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Understanding the uneven use of rental e-scooters and implications for equity: Evidence from England's largest e-scooter trial

Hannah Budnitz^{*}, Xiao Li, Helen Morrissey, Tim Schwanen

Transport Studies Unit, University of Oxford, South Parks Road, Oxford OX1 3QY UK

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ABSTRACT

The availability and adoption of rental e-scooter services, proliferating in cities globally, are spatially and socially uneven. Studies suggest that a majority of users in North American and European cities are men with higher incomes and more education than the average. The use of shared e-scooters by sociodemographic groups that are more likely to have access to a car and a wide range of opportunities raises questions as to whether this new transport technology entrenches inequalities. However, few studies focus on e-scooter use in England, where only shared e-scooters permitted and regulated by the UK's Department for Transport alongside relevant local governments on a trial basis are legal for travel on the public highway. These services were therefore often introduced to achieve policy objectives, and the government commissioned a national evaluation of the e-scooter trials in English cities to understand their impacts. The evaluation report suggests they are popular among low-income and minority ethnic riders, but highlights the need for further study, such as the one presented here. This article uses a transport poverty framing and a dataset of 3.6 million e-scooter trips taken over 13 months in Bristol to investigate the uneven sociodemographic and spatial patterns of rental e-scooter use. We find that, holding all else equal, more e-scooter trips are taken from areas with larger shares of younger (under 35), black and Asian individuals. However, there are fewer e-scooter trip origins from areas of greater deprivation in Bristol. This suggests that while younger, Black, and Asian populations may be more likely to adopt or have access to e-scooters as a mode of transport, fewer e-scooter trips from areas of greater deprivation indicate potential barriers to access or adoption in these communities.

1. Introduction

Shared, electric-powered, standing scooters, or rental e-scooter services, have proliferated in cities around the world in recent years (Gössling, 2020), but their use in the cities where they operate exhibits notable spatial and social disparities (Badia and Jenelius, 2023; Orozco-Fontalvo et al., 2022). Technological transition can embed and entrench inequalities, as expensive or complex new technologies often initially benefit better educated and higher income groups and can reinforce existing social hierarchies (Ahlborg, 2017; Sovacool et al., 2019). Thus, a crucial research question upon the introduction of new transport technologies, such as rental e-scooters, is whether their development and proliferation disproportionately benefit already advantaged populations while marginalizing others.

Various studies have demonstrated that young people, people from deprived communities, and ethnic minorities are disproportionately

affected by certain forms of transport poverty due to their limited access to, ownership of, or the financial burden associated with car usage alongside a lack of alternatives (Headicar and Stokes, 2016; Lucas et al., 2016; Mullen et al., 2020). In light of this, this case study considers the uneven use of shared e-scooters and the implications of this for equity through an analysis of the spatial and geodemographic dynamics of rental e-scooter trips in a medium-sized city. Specifically, we investigate how the frequency of e-scooter trip origins correlates with small area sociodemographic characteristics, focusing on ethnicity, deprivation, and age in Bristol, England.

We choose Bristol as a valuable case study in the English context because it acts as an 'extreme' case in two opposing ways (Flyvbjerg, 2006). First, the city is home to England's largest and most popular e-scooter trial (DfT, 2022). In England, it is illegal to use a private e-scooter on any publicly-adopted road, so rental e-scooter services proposed by local authorities and managed by private operators were

^{*} Corresponding author.

E-mail addresses: hannah.budnitz@ouce.ox.ac.uk (H. Budnitz), xiao.li@ouce.ox.ac.uk (X. Li), helen.morrissey@seh.ox.ac.uk (H. Morrissey), tim.schwanen@ouce.ox.ac.uk (T. Schwanen).

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legalized on a trial basis in English cities and towns from July 2020 during the Covid-19 pandemic – following four extensions, trials are still operational in 22 urban areas (DfT, 2024). This unusual arrangement means that the shared e-scooter operators had to work with local government policymakers to design services that would meet certain policy goals, such as equity of access, and make data available for evaluation of the services' impacts. Since this paper takes a quantitative approach, choosing the trial with the greatest demand offers the most data.

Second, compared to many of the other urban areas with e-scooter trials, the city of Bristol and nearby suburbs included in the trial have both a higher proportion of the population identifying as white, as well as less deprivation (ONS, 2021, 2023). We are interested in understanding the impact of introducing shared e-scooters on mobility opportunities for disadvantaged groups. Thus, in a relatively white, wealthy city, a high level of use where these groups do make up a larger proportion of the population may be an indication of the even greater potential for adoption in more diverse or deprived English cities. Conversely, a low level of use may suggest there are other barriers to be addressed in certain communities.

Guided by concepts of transport poverty, this study maps the uneven use of shared e-scooters in Bristol in order to test the hypothesis that more e-scooter trips originate in neighbourhoods with higher levels of deprivation or shares of ethnic minority populations. A total of 3.6 million e-scooter trips are spatially and statistically examined using descriptive statistics, hot spot analysis, and negative binomial regression, checking for spatial dependency and multicollinearity. Our findings indicate that the spatial distribution of e-scooter trip origins has a statistically significant and positive relationship with small areas that have larger shares of young people and ethnic minorities, but a significant, negative relationship with spatially aggregated deprivation indicators. These mixed results suggest that while targeted spatial distribution may be sufficient to attract riders in the former, other interventions may be necessary before e-scooters become a popular form of mobility in the latter.

The existing literature on e-scooter use, why transport poverty is a useful concept in investigating the uneven use of these new services, and the gaps this study aims to fill are described in Section 2. The data and methods are described in Section 3, then our mixed findings in terms of social and spatial disparities of use are detailed in Section 4. The implications for transport poverty and equity and this study's limitations are discussed in Section 5 before we conclude in Section 6 with thoughts on its potential contribution to policy.

2. Literature review

2.1. Disparities in e-scooter usage

Two literature review articles of the growing body of research into rental e-scooter services summarize that riders are predominantly younger, male, higher income, and, where asked, have a higher level of education (Badia and Jenelius, 2023; Orozco-Fontalvo et al., 2022). Indeed, some studies have linked e-scooter use specifically to the presence of university students (Rodriguez-Roman et al., 2022). One study in New Zealand noted that riders are more likely to be of European descent (Fitt and Curl, 2020). Another review examining car-, bike- and e-scooter sharing services reported mixed findings in terms of equitable e-scooter use in various US cities by ethnicity and income, although they concluded rental e-scooters may be more equitable than bike-sharing (Dill and McNeil, 2020). However, most studies on rental e-scooter services do not explicitly consider equity issues (Israel et al., 2023), and studies in North American cities dominate the review articles, with few empirical, academic studies on the English trials.

