Regional Studies, Regional Science

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rsrs20

Ethnic inequalities in cycling to work in London: mobility injustice and regional approach

Zofia Bednarowska-Michaiel

To cite this article: Zofia Bednarowska-Michaiel (2023) Ethnic inequalities in cycling to work in London: mobility injustice and regional approach, Regional Studies, Regional Science, 10:1, 475-488, DOI: 10.1080/21681376.2023.2186802

To link to this article: https://doi.org/10.1080/21681376.2023.2186802

REGIONAL STUDIES, REGIONAL SCIENCE
2023, VOL. 10, NO. 1, 475–488
https://doi.org/10.1080/21681376.2023.2186802

Routledge
Taylor & Francis Group
RSA Regional Studies Association

SHORT ARTICLE

OPEN ACCESS Check for updates

Ethnic inequalities in cycling to work in London: mobility injustice and regional approach

Zofia Bednarowska-Michaiel

ABSTRACT
This paper investigates ethnic inequity in cycling to work in London, as ethnic minorities in London cycle to work less frequently than white Londoners. The study adopts three methods: spatial statistics, linear regression and spatial econometrics based on recent UK census and official statistical data (2011–17) of 33 London regions. Spatial analysis shows that cycling networks and bike schemes are concentrated around Inner London. Regions with less cycling infrastructure tend to have a greater proportion of residents of ethnic minorities. The paper highlights the spatial dependence between ethnic inequalities and cycling to work at a regional level in London. There is also evidence of spatial spillovers between neighbouring regions. The paper highlights the need to shift the policy focus from the provision of cycling infrastructure to mobility justice. This means recognizing the needs of distinct groups of cyclists coming from various ethnic minorities. Overall, this paper expands the transportation policies approach by linking it with the concepts of mobilities and regional inequalities. This study of London demonstrates the mechanisms responsible for regional ethnic inequalities in cycling to work that could be relevant in other large urban agglomerations.

ARTICLE HISTORY
Received 23 July 2021; Accepted 24 February 2023

KEYWORDS
Cycling; ethnic inequalities; regional inequalities; mobility injustice; commuting; spatial model

JEL CLASSIFICATIONS
C31; R41; Z13

1. INTRODUCTION

Cycling is widely discussed in the context of public health, sustainable transportation and climate change. Increasingly, transportation research studies focus on cycling and local governments are increasingly investing in cycling infrastructure (Fishman, 2016).

While this paper focuses on commuter cycling, since commuting by bike is popular in areas where cycling is popular in general (Goel et al., 2022), some factors that affect the prevalence of commuter cycling will originate from general low cycling levels. One of the most thorough studies on individual's decision to cycle identifies five categories of factors: (1) the built and the natural environment, including distance and landscape; (2) weather conditions and climate; (3) socio-economic variables, including gender, income, age, employment and social status;

CONTACT Zofia Bednarowska-Michaiel zofia.bednarowska-michaiel@warwick.ac.uk
Centre for Interdisciplinary Methodologies, University of Warwick, Coventry, UK

(4) psychological factors, including attitudes; and (5) aspects related to cost, time, effort and safety (Heinen et al., 2010). This list does not include race and ethnicity among the socio-economic factors, and this paper contributes to our understanding of the decision to cycle by investigating the role of ethnic inequalities in the decision to cycle to work, looking at cycling potential across London boroughs.

2. LITERATURE REVIEW

The literature review initially presents the benefits of cycling and presents London's cycling potential to contextualize the research problem. Then, cycling equity is discussed to motivate the study of the relationship between cycling to work and inequalities at regional level. The section concludes with a discussion on mobility injustice.

2.1. Benefits of commuting by bike

There are many benefits of cycling – at the individual (micro) and regional (macro) levels. As an active travel mode, cycling improves physical and mental health (Oja et al., 2011) and is associated with lower stress levels (Avila-Palencia et al., 2017). Promoting cycling has been on the agenda of many cities that did not rely on cycling historically, such as Barcelona or London (Fishman, 2016). As a carbon-neutral transport mode, cycling and public transport facilitate sustainable transportation and tackling climate change.

Fossil fuel-based cars increase air pollution, road traffic injuries, energy consumption and contribute to climate change (Popan, 2019, pp. 64–66). This prompted the introduction of congestion charges in Central London in 2003 and this has contributed to emissions and congestion reduction and greater use of public transport (Croci, 2016). Together with low emission zones, these car traffic restrictions may indirectly encourage travel behaviour change and greater use of cycling. The congestion charge policy is limited to Central London, though, which may generate uneven spatial distribution of environmental benefits and further deepen inequalities.

2.2. Cycling prevalence in London

London, the most populated region within the UK (Greater London Authority (GLA), 2019), is inhabited by almost 9 million people. A total of 33 regions of Greater London (32 boroughs and the City of London) are governed by local councils. The boroughs differ significantly by area and population density, with Outer London boroughs typically larger in area. The City of London is peculiar with only 8000 inhabitants. To review equity in cycling, this paper focuses on Greater London since it is the area administered by the same local authorities and serviced by the same transport organization – Transport for London (TfL).

The mode-share for cycling is 2% across the UK and, although London has the highest level of cycling across the country, it is still considered a low-cycling city with low equity level (Goel et al., 2022). A modal share split in London in 2019 shows 2.4% of daily trips are by bike, 37% by private transport (mostly car), 25% on foot and 36% by public transport (TfL, 2021b). The proportion of commuting by bike increased from 2.7% in 2001 to 4.1% in 2011 among employed 18–74 year olds (GLA, 2019). TfL plans, together with London boroughs, for 33% of Londoners to live within 400 m of a cycle route, an increase from the current level of 19% of Londoners in 2021 (TfL, 2021b, p. 115).

