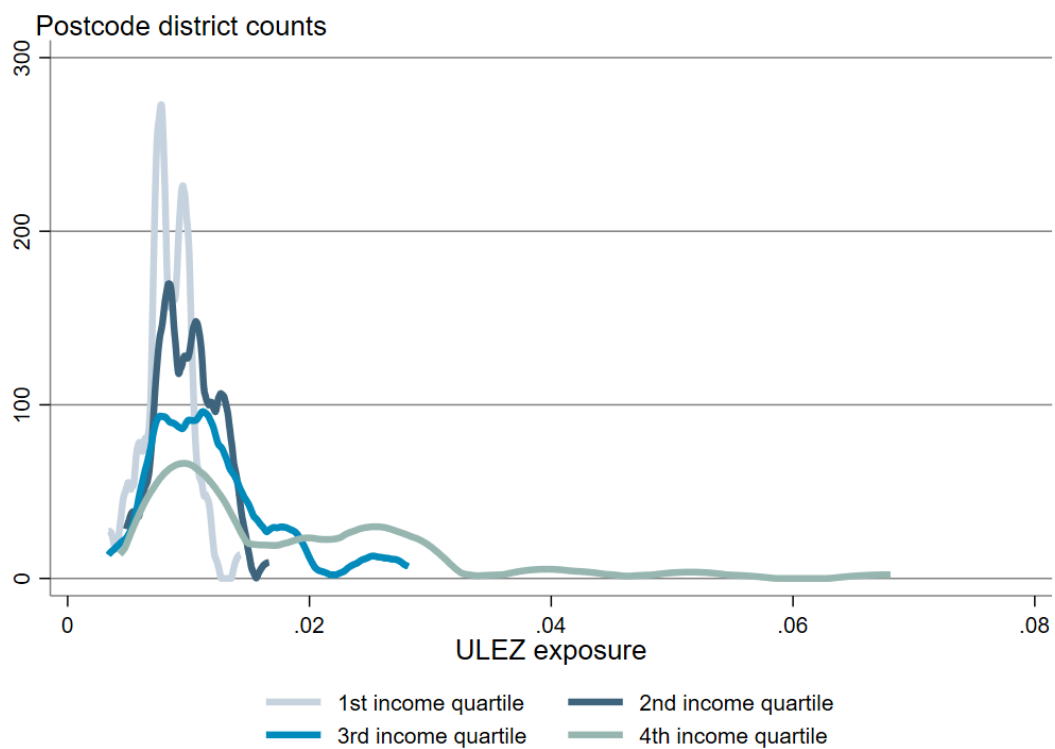
Figure D39: Estimated elasticities to 2021 ULEZ expansion, across income quartiles.
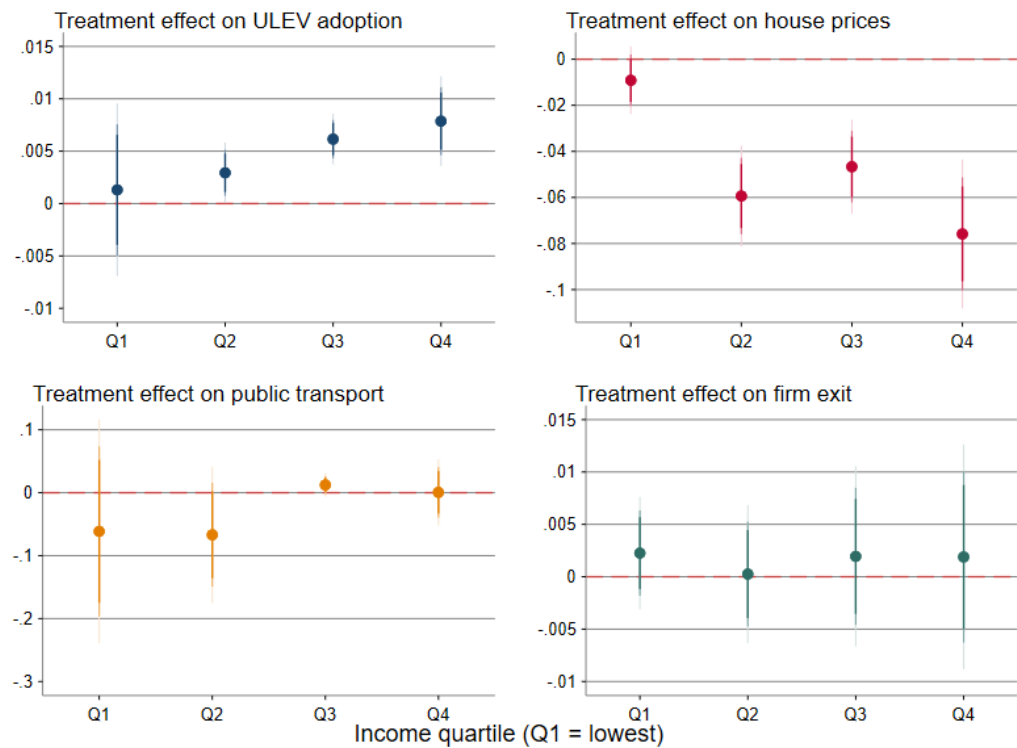
Standardised coefficients for 2021 ULEZ expansion across four margins, with heterogeneity based on 2014 regional net income quartiles.