The most comprehensive empirical analysis on the numerous English trials comes from a national evaluation report commissioned by the UK government. This highlighted a predominance of young men among e-scooter riders (DfT, 2022) – findings similar to those from North

American and European cities. However, the report also noted that, in English cities, rider surveys suggest that lower income and minority ethnic groups were using e-scooters more frequently than white, higher-income riders, and that the introduction of the e-scooters made it easier for them to access diverse activities (ibid.). Two smaller academic studies based on interviews and surveys of British e-scooter riders suggest that the new services may be extending the accessibility and reach of the urban transport system for low-income and minority users (Grant-Muller et al., 2023; Sherriff et al., 2023). These qualitative studies offer insights into how the rental e-scooters services are perceived and used by individuals from groups at greater risk of dimensions of transport poverty related to the individual's capabilities to move through space and time and use different transport options (Lucas et al., 2016; Martens, 2012).

2.2. Rental e-scooter services and transport poverty

Qualitative aspects of transport poverty like exposure to traffic accidents and air pollution speak to widespread concerns among policymakers and researchers about the safety of e-scooters in cities, both for riders and other road users (Gössling, 2020; Janikian et al., 2024), as well as the uneven exposure to unsafe travel conditions (Lucas et al., 2016). Chatterjee et al. (2023) report that among *non-users*, 33 % of those aged over 60 feel discriminated against by the presence of e-scooters in Bristol, mainly because they see the vehicles as a threat to their safety and comfort in the pedestrian environment. Risks to safety are cited as the most common reason for this perception of discrimination, but rental e-scooters could also be seen as less "suited to the [older adult's] physical condition and capabilities" – another dimension of transport poverty (Lucas et al., p356). Since they combine multiple, relatively new transport technologies, including geo-fencing (a type of remote, digital control) for dock-less locking, parking and speed limits, and digital access and payment via mobile phone apps (Badia and Jenelius, 2023), older adults could feel excluded due to a lack of digital skills (Blank et al., 2018). As Moran et al. (2020) note, technological exclusion may also occur when there is a lack of communication about ongoing changes in the use of geofencing that alters spatial access to rental e-scooters over time.

Meanwhile, our study focuses on the dimensions of transport poverty more readily measured by quantitative methods, namely a lack of affordable means to access particular opportunities in space. Like the intended legacy of the public transport investment described by Pereira et al. (2019) in Rio de Janeiro, the introduction of e-scooters in and near Bristol was initially proposed by the metropolitan-level West of England Combined Authority (WECA) as infrastructure to better link deprived communities to employment destinations (WECA, 2019). In other words, the local government authorities in Bristol proposed an e-scooter trial as part of their strategy to overcome the intersection of mobility poverty and accessibility poverty. These are two of the dimensions of transport poverty defined by Lucas et al. (2016) as:

- (a) a lack of access to forms of transport (often a private car); and
- (b) difficulties reaching daily activity needs (e.g. employment) in a reasonable amount of time at a reasonable cost.

With this in mind, WECA commissioned in-depth analysis of the use and users of the scheme. This analysis reported more frequent use among non-white ethnic riders, while acknowledging a slight underrepresentation in minority respondents in their surveys, interviews and observational data (Chatterjee et al., 2023). There is also a report commissioned by Voi, the trial operator, which highlighted that fewer trips start and end in the most deprived areas of Bristol compared to other English cities where Voi e-scooters are deployed (Volterra, 2022). They speculate that this might be due to Bristol being less deprived on average and a lack of service to more peripherally-located pockets of deprivation. However, this conclusion is based on heat mapping and

visual inspection, rather than the robust statistical analysis used in this study to match trip data with neighborhood characteristics. Our analysis also demonstrates the importance of controlling for distance from the city center when assessing the relationships between use and geodemographic characteristics, offering wider insights into the spatial and social patterns of e-scooter use despite the central bias of the trial's operation.

2.3. Studies using e-scooter trip data

Using origin–destination data from rental e-scooter services in 30 cities across continental Europe, the study by Li et al. (2022) on spatial and temporal patterns of e-scooter utilization and efficiency indicates that there is significant room to improve the spatial provision of e-scooters in terms of matching supply to demand. It also notes that e-scooters do not show the same morning and evening weekday peaks in use as other modes, implying they are not tied to typical commuting patterns. Frias-Martinez et al. (2021) used data on thousands of e-scooter trips in four American cities over three months to identify how e-scooter frequency and duration of use differs in low-income areas compared to higher-income areas when controlling for age, education, car ownership and built environment characteristics. They conclude that there are fewer trips from low-income areas in all four cities, suggesting unequal access, but longer (duration) e-scooter trips from low-income areas in Washington DC and Chicago while the opposite was found in New York City and Los Angeles (ibid). Bai and Jiao (2021) also use e-scooter trip data (and e-scooter parking violations) to measure the equity of the service in Austin, Texas, concluding that wealthier and white, non-Hispanic residents have more opportunities to use e-scooters than minority or poorer residents. These examples suggest that such analysis is revealing of the accessibility of rental e-scooters to groups at risk of transport poverty, but as far as the authors are aware no such studies have been undertaken in the UK that can confirm or refute the same patterns. Considering that the UK trials are government-sponsored and were justified by local governments on the basis of policy objectives such as improving accessibility for disadvantaged groups, the value of addressing this knowledge gap is of particular note in policy terms.

2.4. New contributions

Our approach uses extensive mobility records collected from real-world e-scooter riders to examine how area-based sociodemographic features influence the level of e-scooter use. The concept of 'transport poverty' is introduced and used as a lens to help explain the findings. While we do not assess individual capabilities, we consider the intersection between e-scooter use and the spatially uneven distribution of sociodemographic groups that may be lower income, have less access to a private car, or be otherwise disadvantaged (Pereira et al., 2019). Considering that the national evaluation report on the e-scooter trials across England highlight age (under 35), income, and ethnicity as key variables for analysis (DfT, 2022), we investigate whether areas with larger populations of young adults (under 35), and / or identifying as non-white ethnic, and / or of greater deprivation are associated with more e-scooter use.¹ Our analysis is grounded in the examination of 3.6 million e-scooter mobility records collected in Bristol, located in the southwest of England, home to the largest and most popular e-scooter trial in England (DfT 2022). To the best of our knowledge, this study represents one of the pioneering efforts to employ mobility data for quantifying disparities within the rental e-scooter services in England.