However, even with a relatively large share of the population using public transport and an expanding cycling infrastructure, cycling prevalence is low in London. This low prevalence of cycling along with London's ethnic diversity (40% of Londoners are non-white) (GLA, 2019) makes London a useful case study for this research.

2.3. Cycling infrastructure in London

While London's network infrastructure for cyclists has substantially grown in recent years, it remains geographically limited. Figure 1 presents London Cycle Network (LCN) and Cycle Superhighways and the ratio of people commuting by bike in 2011, when the most recent census available was conducted. The cycling network is shown with blue and grey lines and green shade represents the percentage of bike commuters.

Figure 1 indicates a positive correlation between infrastructure and cyclability across boroughs. Most Outer London boroughs have neither a good network nor a high proportion of cycling commuters in 2011. There are strong discrepancies between boroughs. The darkest green shades show the Inner London boroughs of Hackney and Islington located centrally and recognized as being among the most cyclable boroughs.

London bike sharing systems (LBSS) can be used as part of mixed-mode commuting. Centrally located, the LBSS serves London's central business district (CBD). Figure 1 shows how limited the LBSS was in 2011. In 2019, all four LBSS companies continued to be concentrated in central boroughs and did not cover over half of the area of London (O'Brien, 2019).

The difference in cycling levels between Inner London (12 boroughs and City of London) and Outer London (20 boroughs) is not surprising given the former's proximity to the CBD. In Outer London, cycling could be part of mixed-mode commuting due to larger commuting distances. However, these differences (7.4% of Inner London commuters cycled compared with 2.4% in Outer London in 2011) are reinforced by much higher cycling investment in Inner London (£2.78 per capita or £245,453/km^2 in 2001–11) than in Outer London (£1.76 or

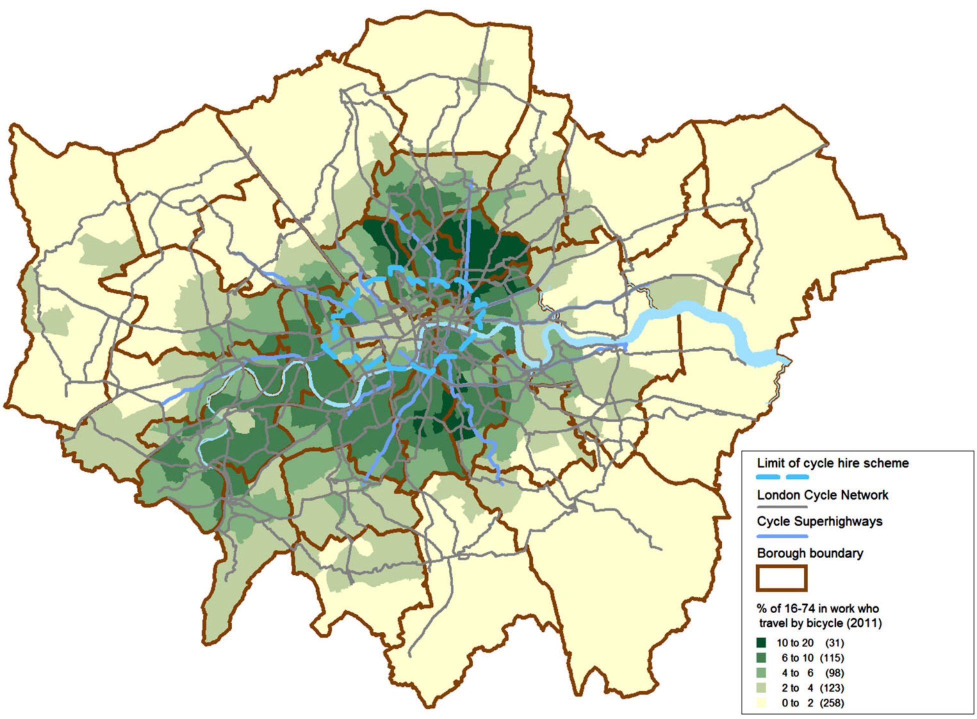

Figure 1. Travel to work by bicycle among 16–74 year olds by London borough from the latest census available, 2011.
Source: Greater London Authority (GLA) (2019). The map is available for publishing under the UK Open Government Licence (OGL v2) licence.

£65,263/km^2) (Martin et al., 2021). This may contribute to cycling inequity, which is considered in the next section and explored quantitatively in this paper.

2.4. Cycling inequity in London

Previous studies highlight cycling inequalities across age, culture norms and gender (Aldred et al., 2016). The UK literature shows little recognition of ethnic inequalities in cycling. While several studies examine the relationship between cycling and socio-economic disadvantage, including ethnicity at the individual level (Martin et al., 2021; Tortosa et al., 2021; Goodman & Aldred, 2018; Lam, 2018), this paper's contribution is to assess the spatial relationship between cycling to work and cycling inequalities solely at the regional level. This section summarizes briefly gender and cultural inequalities that could help better contextualize ethnic inequalities, given their intersectionality.

The gender gap in multimodal travel behaviour is more prevalent in work trips (An et al., 2023). In Europe, women use public transportation more often than men, because fewer have cars and they tend to have more multipurpose journeys (Duchene, 2011). These trip-chains are hypothesized to be the reason for lower prevalence of women cycling to work (Prati et al., 2019). Women's representation in commuter cycling depends on the general level of cycling in a region, and in London only 2.6% of non-work trips and 4.7% of work trips are by bike; women account for only 25.3% of trips in general (Goel et al., 2022). Women's decisions to cycle in England and Wales is mostly determined by the attractiveness of the environment for cycling, with two key elements being hilliness and traffic density (Grudgings et al., 2018). Since London has a relatively flat topography, the major obstacle discouraging female cyclists could be traffic levels.