E   Additional tables

Table E1: Difference-in-differences regression of ULEV share on 2021 ULEZ expansion exposure interacted with a post-policy dummy

	(1)	(2)	(3)
	Dependent variable: ULEV share		
2021 ULEZ exposure	-0.009**	−0.002	0.003
	(0.003)	(0.003)	(0.002)
2021 ULEZ exposure × Post-indicator	0.048***	0.032***	0.038***
	(0.008)	(0.008)	(0.005)
Weight	None	Vehicles	Population
N	11,645	11,645	11,645
R^2	0.330	0.413	0.559

Standard errors in parentheses, clustered at the postcode district level.

* $p < 0.1$, * $p < 0.05$, *** $p < 0.01$. Control for population density, size of postcode district, number of commuters, population-adjusted ULEZ measure and year-quarter fixed effects.

Table E2: Tube station entry placebo test 2019 ULEZ with fake boundary

	(1)	(2)	(3)	(4)
	Dependent variable: Log entry/exit (10000s)			
ULEZ	-0.183	-0.249	-0.123	-0.170
	(0.199)	(0.215)	(0.251)	(0.262)
ULEZ × Post-indicator	0.012	0.014	0.014	0.017
	(0.010)	(0.011)	(0.010)	(0.011)
Post-indicator	-0.009	-0.013	-0.013	-0.017
	(0.018)	(0.022)	(0.018)	(0.022)
Dependent variable	Entry	Entry	Exit	Exit
Postcode district FE	No	No	Yes	Yes
N	104,557	104,703	104,557	104,703
R^2	0.068	0.066	0.455	0.451

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Fixed effects are day, week, month, day of week and week of month.

Table E3: Difference-in-differences regression of station entry/exit on 2021 ULEZ exposure interacted with a post-policy dummy

	(1)	(2)	(3)	(4)
	Dependent variable: Station entry/exit (100,000s)			
2021 ULEZ exposure × Post-indicator	0.033*	0.033***	0.034**	0.035**
	(0.017)	(0.017)	(0.016)	(0.016)
2021 ULEZ exposure	0.011	-0.017	0.011	-0.019
	(0.023)	(0.027)	(0.025)	(0.029)
Post-indicator	-0.004	-0.004	-0.005	-0.005
	(0.005)	(0.005)	(0.005)	(0.005)
ULEZ	0.010	-0.011	0.010	-0.013
	(0.008)	(0.012)	(0.009)	(0.012)
Distance to ULEZ		-0.008***		-0.009***
		(0.002)		(0.002)
Dependent variable	Entry	Entry	Exit	Exit
N	135,631	134,903	135,631	134,903
R^2	0.072	0.098	0.063	0.090

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, * $p < 0.05$, *** $p < 0.01$.

Fixed effects are day, week, month, day of week, week of month.

Table E4: Summary of robustness checks for house price RDD

| Robustness check | *Dependent variable*: Log house price | | |
	Coefficient	Standard error	N
A. Functional form			
1. Asymmetric slopes	0.122***	(0.015)	60,797
2. Cubic polynomial distance	0.118***	(0.015)	130,607
3. Donut RDD	0.119***	(0.016)	57,253
B. Bandwidth sensitivity			
4. Narrow bandwidth (0.5 miles)	0.116***	(0.021)	37,054
5. Wide bandwidth (2.0 miles)	0.118***	(0.015)	130,607
C. Heterogeneity			
6. Distance interaction	0.131***	(0.027)	60,797
7. Triple interaction	0.170***	(0.030)	60,797
D. Falsification test			
8. Placebo boundary	0.005	(0.012)	43,074

The table reports the coefficient on the *ULEZ × Post-indicator* term for various specifications. Unless otherwise noted, specifications use triangular kernel weights and limit the sample to within 1 mile of the boundary. Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table E5: Baseline house price RDD for 2021 ULEZ boundary.