¹ We do not include gender in our analysis, as we are using local area statistics, not individual rider data, and gender is less spatially clustered.

3. Data and methods

3.1. Bristol e-scooter data

Voi, the rental operator of Bristol's e-scooter trial from 2020 to 2023, shared the anonymized trip data used for this study, comprising over 3.9 million e-scooter time-stamped, origin–destination (O-D) pairs or trips taken between March 2021 and March 2022 (13 months, inclusive) in Bristol. After removal of O-D pairs which suggested either the e-scooters were being carried in a vehicle due to calculated speeds of over 20 km per hour or that the user did not successfully hire the e-scooter due to a null trip duration or distance, almost 3.6 million trips were used in our analysis. The origins for these 3.6 million trips were aggregated to match the statistical geography of Lower Super Output Areas (LSOAs), which have been developed by the UK Office for National Statistics (ONS) to publish small area sociodemographic datasets and were last updated following the 2021 census. LSOAs with a single trip were then removed, as these are likely to be beyond the geo-fenced trial boundaries, or otherwise appeared to suggest a data error. The remaining 344 LSOAs² recorded at least two e-scooter trips starting in that LSOA.

The dataset was anonymized by Voi prior to being shared for research purposes – any personal data collected by the company that might identify individual users, including contact and license-holding details, age, or gender of individual users, was excluded. While anonymization was essential to ensure that both parties comply with their obligations under privacy policies and data protection legislation,³ it means that e-scooter trips cannot be linked to specific user's individual characteristics, including age, ethnicity, income or other measure of deprivation. The trips are instead linked to small area statistics produced by the government from the census and other national surveys. Our study thus analyses the marginal differences in e-scooter use between areas with different proportions of the user groups of interest, rather than the actual differences in e-scooter use by individuals with those characteristics of interest.

In other words, the group or 'ecological correlations' highlighted in our analysis cannot be assumed to reflect the behavior of individuals without risking ecological fallacy (Robinson, 1950). We also cannot assume any causal relationships between higher levels of use and reductions in transport poverty. However, small area statistics can provide insights into the relative changes in mobility and accessibility between neighborhoods and their populations, which has valuable implications for designing equitable policies and interventions to address disparities in mobility and accessibility.

3.2. Small area statistics

Policy interventions often take place at the level of geographical areas and populations, and use small area statistics to target and monitor such interventions (Lee et al., 2021). Bristol's proposals for a suite of new mobility infrastructure and services, including the e-scooters, took an explicitly spatial approach to improving mobility opportunities to access major centers of employment and education (WECA, 2019). The delivery of the proposals would fulfil strategic objectives set out in the city and metropolitan area's transport plans – including improving access to opportunities for residents from deprived areas (Bristol City Council, 2019; TravelWest, 2020). Local policymakers identify and define neighborhoods as deprived by referencing a small area statistic produced by the UK Government called the Indices of Multiple

² For the 2021 census in the greater Bristol area, the average LSOA population is just under 1,700 residents.

³ See Voi's privacy policy at <https://www.voi.com/legal/privacy-policy/uk> which includes terms for researchers. The research presented in this paper was also subject to the University of Oxford's ethical approval process (Reference: SOGE1A2021-034) for use of secondary as well as primary data.

Deprivation (IMD). The IMD rank or total score, is a comprehensive geodemographic measure, which calculates and weights deprivation across seven dimensions, including income, employment, education and training, health and disability, crime, barriers to housing and services, and living environment (MHCLG, 2019). The smallest geographical unit for which the IMD is calculated are LSOAs,⁴ with the higher the score, the greater the deprivation. The millions of e-scooter trips are assigned to their LSOA of origin and linked to that LSOA's IMD score.

The trip origins are also linked to data on the proportions of young, black or Asian residents in that LSOA. Ethnicity data for each LSOA was taken from the 2021 census, as was age. The census has four main ethnicity categories: black, Asian, white, and mixed, with a varying number of sub-categories in each, as well as an 'other ethnic group' of about 1 % of the population. The proportion of those identifying as black or Asian in each LSOA was included for analysis, as all those in these groups could be described as 'black and minority ethnic', whereas some of those identifying as 'mixed' ethnicity may have been included in the 'other ethnicity or undeclared' group in the local authority commissioned evaluation report (Chatterjee et al., 2023). The proportion of 15–35-year-olds residing in each LSOA was included as a covariate to control for the popularity of e-scooters among younger adults, as highlighted in the Department for Transport's (DfT) evaluation report (2022).

3.3. Method of analysis

To model the relationships between the number of trips and selected sociodemographic features, including ethnicity, age, and IMD, we specified a negative binomial regression model. The standard modelling approaches used for count data, such as number of e-scooter trips, are Poisson or negative binomial regression. The latter model structure was chosen because it addresses overdispersion of the dependent variable. As Fig. 1 shows, the number of trips originating in each LSOA are extremely over-dispersed and do not follow a normal distribution. Using this type of model addresses both the overdispersion and non-normality issues of the dependent variable (Ver Hoef and Boveng, 2007).

Two negative binomial regression models were built for estimating e-scooter trip origins by LSOA. Model 1 includes only the sociodemographic covariates. Model 2 also includes the distance from the centroid of the Castle Park LSOA to all other LSOAs. This additional covariate controls for the concentration of trip volumes in Bristol city center, in or around the vicinity of Castle Park LSOA (see Fig. 2).

4. Spatial and sociodemographic distribution of e-scooter use in Bristol

4.1. Descriptive statistics of disparities in e-scooter use in Bristol

While trip origins are concentrated in the city center, Fig. 2 also shows high frequencies of trips originating in certain LSOAs to the north and northwest of the city and low frequencies of trips from most peripheral areas. However, there are pockets of low e-scooter use even in LSOAs neighboring those with high scooter use and vice versa. Also, the difference between not only the minimum and maximum number of e-scooter trips originating in the LSOAs included in our analysis, but also between the mean and median number of trips as shown in Table 1

⁴ Last published in 2019, the statistics on deprivation use 2011 LSOA census boundaries. As the IMD scores have not been updated since, the 2011 LSOAs are overlaid onto the 2021 LSOA census boundaries so that the geography for all four sociodemographic variables is consistent. The "2021 LSOAs were created by merging or splitting 2011 LSOAs to ensure that population and household thresholds were met" (<https://www.ons.gov.uk/methodology/geography/ukgeographies/censusgeographies/census2021geographies>, last accessed 2 February 2024).

indicates a potentially complex and irregular spatial distribution, beyond that addressed by the negative binomial model.