During the first three years of the LBSS (2010–13) women were underrepresented (under 20%) and it was infrequently used by people in highly deprived areas (Goodman & Cheshire, 2014). Although the key biking share scheme (Santander Cycling) is becoming more inclusive in terms of income (Lovelace et al., 2020), Santander covers mostly Central London, so inequalities are still present in Outer London.

A typical London cyclist is male and white (TfL, 2018, p. 27). Goodman and Aldred (2018) discuss the prevalence of cycling among the white and non-white population at the national (England) scale, though London is more diverse than any other part of England. Any ethnic minority has much lower probability of cycling than the white British population in London, and cycling is more prevalent among groups with higher socio-economic status (Martin et al., 2021). Ethnic inequity also remains in bike-sharing schemes, as ethnic minorities are underrepresented among members and users of Santander Cycling (TNS, 2018).

There is limited research on the deterrents to cycling among ethnic minorities. TfL research shows ethnic minorities are less likely to cycle due to affordability and limited access, as they also live further from the cycling network (TfL, 2011). This may indicate regional inequality, given the previously mentioned division between Outer and Inner London in cycling infrastructure and investment. Further barriers may include affordability, accessibility, awareness of cycling routes and cycling's health benefits, and safety concerns. In relation to the latter factor, ethnic minority communities may have their own dropping-off network and do not see cycling as a safe mode of transport but as an activity for people of lower status access (TfL, 2011). Other reasons may include racial harassment (Goodman & Aldred, 2018) and lack of role models, when cycling is dominated by white, athletic men in London:

> when few do it means that it is publicly gendered in a way that more normalised modes of transport are not; conversely, the very invisibility of Black and Asian cyclists reduces their opportunities to see cycling as a candidate mode of transport'. (Steinbach et al., 2011, p. 1123)

Local streets play a significant role in replacing short car trips (TfL, 2017). Cycle infrastructure is not the only solution to increase cycling.

2.5. Mobility injustice in cycling

Mobility justice shall be understood in broader terms than transportation justice (Sheller, 2018) as it is more complex than access, understood as 'the exclusion of predefined social groups from certain formal or public services' (Cass et al., 2005, p. 553). In the case of cycling equity, mobility injustice could be led by what Lam calls 'cycle blindness'.

> 'Cycle blindness' is akin to race blindness, the deliberate disregard of a person's race, culture, or ethnicity … it ignores historical legacies of racism, invalidates people's differential experiences based on race and racism, and detracts from the necessity to confront and dismantle systemic racist oppression. (Lam, 2018, p. 118)

As an example, Lam analysed cycling policies of the most cyclable borough: Hackney. By falsely homogenizing the cycling population and assuming all cyclists have the same needs, policies focused on road interventions and cycling infrastructure brought better outcomes for privileged groups of middle-class men who already cycle (Lam, 2018).

Mobility injustice and cycle blindness drive ethnic inequity. They are also deeply ingrained in regional inequalities. In contrast to the UK, in the United States the bicycle commuting rate is increasing at a faster rate across lower income groups (Golub et al., 2017, pp. 1–3), that is, 'invisible cyclists' who cycle out of necessity as they cannot afford a car (Lugo, 2018). The US case suggests two groups of cyclists with presumably distinct needs and further proves that investing in cycling infrastructure does not guarantee mobility justice if it serves only one group. In Portland, 'bike lanes are white lanes', as gentrification is the reason for developing bicycle infrastructure and the cycle lanes are partially designed to increase property values and attract the white middle-class to move into the originally predominantly African-American neighbourhoods (Hoffmann, 2016, pp. 82–84). Often cycling infrastructure is advertised as revitalization but leads to gentrification (Stehlin, 2015, p. 121). This proves how cycling and transit usage are delineated by race: 'Race and mobility are intertwined because we designed segregation into built environments' (Lugo, 2018, p. 190).

The US experience prompts the question whether London cycle tracks and lanes are 'white lanes'. Research shows that London is a low-cycling city with low equity level. Cycling infrastructure and bike schemes are in a limited number of boroughs and the current cycling policies are serving mostly groups already cycling to work. This paper examines whether ethnic minorities in London have equal chances of using a bicycle to commute. It investigates ethnic inequity in cycling by addressing the following questions:

- What are the spatial patterns of cycling to work and how do they compare with the spatial distribution of ethnic minorities?
- What affects cycling to work across London regions? Is cycling to work spatially dependent across boroughs?
- Does a higher percentage of ethnic minorities living in a region reduce the proportion of commuters cycling to work?

3. METHODOLOGY AND DATA

To answer the above research questions and account for spatial differences, this paper uses explorative spatial data analysis (ESDA) and estimates a non-spatial regression model, followed by spatial econometric model.

3.1. Model design

Table 1 details the variables included in the model, which are informed by previous studies, and the data sources. The outcome variable is the percentage of employed Londoners who cycle to work within borough i (y_i). On the right-hand side of the equation are the explanatory variables representing the ethno-demographics of the borough (x_1, x_2), mobility potential (x_3, x_4) and spatial coefficients of the model (ρ, λ or Θ). The residuals (ε_i) account for the unexplained variance.

A dummy variable for City of London filtered out the impact of the smallest region in terms of area and population size.

3.2. Data limitations

The outcome variable comes from the 2011 Census, the most recent that is available. This is the most granular aggregate-level data for cycling to work until the 2021 Census data are released. Nevertheless, the general cycling levels have not changed substantially in London from 1.9% in 2011 to 2.4% in 2019, up to the COVID-19 pandemic, when cycling levels increased to 3.4% (TfL, 2021b). Furthermore, census data are compatible with cycling network data from 2012.

The outcome variable uses a single-response census question on travelling mode to work. The modal share is often used as the indicator of cycling increase (Popan, 2019, p. 22). This details trips to work where cycling is the primary mode. This excludes commuters who cycle to work on some days or use multiple modes of transport within one trip (Grudgings et al., 2018).