	(1)	(2)	(3)	(4)
	Dependent variable: Log house price			
2021 ULEZ	0.031**	-0.051***	-0.043**	-0.075***
	(0.013)	(0.017)	(0.018)	(0.018)
2021 ULEZ × Post-indicator	-0.058***	-0.043***	-0.038***	-0.042***
	(0.002)	(0.004)	(0.004)	(0.005)
Distance	-0.008***	-0.059***	-0.031***	-0.058***
	(0.002)	(0.011)	(0.014)	(0.014)
Fixed Effects	Yes	Yes	Yes	Yes
Triangular kernel weight (2 mile)	No	Yes	No	Yes
Within 1 mile	No	No	Yes	Yes
N	1,028,500	524,444	430,081	430,078
R^2	0.392	0.375	0.371	0.375

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Fixed effects are year-quarter and 4-digit postcode.

Table E6: House price "donut" RDD for 2021 ULEZ boundary

	(1)	(2)	(3)	(4)
	Dependent variable: Log house price			
2021 ULEZ	0.039***	-0.026	-0.017	-0.045**
	(0.013)	(0.017)	(0.018)	(0.019)
2021 ULEZ × Post-indicator	-0.055***	-0.038***	-0.034***	-0.036***
	(0.002)	(0.004)	(0.004)	(0.005)
Distance	-0.008***	-0.042***	-0.010	-0.034***
	(0.003)	(0.026)	(0.051)	(0.053)
Fixed Effects	Yes	Yes	Yes	Yes
Triangular kernel weight (2 mile)	No	Yes	No	Yes
Within 1 mile	No	No	Yes	Yes
N	990,472	486,416	392,053	392,050
R^2	0.387	0.373	0.370	0.374

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Fixed effects are year-quarter and 4-digit postcode.

Table E7: House price RDD for 2019 ULEZ boundary with distance heterogeneity

	(1)	(2)	(3)	(4)
	Dependent variable: Log house price			
Positive distance	-0.042***	-0.189***	-0.435***	-0.451***
	(0.003)	(0.026)	(0.056)	(0.057)
Negative distance	-0.402***	-0.439***	-0.507***	-0.505***
	(0.123)	(0.125)	(0.124)	(0.125)
ULEZ	0.192***	-0.018	-0.079*	-0.088**
	(0.035)	(0.039)	(0.042)	(0.042)
ULEZ × Post-indicator	0.053***	0.117***	0.120***	0.122***
	(0.013)	(0.015)	(0.015)	(0.015)
Fixed Effects	Yes	Yes	Yes	Yes
Triangular kernel weight (2 mile)	No	Yes	No	Yes
Within 1 mile	No	No	Yes	Yes
N	629,217	130,607	60,797	60,797
R^2	0.384	0.357	0.355	0.345

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Fixed effects are year-quarter and 4-digit postcode.

Table E8: House price RDD for 2019 ULEZ boundary varying triangular bandwidths

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Log house price					
ULEZ	-0.056	-0.139***	-0.133***	-0.110***	-0.071**	-0.029
	(0.055)	(0.043)	(0.036)	(0.032)	(0.030)	(0.028)
ULEZ × Post-indicator	0.116***	0.124***	0.123***	0.118***	0.113***	0.109***
	(0.021)	(0.017)	(0.015)	(0.015)	(0.014)	(0.014)
Distance	0.058	-0.196***	-0.179***	-0.140***	-0.092***	-0.041***
	(0.103)	(0.061)	(0.039)	(0.026)	(0.018)	(0.014)
Bandwidth (miles)	0.5	1	1.5	2	2.5	3
N	37,054	60,797	89,868	130,607	170,657	210,474
R^2	0.303	0.326	0.343	0.356	0.360	0.361

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Fixed effects are year-quarter and 4-digit postcode.