Therefore, to better understand where LSOAs with high and low frequency use are spatially clustered, Fig. 3 was produced using an optimized hot spot analysis function that combines the Getis-Ord statistic and incremental spatial autocorrelation. The resulting figure shows statistically significant 'hot spots', where neighboring LSOAs have high values for e-scooter use, and 'cold spots' indicating low e-scooter use. While Fig. 2 shows high e-scooter use in individual LSOAs, including some well to the North of Bristol city center, Fig. 3 demonstrates that the statistically significant spatial autocorrelation of high-frequency e-scooter use occurs only in LSOAs clustered around the city center.

Table 1 also includes the descriptive statistics for sociodemographic characteristics across the LSOAs of Bristol. While the IMD score shows a fairly wide range of relative deprivation, this range relates only to the case study. The proportion of neighborhoods falling into each deprivation decile is fairly even, whereas many other large cities in the UK have a greater proportion of their neighborhoods at the more deprived end of the scale (ONS, 2021). Likewise, in contrast to other larger cities in the UK, the proportion of those identifying as white is similar to the England and Wales average (over 81 %),⁵ while those identifying as black ethnicity – 5.9 % of the total Bristol population – is higher than the national average of 4 % (ONS, 2022; 2023). The balance of minority groups is also unusual compared to other regional urban centers, as those identifying as Asian ethnicity make up 9.3 % of the English and Welsh population and are concentrated in a number of England's larger provincial cities (ONS, 2022), while those of Asian heritage make up only 6.6 % of Bristol residents. Thus, the descriptive statistics for sociodemographic characteristics demonstrate Bristol's position as an 'extreme' case study in terms of deprivation and ethnicity.

Within Bristol and its surrounding suburbs, the black population is highly concentrated in a small number of LSOAs (see Fig. 4a), and the proportion of individuals self-identifying as black is as high as 54.7 % of one LSOA's population (see Table 1). The corresponding share for self-identification as Asian is just over a quarter (25.5 %) in the LSOA with the largest Asian population, and Asian residents are also more widely distributed across the city than the black population (see Fig. 4b, as well as Table 1).

Table 1 also shows that there are LSOAs where the population under 35 is even more concentrated than either top level minority ethnic group. Similar to the black population, some of these LSOAs with predominantly younger populations are near the city center as shown in Fig. 4c. This may be related to the central location of the University of Bristol (highlighted in Fig. 4c). There is also a high proportion of young adults to the north of the city in the LSOA where the University of the West of England is located. In comparison, the areas with the highest IMD scores are more spatially disparate (see Fig. 4d). Despite some overlaps in the proportion of these groups in different LSOAs, our multicollinearity tests show that these sociodemographic features are not linearly related. This means that their influences on e-scooter use are independent and can be modelled as such.

4.2. Modelling results

The results of Models 1 and 2 are shown in Table 2. Central Bristol has a high density of destinations, available e-scooters, and, in a subset of these LSOAs (see Fig. 4a and c), higher proportions of black or young residents. Controlling for the distance from the center in Model 2 substantially changes the coefficients of these and the Asian population covariates, as well as improving goodness of fit as indicated by the AIC

⁵ In comparison, in London, less than 40% of the population identify themselves as "White: English, Welsh, Scottish, Northern Irish or British" (ONS, 2022).

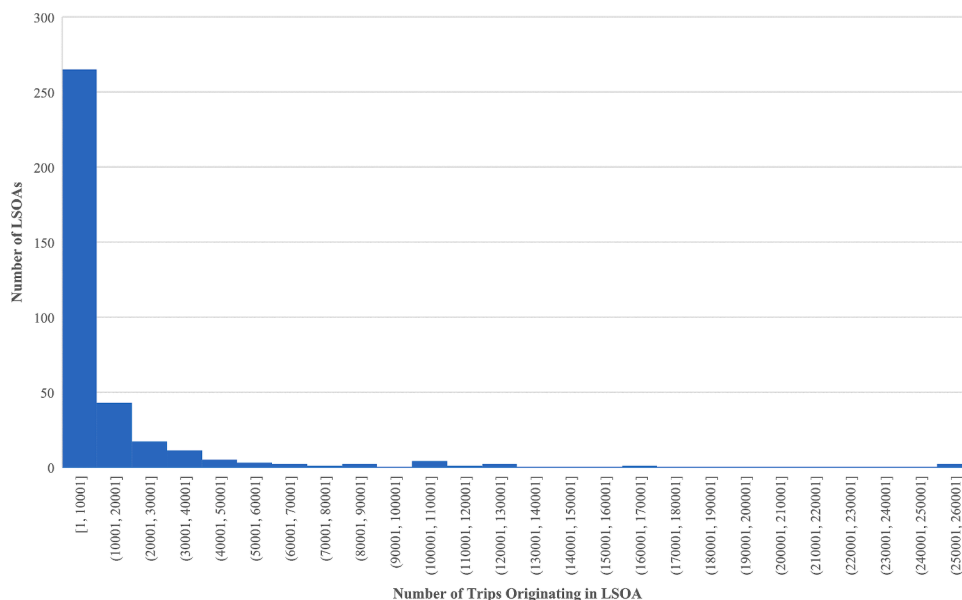


Fig. 1. Histogram of trip origin frequencies per LSOA.

statistic in Table 2.

The results suggest that the relationships between the selected sociodemographic statistics and e-scooter use are ambiguous. On the one hand, the number of e-scooter trips and IMD score are negatively correlated in both models, suggesting that, with all other variables controlled, areas with greater deprivation may observe fewer e-scooter trips. On the other hand, the statistically significant positive correlation between e-scooter trips and proportions of the population that are black or between 18 and 35 years of age suggests that, again controlling for all other variables, e-scooters are being used more in LSOAs where these groups live.

The coefficients are smaller once the distance control covariate is included (Model 2), and a lack of data on the sociodemographic characteristics of individual e-scooter users means we cannot confirm that black or young adult residents in any given area are using the e-scooters more than others who live in that LSOA. Nonetheless, there are still significantly more e-scooter trip origins in areas with higher percentages of these groups than the average per LSOA, despite the larger shares of black and young adult residents in certain LSOAs near central Bristol (see Fig. 4a and c).