The operationalization of cycling infrastructure is challenging. Mapping raw cycling data from TfL (2021a) and OpenStreetMap (2021) was followed by a spatial join with an administrative layer and calculation of length of cycling network per borough, but since this procedure did not bring sufficiently granular data across all boroughs and show infrastructure for 2021, the analysis is based on the total length of the LCN and LCN Plus (LCN+), which aggregates major cycle infrastructure in 2011.

Table 1. Predictors in the model and data sources.

	Variable	Definition	Source
Y_i	Bike commuters among employed	Percentage of employed residents aged 16–74 who travel to work by bicycle in 2011	2011 Census (GLA, 2019)
x_1	Asian minority population	Percentage of Black or Asian ethnicity within the borough. There are four ethnic groups in the UK census and complementary surveys conducted by the Office for National Statistics (ONS): White, Asian, Black and Other	Annual Population Survey 2017, ONS (GLA, 2019)
x_2	Black minority population		Annual Population Survey 2017, ONS (GLA, 2019)
x_3	Cycling network	Total length (km) of London Cycle Network (LCN) and LCN+ cycle network per roads length in 2012 as a proxy of cycling network within the borough	Transport for London (TfL) (2012)
x_4	Private cars per capita	Private vehicles in a borough in 2017 per capita	Department for Transport (GLA, 2019)
ρ, λ or Θ	Neighbourhood structure	Spatial weights matrix	(GLA, 2019)
ε_i	Residual predictors	n.a.	n.a.

Source: Author.

Despite the rise of open-source big data there is a lack of cycling data. Global Positioning System (GPS) and journey data on cycling suffer from limitations, such as a lack of representativeness (Romanillos et al., 2016). The only way to analyse cycling travel patterns of minorities is to have representative survey data or census data.

4. EMPIRICAL ANALYSIS

4.1. Exploratory spatial analysis

Spatial analysis identifies patterns in cycling potential across London among minorities. Figure 2 shows regional variation by borough in bicycle commuters and ethnicity.

The highest proportions of commuting cyclists (Figure 2, top left) are in Hackney and Islington, two boroughs located north of Central London. In general, Inner and south-west London boroughs have relatively more cycling commuters than the rest of the boroughs. However, the levels of cycle commuting are low relative to other modes, so if this map had the same scale as that used for the remaining three maps, it would show mostly very bright colours (low percentage). The spatial distribution of the Asian minority population shows greater concentration in Outer London, mostly north-western and north-eastern. The Black minority population is less concentrated within small clusters than the Asian population, and more spread across northern, eastern and south-eastern London. The final map showing all ethnic minorities (bottom right) indicates there is no one clear cluster. The boroughs with greatest diversity are in north-western and north-eastern London and to a smaller extent in southern London.

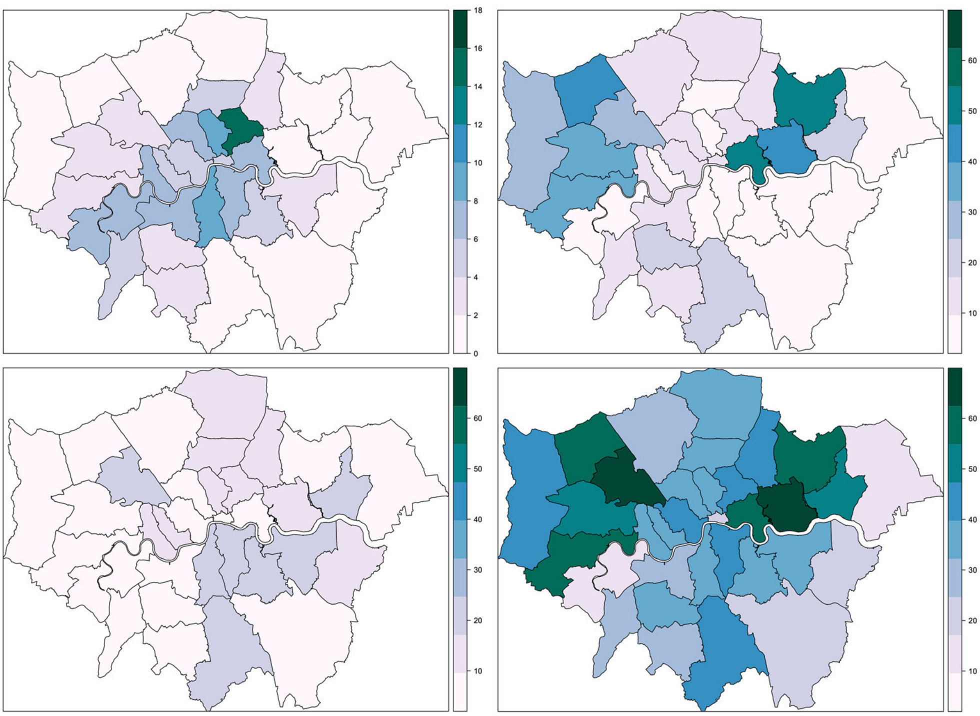

Figure 2. Spatial distribution maps of London boroughs: percentage of bicycle commuters among employed (top left), percentage of Asian minority (top right), percentage of Black minority (bottom left) and percentage of non-white residents (bottom right).
Note: The first map has its own scale. Source: Author based on data sources listed previously.

Figure 3 shows three types of mobilities infrastructure (cycling, car and public transport) and cycling investment 2001–11 per capita. The cycling network (top left) is denser in the central boroughs neighbouring the Thames, in Inner London and in West London. This is partially aligned with the percentage of commuting cyclists, similarly to the cycling investment data (bottom right). Car ownership (top right) is high in Outer London, in particular south-east London, located further from the CBD. Transport accessibility (bottom left) appears most accessible in inner Central London regions. Cycling investment (bottom right) is highly disproportionate, similarly to the percentage of commuters cycling (Figure 2, top left); the larger investments per capita are in the same regions where cycling commuting is highest.