Table E9: House price RDD for 2019 ULEZ boundary with distance interaction

	(1)	(2)	(3)	(4)
	Dependent variable: Log house price			
ULEZ	0.080***	-0.122***	-0.179***	-0.167***
	(0.024)	(0.033)	(0.041)	(0.042)
ULEZ × Post-indicator	0.087***	0.136***	0.133***	0.131***
	(0.014)	(0.020)	(0.026)	(0.027)
Distance	-0.046***	-0.153***	-0.270***	-0.251***
	(0.003)	(0.026)	(0.052)	(0.053)
Post-indicator × Distance	0.006***	0.019*	0.017	0.013
	(0.000)	(0.011)	(0.026)	(0.028)
Fixed Effects	Yes	Yes	Yes	Yes
Triangular kernel weight (2 mile)	No	No	Yes	Yes
Within 1 mile	No	Yes	No	Yes
N	629,217	130,607	60,797	60,797
R^2	0.385	0.356	0.354	0.344

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Fixed effects are year-quarter and 4-digit postcode.

Table E10: House price RDD for 2019 ULEZ boundary with triple interaction

	(1)	(2)	(3)	(4)
	Dependent variable: Log house price			
ULEZ	0.129***	-0.067	-0.118***	-0.121***
	(0.037)	(0.041)	(0.044)	(0.044)
ULEZ × Post-indicator	0.143***	0.187***	0.175***	0.170***
	(0.024)	(0.027)	(0.030)	(0.030)
Distance	-0.04***	-0.197***	-0.427***	-0.435***
	(0.003)	(0.027)	(0.058)	(0.060)
ULEZ × Post-indicator × Distance	0.356***	0.382***	0.401***	0.420***
	(0.103)	(0.105)	(0.106)	(0.109)
Fixed Effects	Yes	Yes	Yes	Yes
Triangular kernel weight (2 mile)	No	No	Yes	Yes
Within 1 mile	No	Yes	No	Yes
N	629,217	130,607	60,797	60,797
R^2	0.385	0.357	0.355	0.345

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Fixed effects are year-quarter and 4-digit postcode.

Table E11: House price RDD for 2019 ULEZ boundary with polynomial distance

	(1)	(2)	(3)
	Dependent variable: Log house price		
ULEZ	-0.110***	-0.101**	-0.055
	(0.032)	(0.044)	(0.046)
ULEZ × Post-indicator	0.118***	0.118***	0.118***
	(0.015)	(0.015)	(0.015)
Distance	-0.140***	-0.122*	0.020
	(0.026)	(0.067)	(0.074)
Distance^2		-0.011	-0.479***
		(0.032)	(0.084)
Distance^3			0.227***
			(0.033)
Fixed Effects	Yes	Yes	Yes
Triangular kernel weight (2 mile)	Yes	Yes	Yes
N	130,607	130,607	130,607
R^2	0.356	0.356	0.357

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Fixed effects are year-quarter and 4-digit postcode.

Table E12: House price "donut" RDD for 2019 ULEZ boundary

	(1)	(2)	(3)	(4)
	Dependent variable: Log house price			
ULEZ	0.131***	-0.093***	-0.169***	-0.160***
	(0.025)	(0.034)	(0.042)	(0.043)
ULEZ × Post-indicator	0.050***	0.114***	0.117***	0.119***
	(0.014)	(0.015)	(0.016)	(0.016)
Distance	-0.041***	-0.153***	-0.282***	-0.270***
	(0.003)	(0.026)	(0.051)	(0.053)
Fixed Effects	Yes	Yes	Yes	Yes
Triangular kernel weight (2 mile)	No	Yes	No	Yes
Within 1 mile	No	No	Yes	Yes
N	625,673	127,063	57,253	57,253
R^2	0.382	0.356	0.354	0.343

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Fixed effects are year-quarter and 4-digit postcode.

Table E13: House price placebo test 2019 ULEZ with fake boundary

	(1)	(2)	(3)	(4)
	Dependent variable: Log house price			
ULEZ	-0.156***	-0.131***	-0.079*	-0.075*
	(0.025)	(0.040)	(0.044)	(0.045)
ULEZ × Post-indicator	-0.023***	0.004	-0.000	0.005
	(0.007)	(0.009)	(0.012)	(0.012)
Distance	-0.055***	-0.022	0.064*	0.042
	(0.003)	(0.026)	(0.037)	(0.038)
Fixed Effects	Yes	Yes	Yes	Yes
Triangular kernel weight (2 mile)	No	Yes	No	Yes
Within 1 mile	No	No	Yes	Yes
N	629,217	76,887	43,074	43,074
R^2	0.384	0.292	0.303	0.298

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.
Fixed effects are year-quarter and 4-digit postcode.

