IPR Policy Brief
November 2023

Low Emission Zones improve air quality, physical health and mental well-being

Evaluating the impact of the Low Emission Zone (LEZ) and Ultra-Low Emission Zone (ULEZ) schemes in England

Professor Eleonora Fichera
Dr Habtamu Beshir
Dr Andrea Serna Castaño

Ambient air pollution is a major public health concern. It has prompted novel policy interventions, in the UK and beyond, notably in the form of Low Emission Zone (LEZ) and Ultra-Low Emission Zone (ULEZ) schemes. This policy brief explores the impact of these schemes on physical health and mental well-being, using large survey and administrative data covering the whole of England.

It finds that these policy interventions have significantly reduced levels of key pollutants, leading to improvements in physical health and mental well-being, and a reduction of hospitalisations for respiratory problems. This effect has been particularly strong for the Central London ULEZ scheme, the strictest of the clean air policies, but we also see positive health impacts over Greater London where the LEZ scheme has been implemented since 2008.

Our evidence suggests that these schemes offer good value for money, with a cost-benefit analysis indicating savings of more than £963 million in Greater London.

IPR Institute for Policy Research

The Policy Challenge

Ambient air pollution is one of the major environmental health threats across the world, with 4.2 million premature deaths per year attributable to it.[1] In Europe and the United Kingdom (UK), air pollution has been brought to the forefront of policy debates, particularly with regards to transport as car exhaust is a major source of ambient air pollution in urban areas.[2]

This policy brief presents findings from several studies on one of the most popular policies in Europe,[3] the Low Emission Zone (LEZ) and Ultra-Low Emission Zone (ULEZ) schemes, focusing on London and other major cities in England as a case study.

LEZ-type policies have been introduced in many cities in Europe.[4] For instance, in Germany LEZ has reduced the number of days levels of particulate matter (PM_{10}) are above the regulatory levels and decreased the number of diagnoses related to diseases of the circulatory and respiratory system.[5] Other studies have found that Greater London's LEZ and Central London's ULEZ improved air quality, however, these studies have either focused on only the earlier phases of LEZ, used before-and-after methodologies, or restricted analyses to a small window of time around scheme implementation.[6]

1 WHO (2022). Ambient (outdoor) air pollution. World Health Organization (WHO).

2 Alexander D. and Schwandt, H. (2022). The impact of car pollution on infant and child health: Evidence from emissions cheating. *The Review of Economic Studies*, 89(6), 2872-2910; Currie, J. and R. Walker (2011). Traffic congestion and infant health: Evidence from e-zpass. *American Economic Journal: Applied Economics*, 3(1), 65–90.

3 Clean Cities (2022). The development trends of low- and zero-emission zones in Europe. Clean Cities Campaign.

4 Pestel, N. and Wozny, F. (2021). Health effects of low emission zones: Evidence from German hospitals. *Journal of Environmental Economics and Management*, 109, 102512; Wolff, H. and Perry, L. (2010). Policy monitor: trends in clean air legislation in Europe: particulate matter and low emission zones. *Review of Environmental Economics and Policy*, 4(2), 293–308; Ellison, R. B., Greaves, S. P. and Hensher, D. A. (2013). Five years of London's low emission zone: Effects on vehicle fleet composition and air quality. *Transportation Research Part D: Transport and Environment*, 23, 25–33; Wolff, H. (2014). Keep your clunker in the suburb: low-emission zones and adoption of green vehicles. *The Economic Journal*, 124(578), F481–F512; Margaryan, S. (2021). Low emission zones and population health. *Journal of Health Economics*, 76, 102402; Gehrsitz, M. (2017). The effect of low emission zones on air pollution and infant health. *Journal of Environmental Economics and Management*, 83, 121–144.

5 Pestel, N. and F. Wozny (2021). Health effects of low emission zones: Evidence from German hospitals. *Journal of Environmental Economics and Management*, 109, 102512.