These two sets of maps suggest that Inner boroughs have more commuting cyclists, more cycling investment and relatively more infrastructure. The maps indicate that bike commuting is more popular in Inner London regions and those with lower proportions of ethnic minorities. The maps confirm TfL's cycling potential analysis that defines the largest potential of cyclable trips is in Outer London regions.

The maps indicate spatial dependence. This was confirmed from spatial statistics and Moran's *I* that show spatial autocorrelation in most potential predictors in the model (for detail, see the Appendix).

As cycling is not limited to a borough in which a cyclist lives, a $k = 5$ nearest-neighbour matrix was selected as a spatially weighted matrix to account for boroughs to which one can cycle within a reasonable time. The distance matrix with a radius of 10 km (a reasonable

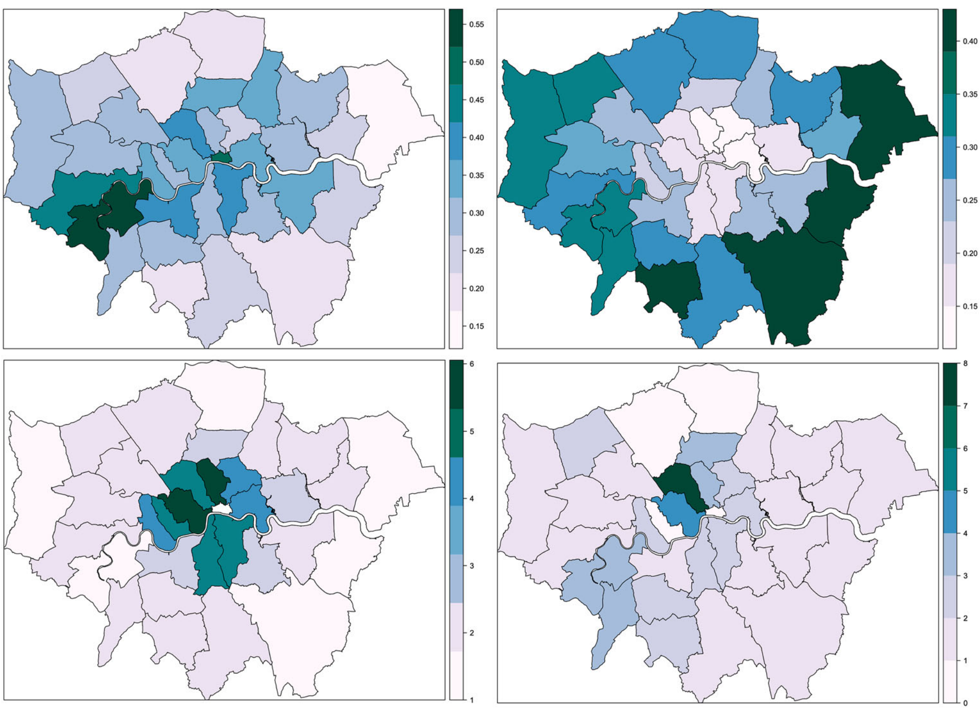

Figure 3. Spatial distribution maps of London boroughs: cycling network per road length (top left), numbers of private cars per capita (top right), public transport accessibility levels (PTAL) (bottom left) and cycling investments per capita (bottom right).
Note: Each map has its own scale.
Source: Author based on data sources listed previously.

maximum cyclable distance for most people) would not be representative of those who live far from the centroid of the borough but cycle across regions.

The global Moran's I for ordinary least squares (OLS) regression residuals is 0.31, which confirms spatial autocorrelation. Omitting spatial dependence between regions would result in biased regression results, hence the analysis that follows uses spatial econometric models.

4.2. A spatial model

First, a general nesting spatial (GNS) model is estimated, which is a full model and includes all three spatial components: WX_i, WY_i and $W\varepsilon_i$.

$$\begin{aligned} \textit{Commuting by bike} \sim \textit{Asian ethnicity} + \textit{Black ethnicity} + \textit{private cars per capita} \\ + \textit{cycling network/road length} + \rho WY + WX\theta + u_i, \\ u_i = \lambda w u_i + \varepsilon_i \end{aligned}$$

A positive value for the spatial parameters (ρ, λ, Θ, or WY, WX or Wu) means that regions have higher values if, on average, their neighbours have higher values. Spatial Durbin models (SDMs) with Durbin elements are estimated, that is, SAC/SARAR (spatial autoregressive combined / Spatial AutoRegressive with additional AutoRegressive error structure), SDM (spatial Durbin model), SDEM (spatial Durbin error model), SAR (spatial autoregressive model), SLX (spatial lag of X model) and SEM (spatial error model) (Elhorst, 2010).

SEM with the lowest Bayesian information criterion (BIC) and the most significant results in terms of statistical and merit understanding was selected. SEM has a spatial error term $\lambda W\varepsilon_i$. Table 2 summarizes the results of SEM, GNS and a non-spatial OLS for comparison.

The SEM results show a spatial correlation between commuting by bike, percentage of ethnic minorities, car ownership and cycling infrastructure across London boroughs.

The strongest relationship with cycling commuting is with car ownership, which is intuitive, as transport-related predictors are most spatially correlated. Owning a car is negatively associated with the propensity to cycle to work. This negative relationship is consistent with previous empirical research (Goodman & Aldred, 2018). The second strongest (also negative) relationship is with the Asian minority population and then with the Black minority population. Regions with a higher percentage of ethnic minorities have smaller proportions of commute

Table 2. Non-spatial ordinary least squares (OLS), general nesting spatial (GNS) and spatial error model (SEM) models with the $k = 5$ nearest neighbours matrix.