Table E14: House price RDD for 2021 ULEZ boundary varying triangular bandwidths

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Log house price					
2021 ULEZ	-0.219***	-0.139***	-0.077***	-0.051***	-0.033**	-0.023
	(0.028)	(0.020)	(0.018)	(0.017)	(0.016)	(0.015)
2021 ULEZ × Post-indicator	-0.060***	-0.046***	-0.043***	-0.043***	-0.044***	-0.045***
	(0.012)	(0.006)	(0.004)	(0.004)	(0.003)	(0.003)
Distance	-0.256***	-0.115***	-0.067***	-0.059***	-0.049***	-0.043***
	(0.029)	(0.017)	(0.013)	(0.011)	(0.010)	(0.009)
Bandwidth (miles)	0.5	1	1.5	2	2.5	3
N	335,307	428,523	483,064	524,444	561,572	597,231
R^2	0.393	0.380	0.376	0.375	0.374	0.375

Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Fixed effects are year-quarter and 4-digit postcode.

Table E15: Summary of robustness checks for firm entry and exit RDD

Dependent variable:	Firm entry rate		Firm exit rate		
Robustness check	Coeff	SE	Coeff	SE	N
A. Functional form					
1. Baseline	0.013**	(0.005)	0.035**	(0.016)	245,189
2. Donut RDD	0.014**	(0.005)	0.037**	(0.017)	225,852
3. Triple difference	0.009	(0.006)	0.040*	(0.023)	245,189
B. Bandwidth sensitivity					
4. Narrow bandwidth (1 mile)	0.013**	(0.005)	0.035**	(0.016)	245,189
5. Wide bandwidth (5 miles)	0.010**	(0.004)	0.028**	(0.012)	1,079,163
C. Falsification test					
6. Placebo boundary	-0.067	(0.051)	-0.044	(0.029)	245,189

Notes: The table reports the coefficient on the *ULEZ × Post-indicator* term (or *Fake ULEZ* equivalent) for various specifications. All specifications use "combined" weights (triangular kernel + firm count weighting) unless otherwise noted. Standard errors in parentheses, clustered at the postcode level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table E16: Baseline firm entry and exit RDD for 2021 ULEZ boundary.

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Firm entry rate			*Dependent variable*: Firm exit rate		
ULEZ	-0.0095**	-0.0031	-0.0032	-0.0072**	-0.0000	0.0021
	(0.0029)	(0.0032)	(0.0035)	(0.0030)	(0.0059)	(0.0073)
ULEZ × Post-indicator	0.0023	-0.0001	-0.0004	0.0011	0.0031	0.0009
	(0.0033)	(0.0028)	(0.0030)	(0.0043)	(0.0048)	(0.0055)
Distance	-0.0038*	-0.0012	-0.0029	-0.0051**	0.0019	0.0011
	(0.0022)	(0.0030)	(0.0036)	(0.0022)	(0.0023)	(0.0026)
Weight	Triangular	# firms	Combined	Triangular	# firms	Combined
N	1,024,202	961,039	961,039	1,024,202	961,039	961,039

Standard errors in parentheses, clustered at the postcode level.

* $p<0.1$, ** $p<0.05$, *** $p<0.01$. Fixed effects are year, quarter, postcode district.

Table E17: Baseline firm entry rate RDD for 2019 ULEZ boundary.

	(1)	(2)	(3)
	Dependent variable: Firm entry rate		
ULEZ	-0.0009	-0.0078	-0.0094*
	(0.0055)	(0.0050)	(0.0056)
ULEZ × Post-indicator	-0.0003	0.0121**	0.0132**
	(0.0076)	(0.0048)	(0.0048)
Distance	0.0134**	0.0073*	0.0015
	(0.0042)	(0.0043)	(0.0078)
Weight	Triangular	# firms	Combined
N	259,590	245,189	245,189

Standard errors in parentheses, clustered at the postcode level.

* p<0.1, ** p<0.05, *** p<0.01. Fixed effects are year, quarter, postcode district.