6 Ellison, R. B., Greaves, S. P. and Hensher, D. A. (2013). Five years of London's low emission zone: Effects on vehicle fleet composition and air quality. *Transportation Research Part D: Transport and Environment*, 23, 25–33; Ma, L., Graham, D. and Stettler, M. (2021). Has the ultra low emission zone in London improved air quality? *Environmental Research Letters*, 16(124001); Prieto-Rodriguez, J., Perez-Villadoniga, M., Salas, R. and Russo, A. (2022). Impact of London Toxicity Charge and Ultra Low Emission Zone on NO_2. *Transport Policy*, 129, 237–247; Zhai, M. and Wolff, H. (2021). Air pollution and urban road transport: evidence from the world's largest low-emission zone in London. *Environmental Economics and Policy Studies*, 23, 721-748.

This policy brief presents new causal evidence on the effectiveness of LEZ and ULEZ with regard to improving physical health and mental well-being, using large survey and administrative data covering the whole of England. We do so by using a Difference-in-Differences methodology, comparing London to comparable cities that have not implemented these policies, before and after their introduction. Therefore, we are able to account for time trends as well as other confounding factors affecting both the adoption of the policies, air quality and health.[7]

This evidence shows both schemes improve air quality as measured by particulate matter (PM_{10}) and nitrogen dioxide (NO_2), with stronger impacts by ULEZ, the strictest of the two schemes. It also suggests there are physical health and mental well-being improvements with sizeable financial savings for the overall population.

The Policy Context

In the years before the implementation of LEZ, London's ambient air pollution was the worst of any city in the UK and amongst the worst in Europe. Levels of key pollutants such as PM_{10} and NO_2 exceeded national and European air quality targets.[8] As a result, LEZ was introduced from the 4th of February 2008 in four stages to target road traffic pollution in almost all of Greater London. Each stage sets increasingly demanding emission standards on vehicles, targeting specifically the most polluting ones such as older, heavier diesel-fuelled vehicles.[9]

Other cities that have adopted LEZ-type clear air policies include Norwich in 2008, Oxford in 2014, Brighton in 2015, Birmingham and Bath in 2021, and Bristol in 2022. Many more cities are considering the introduction of clean air zones such as Manchester, Sheffield, Dundee, Edinburgh and Aberdeen.

To further improve London's air quality, and in response to findings on the health costs of air pollution,[10] the Mayor of London, Sadiq Khan, introduced ULEZ in Central London from the 8th of April 2019. ULEZ is the strictest scheme of any city in the world, requiring Euro 3 emission standards for motorcycles and Euro 4, 6 for different types of cars, vans and lorries. A stepping-stone to ULEZ, the Toxicity Charge (T-charge) was seen as the starting point for a change in the vehicle fleet in Central London.[11] Both LEZ and ULEZ operate 24 hours a day, all year round, and impose penalties for non-compliers.

7 Beshir H. and Fichera E. (2022). "And breathe normally": The Low Emission Zone impacts on physical health and mental wellbeing in England. Working Paper, HEDG WP 22/09, University of York; Beshir H. and Fichera E. (2023). Impacts of Low Emission Zones on population health: Evidence from Hospital Episode Statistics. Working Paper.

8 Transport for London (2008). London low emission zone: Impacts monitoring baseline report.

9 Ibid.

10 Brand, C. and Hunt, A (2018). The health costs of air pollution from cars and vans. Global Action Plan.

11 Greater London Authority (2019). Central London ULEZ: Six month report.

Air Quality Effects of LEZ and ULEZ

To analyse the air pollution effect of LEZ and ULEZ, we use daily average data on NO_2 and PM_{10} that are mostly generated by vehicle exhaust. We also use data from the Met Office – MIDAS Land Surface Stations on daily average weather variables (rainfall, temperature and wind). We examine air pollution levels before and after the introduction of these policies, comparing London to other cities in England.