	GNS ρWy_i θWX_i $\lambda W\varepsilon_i$	**SEM** $\lambda W\varepsilon_i$	**Non-spatial OLS**
Intercept (bike commuters)	1.37*	2.38***	2.24***
Asian population (logged)	−0.41***	−0.44***	−0.40***
Black population	−0.05	−0.15***	−0.19*
Private cars per capita	−0.56***	−0.67***	−0.60***
Cycling network	0.16***	0.08$^+$	0.23**
Spatial components	$\rho = 0.58$** $\lambda = -0.48$	$\lambda = 0.80$ ***	n.a.
Adjusted R^2 or	–	–	0.76
Nagelkerke pseudo-R^2	0.90	0.86	–
Akaike information criterion (AIC)	25.155	25.80	37.05
Bayesian information criterion (BIC)	46.10	37.77	47.52

Note: Significance: ***$p = 0.001$; **$p = 0.01$; *$p = 0.05$; $^+p = 0.1$.

by cycling and a higher proportion of car ownership. The association between cycling infrastructure and cycling prevalence is positive but weaker than other predictors.

More granular data and a larger sample could help estimate Durbin models with spatial lags of predictors (WX_i), which would indicate interregional flows and neighbourhood interactions to show how cycling to work depends on what happens between the regions. Nevertheless, this analysis demonstrates that the borough-level spatial distribution of cycling to work in London is spatially correlated, and that boroughs' cycling prevalence are not independent from each other.

5. DISCUSSION

5.1. Summary of the findings

The study indicates that London boroughs with higher proportions of minority populations have lower levels of cycling commuting to work. To the best to my knowledge, no study has shown a similar finding. The recent literature explores the issue of cycling inequities in London primarily from the perspective of gender and age inequalities, and this paper is the first to analyse cycling to work and cycling equity in London from a regional/spatial perspective. The results are consistent with previous studies that consider ethnicity and cycling at the individual level (Martin et al., 2021; Tortosa et al., 2021; Goodman & Aldred, 2018; Lam, 2018).

The spatial analysis presented in this paper shows that diverse boroughs have less access to LBSS or cycling infrastructure. Cycling to work is associated with car ownership, cycling network and ethnic diversity within boroughs. Commuting by bike is shown to be spatially dependent across boroughs, which may be reinforced by regional inequalities.

5.2. General policy implications

This paper shows the need to address ethnic inequity in cycling in transportation policies at a regional level, including a localized approach in large cities such as London. Such agglomerations cannot have a one-size-fits-all cycling policy, as regions have varied contexts due to different levels of cycling, equity and infrastructure supply.

The mobilities framework reveals that it is not only infrastructure that prevents people from cycling to work but also their mobility potential, which means cultural differences in diverse boroughs also play a role. By making cycling visible, it can be 'seen as a legitimate, useful and practical form of mobility before it can properly be addressed in the policy context' (Tschoerner-Budde, 2020, p. 321). By moving towards discussing 'mobility futures', rather than solely focusing on transport, routes and finance, transport policymaking can introduce 'soft' measures that would also frame cycling in terms of greater inclusion, safety and accessibility (Tschoerner-Budde, 2020), such as first promoting cycling among non-cyclists. Bringing a sustainable mobilities perspective to transport policymaking could make it more inclusive. Transportation policies and cycle-related investments should adopt inclusive mobility justice and not ignore 'invisible' cyclists.

This paper reconfirms that the greatest potential in enhancing cycling equity is changing cycling demographics (TfL, 2017). There is a need to establish an environment where all groups have the same opportunities to cycle, for example, accommodating infrastructure for shorter trips, rather than prioritizing commuting traffic (Goel et al., 2022), or designing an 'attractive cycling environment' to support women and other underrepresented groups in cycling (Grudgings et al., 2018).

Policies that only serve groups that already have greater levels of cycling, in terms of age and gender, would increase inequalities (Goel et al., 2022). The same approach would apply in relation to ethnicity and race. Hence, cycling policies and projects should consider 'social categories of identity, such as race, class, gender, sexuality, and ability/disability' (Lam, 2018, p. 116). Otherwise, these policies will continue to marginalize underrepresented groups and overlook structural racism that creates and sustains mobility injustice. This requires acknowledging cycling equity in intersectionality framing: exclusion in terms of individual justice arising based on socio-political identities but also exclusion at a regional level in long-term policymaking, such as the previously mentioned ‘white lanes’.

5.3. The model transferability

While it is not possible to generalize to other cities from the results of this analysis, since they are based on a small number of London regions, the mechanisms producing inequalities may be present in similar urban agglomerations with low cycling equity. The model can be adapted with demographic or modal share variables adjusted to local distributions. For smaller cities, it may be useful to add neighbouring commuter regions outside of administrative boundaries.

5.4. Limitations and further research

Besides data limitations discussed previously, the are some limitations in the current analysis. A network of 33 regions of various area size might not represent adequately how cycling commuting happens across the boroughs. One of major challenges could be the modifiable areal unit problem (MAUP). Data observed on polygon entities rely on administrative boundaries defined for the research’s sake which are arbitrary (Bivand et al., 2008, p. 236).

Research on this topic is challenging due to invisible data – invisible cyclists might be missing from the official data, such as the non-recording of unreported immigrants, and aggregate-level data might not reflect variability in smaller ethnic minority groups.

A small sample size, n affects Moran’s I value, robustness and model fit. A small change with the model variables has led to differences in their significance or spatial lags. Therefore, a model using more granular ward data, if that data became available, may be worth testing to assess the stability of the results of spatial effects and estimate models with Durbin components. This could help improve coefficients and better explain interregional relations. Using an ethnic diversity index (Harris, 2020) may also account for small pockets of diversity within wards or boroughs. A larger sample would also facilitate estimation of two models for Inner and Outer London.