Table E18: Bandwidth sensitivity for firm entry and exit RDD around 2019 ULEZ boundary.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Dependent variable: Entry rate					*Dependent variable*: Exit rate				
ULEZ	-0.009*	-0.009*	-0.008*	-0.008*	-0.008*	-0.003	-0.011	-0.011	-0.010	-0.010
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.008)	(0.009)	(0.009)	(0.009)	(0.009)
Post-indicator	-0.007**	-0.007***	-0.006***	-0.005***	-0.004***	-0.000	-0.001	-0.001	-0.000	0.001
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.007)	(0.006)	(0.005)	(0.004)	(0.004)
ULEZ × Post-indicator	0.013**	0.012**	0.011**	0.011**	0.010**	0.035**	0.033**	0.031**	0.029**	0.028**
	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.016)	(0.015)	(0.014)	(0.013)	(0.012)
Distance	0.002	0.004*	0.003	0.001	0.001	0.044	0.010	0.005	0.003	0.001
	(0.008)	(0.002)	(0.002)	(0.001)	(0.001)	(0.031)	(0.008)	(0.005)	(0.003)	(0.002)
Bandwidth (miles)	1	2	3	4	5	1	2	3	4	5
N	245,189	451,302	669,878	857,316	1,079,163	245,189	451,302	669,878	857,316	1,079,163

Standard errors in parentheses, clustered at the postcode level. Weights are triangular and adjust for the number of firms at the postcode-quarter level.
* p<0.1, ** p<0.05, *** p<0.01. Fixed effects are year, quarter, postcode district.

Table E19: Donut RDD for firm entry and exit around 2019 ULEZ boundary.

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Entry rate			*Dependent variable*: Exit rate		
ULEZ	-0.003	-0.008	-0.010*	-0.006	-0.011	-0.004
	(0.006)	(0.005)	(0.006)	(0.005)	(0.009)	(0.008)
ULEZ × Post-indicator	0.000	0.013**	0.014**	0.009	0.037**	0.037**
	(0.008)	(0.005)	(0.005)	(0.005)	(0.017)	(0.017)
Distance	0.012**	0.007	-0.001	0.010**	0.018	0.041
	(0.004)	(0.004)	(0.008)	(0.004)	(0.013)	(0.030)
Weight	Triangular	# firms	Combined	Triangular	# firms	Combined
N	239,135	225,852	225,852	239,135	225,852	225,852

Standard errors in parentheses, clustered at the postcode level.

* $p<0.1$, ** $p<0.05$, *** $p<0.01$. Fixed effects are year, quarter, postcode district.

Table E20: Triple difference RDD for firm entry and exit around 2019 ULEZ boundary.

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Entry rate			*Dependent variable*: Exit rate		
ULEZ × Post-indicator	-0.005	0.010	0.009	0.007	0.041*	0.040*
	(0.009)	(0.006)	(0.006)	(0.010)	(0.021)	(0.023)
Post-indicator × Distance	0.003	0.005	-0.007	0.006**	-0.003	-0.026
	(0.003)	(0.003)	(0.009)	(0.003)	(0.006)	(0.020)
ULEZ × Post-indicator × Distance	-0.007	0.035	0.052	0.022	0.139*	0.177*
	(0.045)	(0.037)	(0.037)	(0.042)	(0.071)	(0.090)
Weight	Triangular	# firms	Combined	Triangular	# firms	Combined
N	259,590	245,189	245,189	259,590	245,189	245,189

Standard errors in parentheses, clustered at the postcode level.

* $p<0.1$, ** $p<0.05$, *** $p<0.01$. Fixed effects are year, quarter, postcode district.

Table E21: Placebo RDD for firm entry and exit around 2019 ULEZ boundary.

	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable: Entry rate			*Dependent variable*: Exit rate		
Fake ULEZ	0.050	0.021	0.023	0.039	-0.007	0.017
	(0.056)	(0.041)	(0.056)	(0.033)	(0.030)	(0.029)
Fake ULEZ × Post-indicator	-0.099*	-0.071*	-0.067	-0.072**	-0.006	-0.044
	(0.053)	(0.038)	(0.051)	(0.032)	(0.040)	(0.029)
Distance	0.000	0.000	0.000	0.000	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Weight	Triangular	# firms	Combined	Triangular	# firms	Combined
N	259,590	245,189	245,189	259,590	245,189	245,189

Standard errors in parentheses, clustered at the postcode level.

* $p<0.1$, ** $p<0.05$, *** $p<0.01$. Fixed effects are year, quarter, postcode district.