Figure 1: Impact of LEZ on air quality in Greater London*[12]

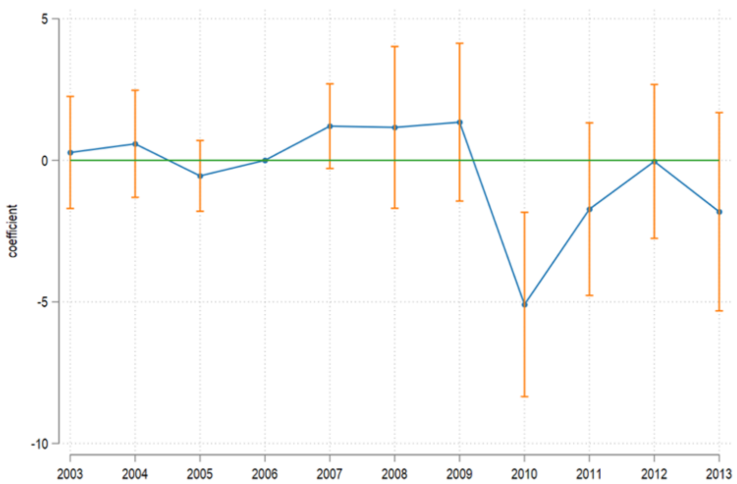

Figure 1a: Impact of LEZ on NO_2

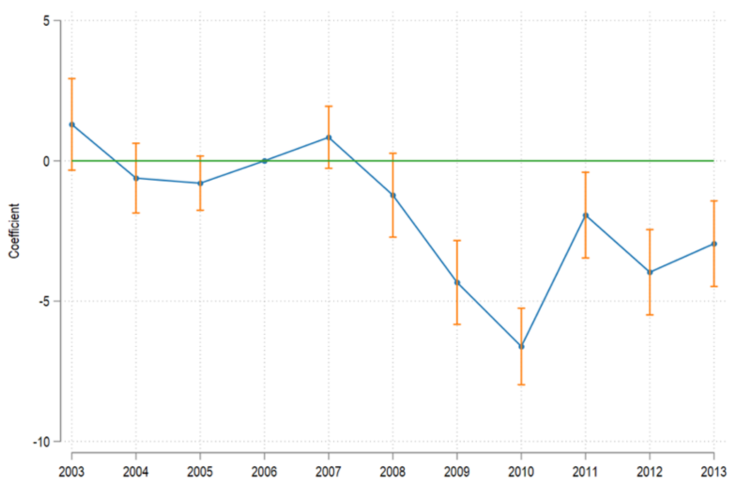

Figure 1b: Impact of LEZ on PM_{10}

* Note: The plot displays the coefficients from an event study model using Difference-in-Differences of LEZ/ULEZ on air quality. The vertical lines indicate confidence intervals. When these cross zero, the coefficients are not statistically significant.

12 Source: Beshir H. and Fichera E. (2022). "And breathe normally": The Low Emission Zone impacts on physical health and mental wellbeing in England. Working Paper, HEDG WP 22/09, University of York.

Figure 2: Impact of ULEZ on air quality in Central London[13]