Given the extent of the problem of cycling inequity, this paper should be followed by a more detailed study to review current policies and discuss in detail how equity can be overcome. Further research could expand the model by adding other predictors, such as public transport accessibility levels, residential segregation, deprivation index, odds of cycling due to jobs density or sectors, transport investment, or an alternative outcome variable that could include cycling as part of mixed-mode travel. Other suggestions are presented in the Appendix.

Nevertheless, spatial dependency between cycling to work and ethnic composition of boroughs has been shown in this paper, and this problem should be addressed in transport and urban policies.

6. CONCLUSIONS

This study reveals ethnic inequity in cycling to work in London, where people from ethnic minorities are less likely to cycle due to spatially dependent inequalities. Cycling to work is dependent on borough ethnic composition as well as cycling infrastructure and car ownership rates.

The findings are useful for policymaking, though the analysis cannot indicate causality. This paper advocates recognizing ethnic inequalities in cycling. First, this research adds to the growing body of evidence that cycling demographics are key to increased cycling levels, by, for example, increasing visibility of cycling across these low-cycling groups. Second, policymakers should acknowledge different needs of cyclists across ethnic groups to avoid policies being aimed at those who already cycle: white men from middle-class groups. Ethnic minorities might not feel safe when cycling as they have a lower tendency to cycle. This should be accommodated by ‘soft measures’ in transportation policies to account for these needs, such as shifting from infrastructure for high-speed cycle commuting. In Outer London potentially cyclable trips are often short car trips that do not require cycle superhighways but instead local streets adapted for cyclists or segregated cycle tracks that can provide more security.

This paper contributes to an important policy discussion by recommending a review of current active transportation policies to focus on equity. A regional approach brings the localized perspective of spatial inequalities that facilitates tailored policies to communities’ needs and this can contribute to equity in cycling. The novelty of this study is twofold: recognizing ethnic inequity in cycling, and applying an intersectionality framework by linking regional and mobilities studies.

ACKNOWLEDGEMENTS

I thank Dr Declan Jordan for his guidance and support throughout the publication process. I also express my thanks to the anonymous reviewers for their suggestions, as well as comments from Dr Greg McInerny. Lastly, I thank for methods discussions with Professor Roger Bivand and the teaching staff of the Warsaw ERSA Winter School. An early draft of this paper was presented at the Young Scientists session at the ERSA conference in 2019.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available in **Zenodo** at https://zenodo.org/badge/latestdoi/388771527. These data were derived from the resources available in the public domain. The detailed resources are listed in the paper and in Zenodo.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author.

ORCID

Zofia Bednarowska-Michaiel http://orcid.org/0000-0002-0369-3020

REFERENCES

Aldred, R., Woodcock, J., & Goodman, A. (2016). Does more cycling mean more diversity in cycling? *Transport Reviews*, *36*(1), 28–44. https://doi.org/10.1080/01441647.2015.1014451

An, Z., Heinen, E., & Watling, D. (2023). The level and determinants of multimodal travel behavior: Does trip purpose make a difference? *International Journal of Sustainable Transportation*, *17*(2), 103–117. https://doi.org/10.1080/15568318.2021.1985195

Avila-Palencia, I., de Nazelle, A., Cole-Hunter, T., Donaire-Gonzalez, D., Jerrett, M., Rodriguez, D. A., & Nieuwenhuijsen, M. J. (2017). The relationship between bicycle commuting and perceived stress: A cross-sectional study. *BMJ Open*, *7*(6), 1–11, e013542. https://doi.org/10.1136/bmjopen-2016-013542

Bivand, R. S., Pebesma, E., and Gómez-Rubio, V. (2008). *Applied spatial data analysis with R*. Springer.

Cass, N., Shove, E., & Urry, J. (2005). Social exclusion, mobility and access. *The Sociological Review*, *53*(3), 539–555. https://doi.org/10.1111/j.1467-954X.2005.00565.x

Croci, E. (2016). Urban road pricing: A comparative study on the experiences of London, Stockholm and Milan. *Transportation Research Procedia*, *14*, 253–262. https://doi.org/10.1016/j.trpro.2016.05.062

Duchene, C. (2011). *Gender and transport*. OECD. https://www.itf-oecd.org/sites/default/files/docs/dp201111.pdf.

Elhorst, J. P. (2010). Applied spatial econometrics: Raising the Bar. *Spatial Economic Analysis*, *5*(1), 9–28. https://doi.org/10.1080/17421770903541772

Fishman, E. (2016). Cycling as transport. *Transport Reviews*, *36*(1), 1–8. https://doi.org/10.1080/01441647.2015.1114271

Goel, R., Goodman, A., Aldred, R., Nakamura, R., Tatah, L., Garcia, L. M. T., … Woodcock, J. (2022). Cycling behaviour in 17 countries across 6 continents: levels of cycling, who cycles, for what purpose, and how far?. *Transport Reviews*, *42*(1), 58–81. https://doi.org/10.1080/01441647.2021.1915898

Golub, A., Hoffmann, L. M., Lugo, E. A., & Sandoval, F. G. (2017). Creating an Inclusionary Bicycle Justice Movement. In A. Golub, L. M. Hoffmann, E. A. Lugo, and F. G. Sandoval (Eds.), *Bicycle justice and urban transformation: Biking for all?* (pp. 1–16). Routledge.