The strength of the relationships between the share of black people and young adults with the generation of e-scooter trips is shown in Fig. 5. The blue line represents the estimated e-scooter trip origins in an LSOA, as calculated using Model 2, while varying the percentage of black residents from 5 % (the minimum across all LSOAs) to 54.7 % (the maximum across all LSOAs). The orange line illustrates the variation in estimated e-scooter volumes as the percentage of young people changes from 11.6 % to 84.9 % (see Table 1). In both cases, all other variables are held constant at their city-wide average values. Fig. 5 shows how an increase in the presence of black individuals and young adults has a strong and exponentially positive relationship with the estimated frequency of e-scooter trips.

Meanwhile, the relationship between LSOAs with share of residents from Asian heritage and e-scooter use is positive in Model 2, but the statistical significance is marginal (at 85 % confidence). As Fig. 4b shows, Asian ethnic groups are fairly dispersed across the city-region, and are nowhere as concentrated as black or young adult residents. Somewhat higher proportions of Asian residents live in central and northern areas of the city, rather than the south, matching many areas with higher e-scooter trip frequencies. The diffuse spatial pattern may explain why the coefficient for and significance of the proportion of

Asian residents in an LSOA’s population shifts once the distance variable is added to account for at least some spatial skew, but does not quite become significant within a 95 % or even 90 % confidence interval.

While Fig. 3 shows that we captured the main spatial autocorrelation for the dependent variable, we also considered whether there might be other spatial dependencies for the sociodemographic covariates, such as differential population density or the potential that e-scooter user origins and e-scooter trip origins are located in different, adjacent LSOAs. We performed Global Moran’s I test to assess the presence of spatial autocorrelation in the residuals, which was statistically significant ($p = 0.000$). A number of spatial lag variables were then tested based on various population density weighted contiguity matrices. However, adding spatial lag variable(s) did not significantly improve the model fit as measured by the AIC, had little effect on the coefficients for the independent variables, and increased model complexity. For the sake of model parsimony, we include only the simpler Models 1 and 2 in this paper.

For IMD score, the negative effect increases in size with the addition of the distance variable, although only slightly. In other words, even when controlling the distance from the city center, deprivation made an area likely to host fewer e-scooter trip origins. Although certain neighborhoods to the south were not officially included in the trial until later in 2022, e-scooter provision to deprived neighborhoods in the center and northwest of the city mean that the evaluation report commissioned by WECA reported that they could find no relationship between e-scooter parking provision and deprivation (Chatterjee et al., 2023). Our study goes a step further to show a negative relationship between e-scooter use and deprivation.

5. Discussion

5.1. E-scooter use and equity implications – The value of the Bristol case study

The local authorities in Bristol proposed the introduction of rental e-scooters in part because they wanted to offer an alternative form of transport to private cars for those who lived in areas where car ownership was low, and where public transport connections to areas of employment, particularly to the north of the metropolitan area were poor (WECA, 2019). In other words, they hoped e-scooters would reduce the risk of the two dimensions of transport poverty described in section

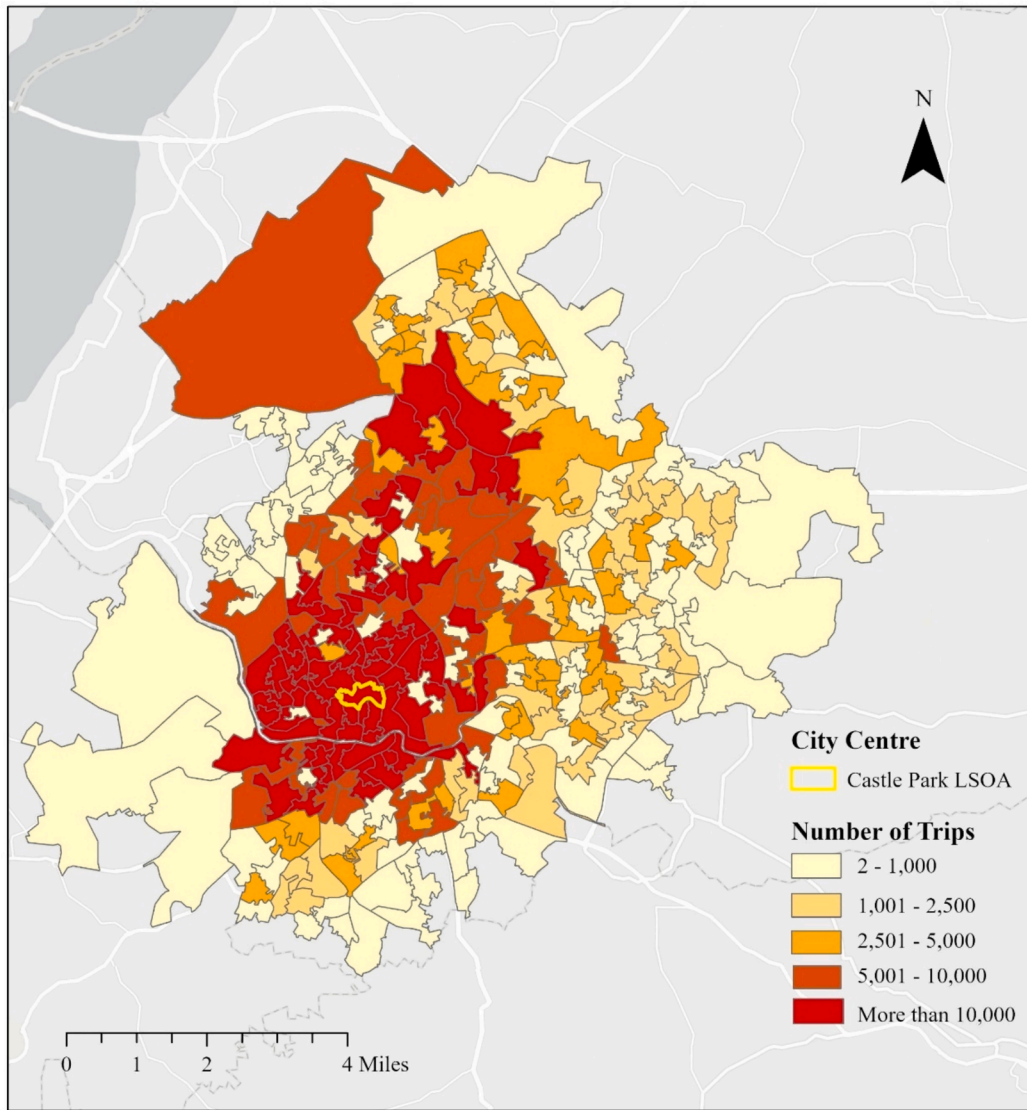


Fig. 2. Frequency of e-scooter trips (by origin) in Bristol by LSOA. Castle Park LSOA was chosen as the closest LSOA to the city center, and is highlighted.