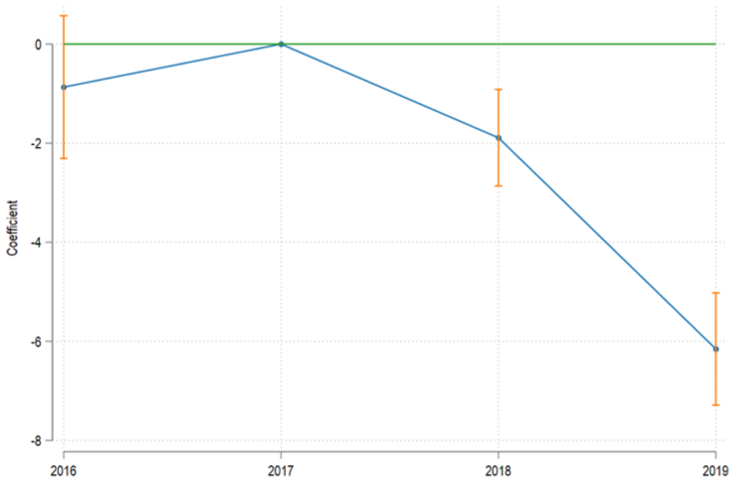

Figure 2a: Impact of ULEZ on NO_2

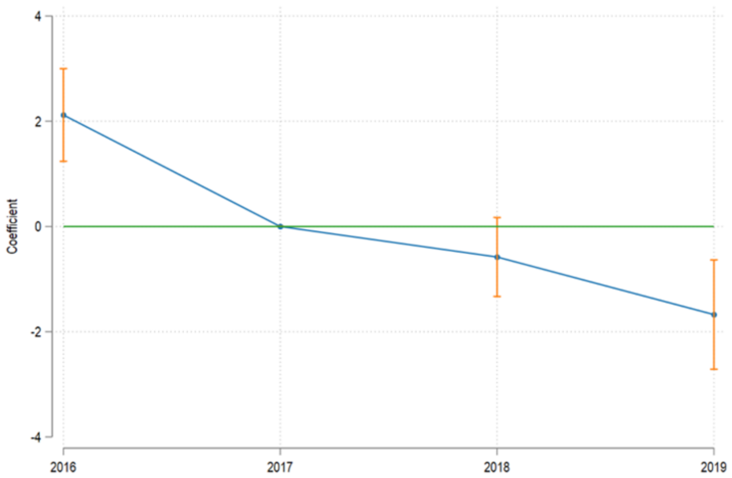

Figure 2b: Impact of ULEZ on PM_{10}

We find a significant drop in PM_{10} after LEZ was introduced in 2008, but only a significant drop in NO_2 in 2010 (Figures 1a and 1b). To give an idea of the magnitude of its impact, the introduction of LEZ reduced daily average PM_{10} by 3.8 $\mu g/m^3$, equivalent to 13% of the average pre-LEZ PM_{10} levels in Greater London (Figure 1b). This is an average across the post-LEZ years 2009-2013, but in fact the impact was stronger as the policy became stricter in its second stage, with an average reduction of PM_{10} equivalent to 14.13% of the pre-LEZ levels. Because of its stricter emission standards, the impact of ULEZ on NO_2 has been even stronger with a 18.4% reduction compared to the baseline mean (equivalent to 6.8 $\mu g/m^3$).

Using data from the UK Driver and Vehicle Licensing Agency (DVLA), we infer that one of the mechanisms at play was a sharp rise in the number of Ultra-Low Emission Vehicles (ULEVs) in Central London after ULEZ was introduced, compared to other local authorities in England (equivalent to an additional increase of 348 new ULEVs).

13 Source: Ibid.

Physical Health and Wellbeing Effects of LEZ and ULEZ

To analyse the health and well-being effects of LEZ and ULEZ, we use survey data from the Quarterly Labour Force Survey (QLFS) and Annual Population Survey (APS), and administrative data from the Hospital Episode Statistics (HES). We examine physical health and mental well-being changes before and after the introduction of LEZ/ULEZ, comparing London to other cities in England.

We find that LEZ reduced long-term health problems by 4.5% of the baseline mean and respiratory problems such as asthma and bronchitis by 8% of the baseline mean in the second stage of its introduction (Figures 3a and 3b). It has also reduced the likelihood of sick leave by 14.3% of the baseline mean.