Goodman, A., & Aldred, R. (2018). Inequalities in utility and leisure cycling in England, and variation by local cycling prevalence. *Transportation Research Part F: Traffic Psychology and Behaviour*, *56*, 381–391. https://doi.org/10.1016/j.trf.2018.05.001

Goodman, A., & Cheshire, J. (2014). Inequalities in the London bicycle sharing system revisited: Impacts of extending the scheme to poorer areas but then doubling prices. *Journal of Transport Geography*, *41*, 272–279. https://doi.org/10.1016/j.jtrangeo.2014.04.004

Greater London Authority (GLA). (2019). *London Datastore*. Mayor of London. https://data.london.gov.uk

Grudgings, N., Hagen-Zanker, A., Hughes, S., Gatersleben, B., Woodall, M., & Bryans, W. (2018). Why don't more women cycle? An analysis of female and male commuter cycling mode-share in England and Wales. *Journal of Transport & Health*, *10*(August), 272–283. https://doi.org/10.1016/j.jth.2018.07.004

Harris, R. (2020). Visualising the scales of ethnic diversity in London using a multilevel entropy index. *Environment and Planning A: Economy and Space*, *52*(7), 1239–1242. https://doi.org/10.1177/0308518X20904728

Heinen, E., van Wee, B., & Maat, K. (2010). Commuting by bicycle: An overview of the literature. *Transport Reviews*, *30*(1), 59–96. https://doi.org/10.1080/01441640903187001

Hoffmann, L. M. (2016). *Bike lanes are white lanes: Bicycle advocacy and urban planning*. University of Nebraska Press.

Lam, T. F. (2018). Hackney: A cycling borough for whom? *Applied Mobilities*, *3*(2), 115–132. https://doi.org/10.1080/23800127.2017.1305151

Lovelace, R., Beecham, R., Heinen, E., Vidal Tortosa, E., Yang, Y., Slade, C., & Roberts, A. (2020). Is the London cycle hire scheme becoming more inclusive? An evaluation of the shifting spatial distribution of uptake based on 70 million trips. *Transportation Research Part A: Policy and Practice*, *140*(April), 1–15. https://doi.org/10.1016/j.tra.2020.07.017

Lugo, A. E. (2018). *Bicycle/race. The intersection of advocacy, city planning, and racism*. Microcosm Publishing.

Martin, A., Morciano, M., & Suhrcke, M. (2021). Determinants of bicycle commuting and the effect of bicycle infrastructure investment in London: Evidence from UK census microdata. *Economics & Human Biology*, *41*, 100945, 1-12. https://doi.org/10.1016/j.ehb.2020.100945

O'Brien, O. (2019). Bikeshare in London. https://oobrien.com/2018/02/bikeshare-in-london-borough-update/.

Oja, P., Titze, S., Bauman, A., de Geus, B., Krenn, P., Reger-Nash, B., & Kohlberger, T. (2011). Health benefits of cycling: A systematic review. *Scandinavian Journal of Medicine & Science in Sports*, *21*(4), 496–509. https://doi.org/10.1111/j.1600-0838.2011.01299.x

OpenStreetMap. (2021). Cycle routes. www.openstreetmap.org.

Popan, C. (2019). *Bicycle utopias – Imagining fast and slow cycling futures. Changing mobilities*. Routledge.

Prati, G., Fraboni, F., De Angelis, M., Pietrantoni, L., Johnson, D., & Shires, J. (2019). Gender differences in cycling patterns and attitudes towards cycling in a sample of European regular cyclists. *Journal of Transport Geography*, *78*(August 2018), 1–7. https://doi.org/10.1016/j.jtrangeo.2019.05.006

Romanillos, G., Zaltz Austwick, M., Ettema, D., & De Kruijf, J. (2016). Big data and cycling. *Transport Reviews*, *36*(1), 114–133. https://doi.org/10.1080/01441647.2015.1084067

Sheller, M. (2018). *Mobility justice: The politics of movement in an age of extremes*. Verso.

Stehlin, J. (2015). Cycles of investment: Bicycle infrastructure, gentrification, and the restructuring of the San Francisco bay area. *Environment and Planning A: Economy and Space*, *47*(1), 121–137. https://doi.org/10.1068/a130098p

Steinbach, R., Green, J., Datta, J., & Edwards, P. (2011). Cycling and the city: A case study of how gendered, ethnic and class identities can shape healthy transport choices. *Social Science & Medicine*, *72*(7), 1123–1130. https://doi.org/10.1016/j.socscimed.2011.01.033

TNS. (2018). *Santander Cycles customer satisfaction and usage survey – Casual users only: Quarter 2 2017/18*. https://content.tfl.gov.uk/santander-cycles-casuals-css-q2-2017-18.pdf.

Tortosa, E. V., Lovelace, R., Heinen, E., & Mann, R. P. (2021). Infrastructure is not enough: Interactions between the environment, socioeconomic disadvantage, and cycling participation in England. *Journal of Transport and Land Use*, *14*(1), 693–714. https://doi.org/10.5198/jtlu.2021.1781

Transport for London (TfL). (2011). Barriers to cycling for ethnic minorities and deprived groups. Policy Analysis Research Summary. https://www.tfl.gov.uk/cdn/static/cms/documents/barriers-to-cycling-for-ethnic-minorities-and-deprived-groups-summary.pdf.

Transport for London (TfL). (2012). *Freedom of information request response from TfL, ref: 1011509246/MOS*. www.whatdotheyknow.com/request/total_length_of_cycle_routes_in.

Transport for London (TfL). (2017). *Analysis of Cycling Potential* 2016. http://www.tfl.gov.uk/cdn/static/cms/documents/analysis-of-cycling-potential.pdf.

Transport for London (TfL). (2018). *Cycling action plan*. https://content.tfl.gov.uk/cycling-action-plan.pdf.

Transport for London (TfL). (2021a). Transport Data Service. https://cycling.data.tfl.gov.uk/.

Transport for London (TfL). (2021b). Travel in London. Report 14. https://content.tfl.gov.uk/travel-in-london-report-14.pdf.

Tschoerner-Budde, C. (2020). Cycling policy futures: Diversifying governance, expertise and the culture of everyday mobilities. *Applied Mobilities*, *5*(3), 306–323. https://doi.org/10.1080/23800127.2020.1766217