Table 1
Descriptive statistics for 344 LSOAs recording 2 + trips in the Bristol e-scooter trial 2021–22.

Variables by LSOA	Mean	Median	Minimum	Maximum
Number of Trip Origins	12,348.6	2,941.5	2	259,943
IMD Score	21.3	17.9	1.9	72.3
% Asian	6.5 %	5.0 %	0.4 %	25.5 %
% Black	5.0 %	2.6 %	0.1 %	54.7 %
% 15–30-year-olds	33.7 %	29.0 %	11.6 %	84.9 %

2, as defined by Lucas et al. (2016). Our quantitative analysis suggests that the e-scooter trial in Bristol during 2021–22 may indeed have reduced the risk of transport poverty in neighborhoods with greater proportions of black and young adult residents. If residents are the majority of users in those neighborhoods, then e-scooters may be offering them a form of transport to help fulfil daily needs for an amount of time and money that they are willing to spend. However, the observation of less e-scooter travel in areas with higher levels of deprivation could be an indication that e-scooters are not having the same impact among this group. The analysis also highlights the spatial unevenness of sociodemographic characteristics and how such uneven distribution affects the relationship between age, ethnicity and e-scooter trip

frequency – particularly when the distance from the city center variable is included.

For ethnicity, the findings presented here reinforce and extend the conclusions from surveys and observational data in Bristol (Chatterjee et al., 2023): E-scooters are more popular in areas with larger shares of black, and to some extent, Asian populations. Our analysis, based on a dataset of 3.6 million e-scooter trips, also adds weight to the findings of Grant-Muller et al. (2023) and Sherriff et al. (2023) that non-white minority ethnic groups report greater improvements to their well-being from using e-scooters, including improved accessibility and travel time reliability. This potential reduction in risk of transport poverty compares favorably to the studies in Texas and New Zealand, which both suggested less use and access for ethnic minority users (Bai and Jiao, 2021; Fitt and Curl, 2020).

Our analysis also adds to evidence from multiple countries highlighting the popularity of e-scooters among young adults (Badia and Jenelius, 2023; Orozco-Fontalvo et al., 2022). Younger adults have lower levels of car access, the causes of which have been identified as including the high costs of motoring combined with delayed engagement in full-time, secure employment compared to previous generations (Chatterjee et al., 2018). Rental e-scooters offer a new and alternative form of urban mobility, and can mediate low car ownership and use,

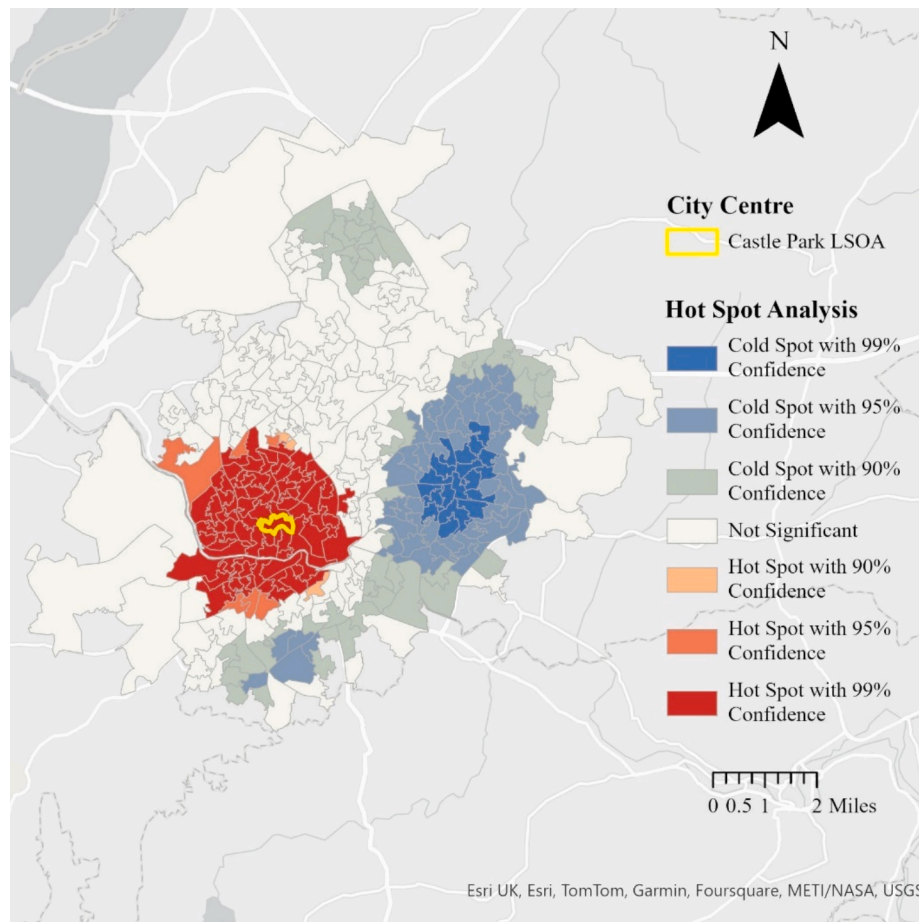


Fig. 3. Statistically significant hot (high frequency of use) and cold (low frequency of use) spots identified using optimized hot spot analysis function in ArcGIS.

particularly for younger men, and is thus relevant to reducing their risk of transport poverty. Less encouraging, the relationship between IMD and e-scooter use in Bristol is similar to conclusions in four American cities (Frias-Martinez et al., 2021) – that low-income is associated with lower levels of e-scooter use.

5.2. Limitations and further research into a novel form of transport

While this study provides insights into the impact of introducing shared e-scooters on mobility opportunities for disadvantaged groups, the approach taken does have a number of limitations. First, due to a lack of data on the sociodemographic characteristics of individual e-scooter riders, the reliance on small-area statistics may result in an ecological fallacy. As discussed in section 3.1, conclusions drawn about individuals based on aggregate data may not accurately represent individual behaviors or characteristics, nor can we assume a causal relationship between the presence of certain social groups and e-scooter use. Our methodological approach also does not allow for exploration of how intersectionality, cultural attitudes, or personal capabilities may condition e-scooter use. Furthermore, data on resident populations may differ from the characteristics of those using e-scooters who are present in an area but do not live there. Future work should ideally be able to distinguish between resident and visitor use of e-scooters in an area.