Figure 3: Impact of LEZ on long-term health and respiratory problems in Greater London[14]

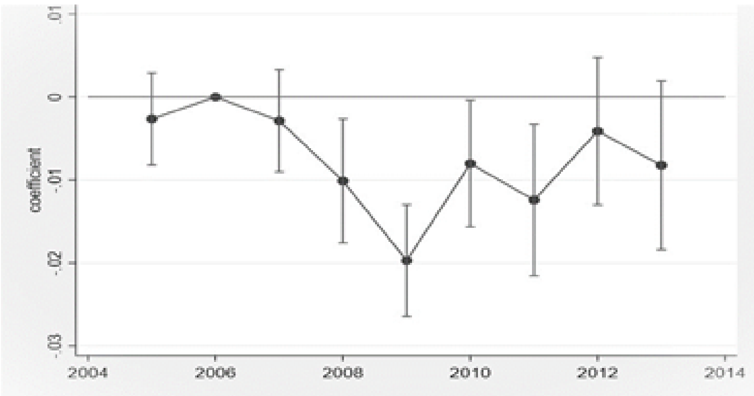

Figure 3a: Impact of LEZ on long-term health

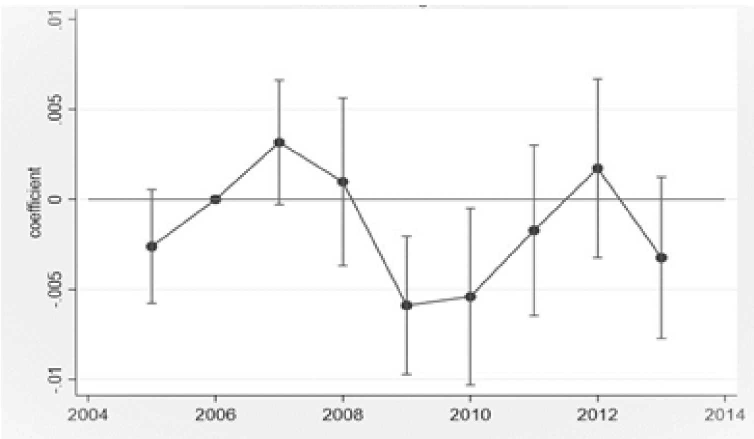

Figure 3b: Impact of LEZ on chronic obstructive pulmonary disease (COPD)

14 Source: Ibid.

ULEZ improved general health by 3% of the baseline mean and reduced anxiety, with an effect equivalent to 6% of the baseline mean (Figures 4a and 4b).

Figure 4: Impact of ULEZ on general health and mental well-being in Central London [15]

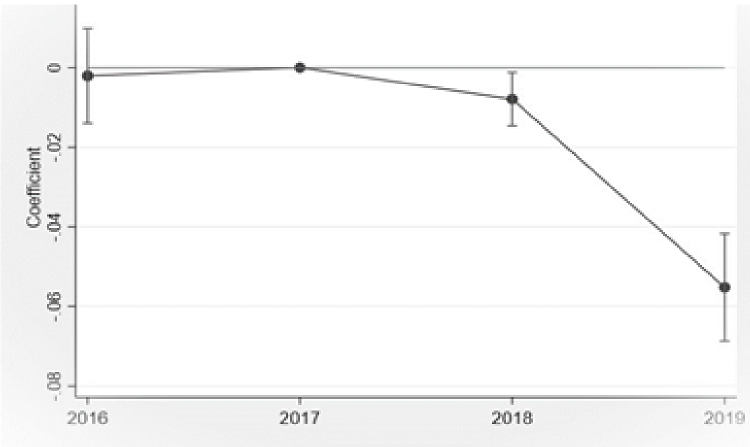

Figure 4a: Impact of ULEZ on general health

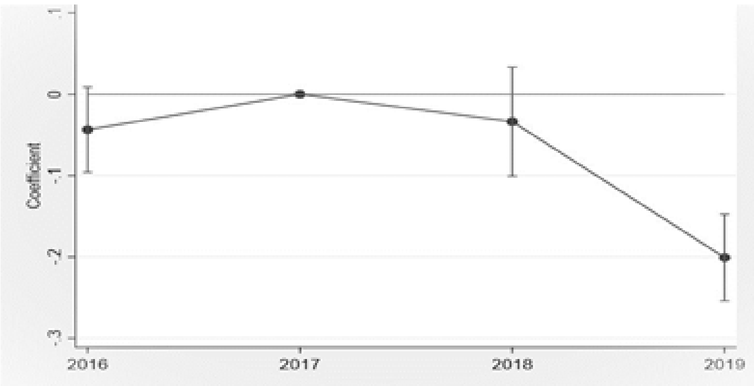

Figure 4b: Impact of ULEZ on anxiety

In terms of hospitalisation, LEZ has led to a reduction in 12 respiratory admissions per 10,000 people, and 2.88 acute respiratory admissions per 10,000 people, in Greater London compared to other areas in England. These results hold even when looking at Accidents & Emergency (A&E) data, with a reduction of respiratory admissions equal to 12 cases per 10,000 people.

In additional analyses we examine the impacts of LEZ-type policies of London and Norwich compared to other cities that have not implemented any clean air policy and we find our results are similar, indicating that the improvements in physical health and mental well-being might extend beyond London, although this could be due to the London sample being bigger.

15 Source: Ibid.

Lastly but importantly, we show that ULEZ has reduced GP quarterly prescriptions for respiratory infections by 9 prescriptions per 1,000 registered patients. This in turn led to a reduction of GP quarterly respiratory prescription costs by £74 per 1,000 registered patients.

Cost-Benefit Analysis

We have done a back-of-the-envelope cost-benefit analysis of these policies under several subjective assumptions based on our in-sample estimates from the survey data. A feasibility report commissioned by the Greater London Authority (GLA) and Transport for London (TfL), amongst others, has estimated the start-up costs of the Greater London LEZ to be £36.5 million, the annual operating costs to be £28.1 million and the annual revenues to be £11.6 million.[16]

Based on our findings, at an average cost of £27,747,[17] the extra 348 ULEVs would cost consumers about £9,655,956. However, this estimate does not account for running vehicle costs, and other behavioural components such as switching to other transport modes.

In calculating the benefits of LEZ, we attempt to take a wider perspective by considering not just the health benefits, but also the wider reported satisfaction by individuals and the impact on the labour market. However, we do recognise that we have not captured all potential benefits, for example those related to education.

To calculate the financial costs on health and the labour market, we use the per capita cost of illness values for chronic obstructive pulmonary disease (COPD) provided by Public Health England[18] and define COPD patients as those who have bronchitis and a limiting health condition in our sample. We then apply our in-sample estimates to the London population and calculate savings to be just over £480 million. Using the UK statutory sick pay figure of £96.35 per week, for an estimated 141.4 million working days lost,[19] and applying our in-sample estimates for sick leave, we calculate savings to be over £15.5 million. This calculation then leads to savings of approximately £963,706,221 in Greater London, excluding the life satisfaction benefits.

16 AEA Technology Environment (2003). The London low emission zone feasibility study. Technical report, Research on behalf of Greater London Authority (GLA), the Association of London Government (ALG) on behalf of London Boroughs, Transport for London (TfL), the Department for Transport (DfT), and the Department for Environment, Food and Rural Affairs (DEFRA).

17 ONS (2021). Over half of younger drivers likely to switch to electric in next decade. Office for National Statistics.

18 Public Health England (2020). The health and social care costs of a selection of health conditions and multi-morbidities.

19 ONS (2018). Sickness absence in the UK labour market: 2018. Office for National Statistics.

Policy Implications

- Given the evidence presented, both LEZ and ULEZ have led to improvements in physical health and mental well-being, and reduced hospitalisations and prescriptions for respiratory problems. These improvements have been stronger for ULEZ, the strictest of the clean air policies.

- Our results suggest improvements in physical health and mental well-being could be even larger with the recent expansion of ULEZ across all London boroughs, in force since the 29th of August 2023.