Second, the framing of transport poverty could be improved. This study only considers two dimensions of transport poverty described by Lucas et al. (2016), and the concept of transport poverty in turn does not include all the dimensions of mobility (in)justice that may be relevant to understanding the social impacts of a novel form of mobility. For example, our approach does not consider the uneven powers of and rights to use e-scooters in a city's diverse public spaces (Sheller, 2018),

although the results presented here may complement prior and future studies (e.g. Chatterjee et al., 2023; Grant-Muller et al., 2023; Sherriff et al., 2023).

Third, while key sociodemographic features related to transport poverty have been examined in this study, other variables could also be revealing. In particular, variables related to public transport accessibility, land use or built environment would offer a different perspective, and may account for the unobserved spatial autocorrelation we identified. One study in Louisville, Kentucky found that the 'WalkScore' measure of urbanism was most significant in influencing e-scooter use (Hosseinzadeh et al., 2021), and the application of this sort of measure in a location like Bristol could provide further insights. Temporal patterns in e-scooter use, such as the impact of changes in weather and air pollution would also be of interest (Hawa et al., 2021), as would variables related to other aspects of transport poverty, such as disparities in digital skills, or exposure to traffic accidents and air pollution (Li et al., 2025). These are all avenues for further research.

Finally, the use of large mobility datasets collected from individuals raises ethical considerations, framed as social and political challenges in some studies (Li et al., 2021). The anonymisation process undertaken by Voi in its privacy policy and the responsibilities agreed in the transfer of data to the researchers is one of many approaches adopted to protect data privacy and confidentiality under regulations like the General Data Protection Regulation (GDPR) in the UK and EU. However, there remains a significant need for more standardized regulations and a transparent consent process for the passive collection of individual mobility data from vehicles and mobile devices (Halder, 2017; Li et al., 2021).

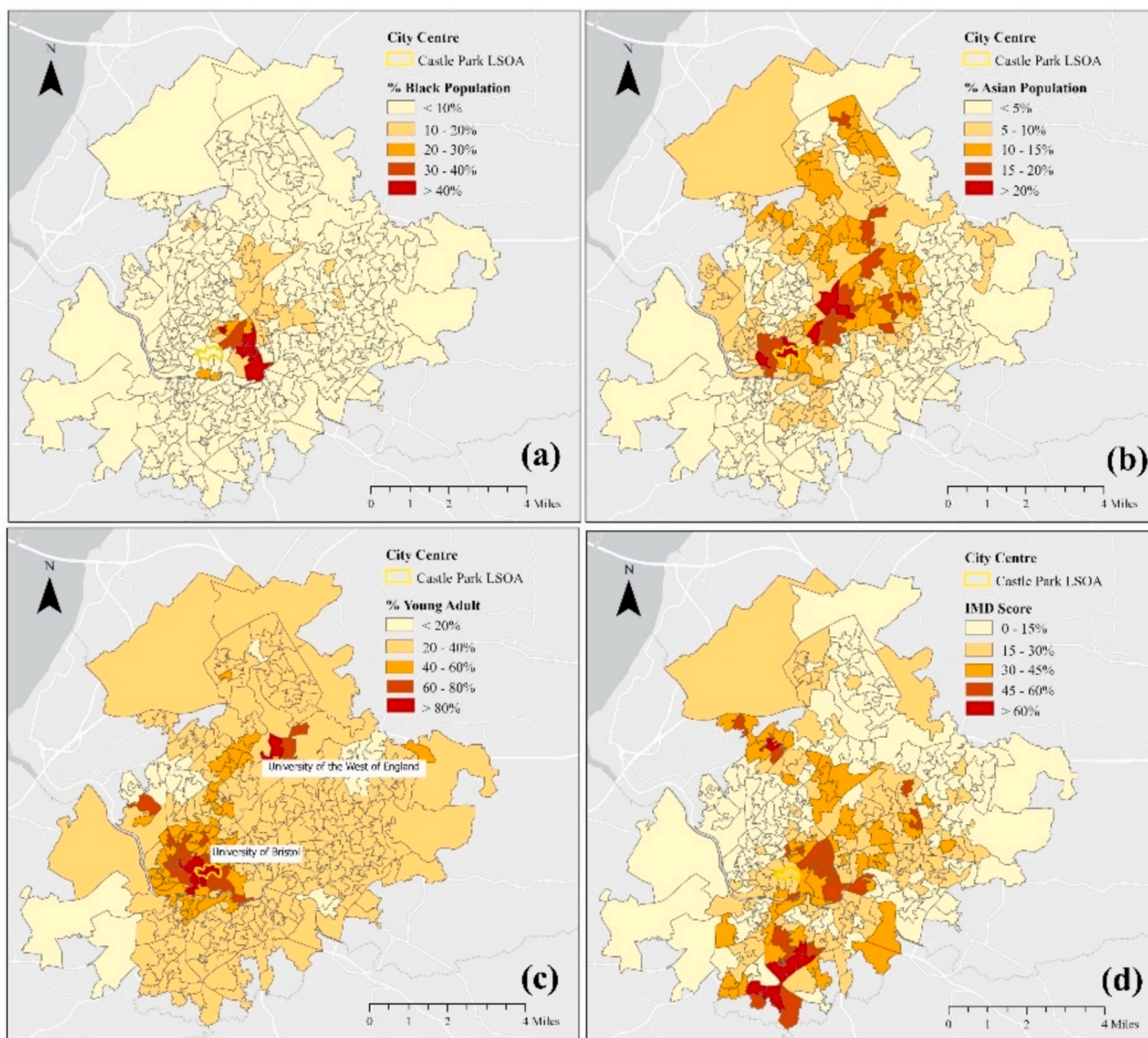


Fig. 4. Spatial distribution of independent variables by LSOA: (a) Percentage black population; (b) Percentage Asian population; (c) Percentage of population between 15–35 years old; and (d) index of multiple deprivation (IMD) – a higher IMD score represents a greater deprivation.

Table 2

Results of negative binomial models without and with distance from city center.

	Model 1 Coefficient	p	Model 2 Coefficient	p
Constant	6.307	0.000	8.401	0.000
% Asian	-2.343	0.213	2.734	0.139
% Black	7.416	0.000	4.585	0.000
IMD Score	-0.025	0.002	-0.028	0.000
% 15–35-year-olds	7.881	0.000	4.639	0.000
Distance from Bristol Center			-0.275	0.000
Global Moran I	0.456	0.000	0.475	0.000
AIC	6,519.4		6,469.9	

6. Conclusion

The Department for Transport’s initial evaluation report (2022) into the e-scooter trials suggests more frequent use of the rental e-scooters among both low-income and ethnic minority riders. In comparison, with

the extensive data from our extreme case study of a city with a whiter, wealthier population compared to other English cities (Flyvbjerg, 2006), we have found a mixed picture in terms of the potential of rental e-scooters to mitigate transport poverty for these groups. The accessibility-led approach taken by local policymakers to introduce shared e-scooters in neighborhoods with fewer sustainable mobility opportunities has resulted in more use where there are larger shares of younger adults or minority groups in the population, but the same effect is not observed in relation to deprivation. This has clear policy implications for targeting and promoting e-scooter use among ethnic minorities and low-income communities both in Bristol and in other English cities with greater levels of deprivation and larger black and minority ethnic populations.