- LEZ-type policies could be effective in improving physical health and mental well-being even outside London, particularly in major cities in England.

- Even without considering mental well-being improvements, our evidence suggests LEZ-type policies offer good value for money as the benefits are greater than the costs.

Methodology

This policy brief summarises key findings from two working papers written by Dr Habtamu Beshir and Professor Eleonora Fichera (2022, 2023), University of Bath. The first article is currently being revised for resubmission in an international peer-reviewed academic journal and the second has been presented at the International Health Economics Association (2023, Cape Town, South Africa).

This research has been funded by the UKPRP Consortium Awards MR/S037586/1, 'Tackling root causes upstream of unhealthy urban development (TRUUD)', a larger project assessing how prevention of non-communicable diseases can be better integrated in upstream urban planning policies.

Both articles use a quasi-experimental methodology called 'Difference-in-Differences' (DiD). This methodology allows us to determine the causal impact of LEZ/ULEZ on physical health and mental well-being by comparing cities that have implemented these policies (London and then other cities) to comparable cities across England that have not implemented LEZ-type schemes, before and after the implementation of the policies.

Using comparable areas and a before-and-after approach allows us to establish that changes in physical health and well-being are due to these policies and not to other confounders or time trends. We test for the key assumptions in this methodology, namely, that trends in pollution and health outcomes were similar in sampled cities, prior to the implementation of LEZ-type policies by some of them, and that there are no spillovers between cities that have implemented the policies and those that have not.

Our models estimate first the impact of LEZ/ULEZ on air quality (NO_2 and PM_{10}) and then the impact of LEZ/ULEZ on measures of physical health and mental well-being. For the latter, we use two sources of data:

Firstly, we use survey data from the Quarterly Labour Force Survey (QLFS) and the Annual Population Survey (APS). QLFS is a large survey collecting information on approximately 40,000 households and 100,000 individuals every quarter and is representative of the UK population. APS is a continuous household survey, based on an annual sample of approximately 320,000 respondents. Our estimation sample from 2005 to 2013 contains over 227,800 observations. These surveys contain rich information on socio-economic characteristics of respondents (e.g. employment, education, type of housing, ethnicity, age and gender) which we control for. They also contain self-reported information on physical health and well-being (e.g. respiratory diseases, long-term illnesses and measures of life satisfaction and happiness).

Secondly, we use administrative data from the Hospital Episode Statistics (HES), containing all admission records of patients in English hospitals from Admitted Patient Care and Accident & Emergencies. Our estimation sample from 2006 to 2013 contains over 2,000 observations. HES contains information on admissions and the cause of admission (e.g. respiratory admissions can be retrieved via the ICD10 codes*).

We use postcode data from Transport for London (TfL) to identify areas covered by LEZ and ULEZ and match them to our sources of data above, using Lower Super Output Area (LSOAs) information. We also link in weather data (e.g. rain, wind, temperature) using the Met Office – MIDAS Land Surface Stations and other area characteristics such as house prices and the Index of Multiple Deprivation from the Office for National Statistics (ONS).

Researchers acknowledge funding from the UKPRP Consortium Awards MR/S037586/1, 'Tackling root causes upstream of unhealthy urban development (TRUUD)'.

* The International Classification of Diseases, tenth revision (ICD-10) is a system that codifies all clinical diagnoses, symptoms and procedures in a standard way across countries.

Connect with us

Email us
ipr@bath.ac.uk

Find us online
www.bath.ac.uk/ipr

Read our blog
blogs.bath.ac.uk/iprblog

Join our mailing list
bit.ly/IPRnewsletter

Follow us on X
@UniofBathIPR

Follow us on LinkedIn
linkedin.com/school/bath-ac-uk-ipr

Subscribe to us on YouTube
bit.ly/IPRyoutube

Follow us on SoundCloud
bit.ly/IPRsoundcloud