Dill and McNeil (2020) suggest that there may be fewer ethnic or racial disparities in e-scooter use than for bike-share schemes, perhaps due to the lack of prior cultural associations. In other words, e-scooters may be perceived as more accessible to Bristol’s minority groups on introduction, without further policy interventions. If so, the scale of Bristol’s trial may be seen as the key policy enabling high levels of use

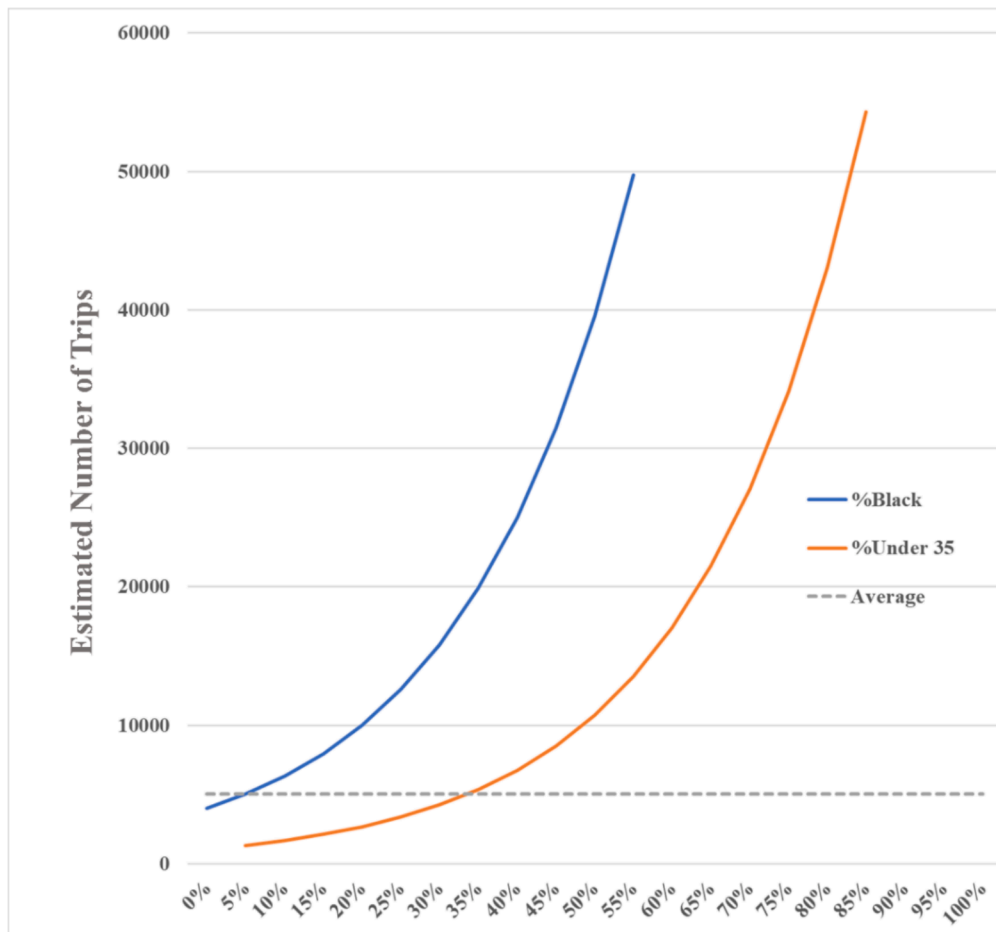


Fig. 5. Non-linear relationship between e-scooter trips and the proportion of an LSOA's population that is black (blue line) or under 35 (orange line).

within ethnically diverse areas of the city. Conversely, the lack of understanding of the preferences of low-income populations in Bristol, as a relatively wealthy city, could be a barrier to increasing e-scooter use in deprived neighborhoods and appropriately addressing uneven infrastructure and service access (Frimpong Boamah et al., 2024). Similar analyses in other UK cities and geographies would enable a greater understanding of whether the patterns identified in Bristol are a product of its unusual sociodemographic composition or a reflection of the income inequity in e-scooter use reported in other cities in Europe and North America (Badia and Jenelius, 2023; Frias-Martinez et al., 2021; Orozco-Fontalvo et al., 2022). Nonetheless, our findings suggest the need for more deliberate and co-produced policies and regulations to attract users in deprived neighborhoods (Frimpong Boamah et al., 2024; Riggs et al., 2021) – for example, enabling alternative (non-digital) registration and payment (e.g. cash) methods.

Bristol's rental e-scooter service, similar to those in cities around the world, is not only a recent addition to its urban transport system, but is also evolving rapidly, as are the policies to support and regulate it. This state of flux augments the importance and timely contribution that research, including this study, can make to policy development. As of October 2023, a different company⁶ was appointed to expand Bristol's service and meet additional policy goals, such as the parallel provision of e-bikes and new parking infrastructure. The latter could reduce feelings of discrimination among non-users, while a broader micro-mobility service that includes e-bikes could attract increased use from

areas with different socioeconomic profiles or even more trips from areas with diverse ethnic populations. Utilization will in turn indicate differential impacts on reducing transport poverty, and, as with other new technologies, on alleviating or exacerbating embedded inequalities (Sovacool et al., 2019). In conclusion, while our study did not indicate significantly more e-scooter use from deprived neighborhoods in this extreme case study of a relatively white, wealthy English city, it did suggest that e-scooters are being used more in neighborhoods with larger proportions of certain ethnic minority groups.

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CRedit authorship contribution statement

Hannah Budnitz: Writing – review & editing, Writing – original draft, Project administration, Funding acquisition, Formal analysis, Conceptualization. **Xiao Li:** Writing – review & editing, Visualization, Methodology, Conceptualization. **Helen Morrissey:** Resources, Investigation, Data curation. **Tim Schwanen:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

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⁶ <https://www.tier.app/en/press/tier-e-scooters-and-e-bikes-rolling-out-in-bristol-from-saturday-14-october>.

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