Changes in life expectancy and house prices in London from 2002 to 2019: hyper-resolution spatiotemporal analysis of death registration and real estate data

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Summary

Background London has outperformed smaller towns and rural areas in terms of life expectancy increase. Our aim was to investigate life expectancy change at very-small-area level, and its relationship with house prices and their change.

Methods We performed a hyper-resolution spatiotemporal analysis from 2002 to 2019 for 4835 London Lower-layer Super Output Areas (LSOAs). We used population and death counts in a Bayesian hierarchical model to estimate age- and sex-specific death rates for each LSOA, converted to life expectancy at birth using life table methods. We used data from the Land Registry via the real estate website Rightmove (www.rightmove.co.uk), with information on property size, type and land tenure in a hierarchical model to estimate house prices at LSOA level. We used linear regressions to summarise how much life expectancy changed in relation to the combination of house prices in 2002 and their change from 2002 to 2019. We calculated the correlation between change in price and change in sociodemographic characteristics of the resident population of LSOAs and population turnover.

Findings In 134 (2.8%) of London's LSOAs for women and 32 (0.7%) for men, life expectancy may have declined from 2002 to 2019, with a posterior probability of a decline >80% in 41 (0.8%, women) and 14 (0.3%, men) LSOAs. The life expectancy increase in other LSOAs ranged from <2 years in 537 (11.1%) LSOAs for women and 214 (4.4%) for men to >10 years in 220 (4.6%) for women and 211 (4.4%) for men. The 2.5th-97.5th-percentile life expectancy difference across LSOAs increased from 11.1 (10.7–11.5) years in 2002 to 19.1 (18.4–19.7) years for women in 2019, and from 11.6 (11.3–12.0) years to 17.2 (16.7–17.8) years for men. In the 20% (men) and 30% (women) of LSOAs where house prices had been lowest in 2002, mainly in east and outer west London, life expectancy increased only in proportion to the rise in house prices. In contrast, in the 30% (men) and 60% (women) most expensive LSOAs in 2002, life expectancy increased solely independently of price change. Except for the 20% of LSOAs that had been most expensive in 2002, LSOAs with larger house price increases experienced larger growth in their population, especially among people of working ages (30–69 years), had a larger share of households who had not lived there in 2002, and improved their rankings in education, poverty and employment.

Interpretation Large gains in area life expectancy in London occurred either where house prices were already high, or in areas where house prices grew the most. In the latter group, the increases in life expectancy may be driven, in part, by changing population demographics.

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Research in context

Evidence before this study

We searched PubMed for articles published from database inception up to May 31, 2022, using search terms ("small area" OR "neighborhood" OR "neighbourhood" OR "spatial") AND ("housing" OR "accommodation" OR "rent" OR "house" OR "real estate") AND ("price" OR "pricing" OR "affordability" OR "cost" OR "hedonic") AND ("life expectancy" OR "mortality") with no language restrictions. We searched for reports on small-area life expectancy variations in London through the websites of the Office for National Statistics and Public Health England. We also searched for reports on housing cost/affordability and social inequalities through think-tanks and charities.

In terms of life expectancy variations, we found articles and reports on trends in life expectancy for districts and on snapshots of life expectancy for Middle-layer Super Output Areas (MSOAs), which had combined data for 5 years to overcome the issue of small numbers of deaths. None of these had analysed life expectancy for Lower-layer Super Output Areas (LSOAs).

We found some studies that examined the association between house prices, or their change, and physical and mental health, but not mortality nor covering entire cities. We found two articles that had analysed the cross-sectional association of house prices with mortality, one in Rome and one in Seoul, but neither had considered change in price nor change in resident population characteristics. These studies both found that all-cause mortality was inversely associated with house prices, and that adjustments for socioeconomic variables, such as education, attenuated the magnitude of the association. However, to the best of our knowledge, no previous work has either examined the association of house price *changes* with mortality, especially across an entire city's neighbourhoods, or how those changes covary with resident population characteristics.

Added value of this study

This study presents novel hyper-resolution data for trends in life expectancy at very-small-area geographies in London, a major global metropolis, and reveal how inequalities in life expectancy have changed both between and within different parts (districts) of the city. By using spatiotemporal models we obtained robust yearly estimates of mortality and house prices for small geographies.

We also analysed for the first time how life expectancy improvements varied with house prices and their changes throughout the city, and investigated whether population change may partly mediate this association. These issues are relevant for economic, housing and health policies in all major cities.

Implications of all the available evidence

Life expectancy improvement has been accompanied by a substantial rise in inequalities both within and between the city's districts. The largest gains in life expectancy occurred where house prices were already high or where they increased the most, especially from low levels, possibly due to an influx of new, more educated and better-off working age residents.

Introduction

In high-income countries, life expectancy has risen faster in metropolitan areas than in smaller towns and rural areas.[1,2] In England, London has outperformed northern cities and towns in terms of average life expectancy since 2002.[1] In 2019, female and male life expectancy in London were respectively 1.7 years and 1.5 years higher than those of England as a whole. Further, the post-2010 stagnation and reversal in life expectancy happened in fewer London Middle-layer Super Output Areas (MSOAs) than in the rest of the country.[1] But there are limited data on the variability of this progress within London, where socioeconomic status varies substantially over short distances.[3,4]

Large cities, including London, have also experienced substantial increases in house prices.[4,5] Some neighbourhoods that were affordable to lower income families at the end of the 20th century have become more costly, especially areas close to, or with good transport links to, jobs and amenities.[4] There is little data on how much the trends in house prices and health,[6] especially life expectancy, have spatially coincided within large cities (Research in Context Panel), and to what extent life expectancy gains in some parts of cities reflect real health improvements in the incumbent population versus a change in who lives in the area, because better-off residents move in and/or those who had lived there are displaced (Appendix Figure 1).[7–10]

These data are needed to identify where action, through both urban policy and health sector, is needed to improve health, benchmark areas with good versus poor performance, and provide data to measure the impacts of policies. Our aim was to map life expectancy at very high resolution in London from 2002 to 2019, and understand how much life expectancy change across London varied with initial house prices and their change. We also examined changes in the resident population as a mechanism underlying the relationship between house price dynamics and life expectancy.

Methods

Study setting

London is divided into 33 local authority districts: London's 32 boroughs and the City of London (referred to as districts hereafter). Population increased from 7.4 million in 2002 to 9.0 million in 2019 (Appendix Table 1). The share of population in different age groups was relatively stable over this period—the population share aged 0–14 years changed from 18.6% to 19.5%, aged 15–29 years from 23.1% to 20.1%, aged 30–69 years from 49.5% to 51.8%, and aged 70+ years from 8.7% to 8.6%. Using the boundaries from the 2011 census, London consists of 25,031 census output areas (OAs), grouped into 4835 Lower-layer Super Output Areas (LSOAs), with a median population of 1765 in 2019. We used consistent LSOA boundaries through the entire period of analysis.

Study overview

We conducted the following analyses, summarised in Appendix Figure 2.

First, we used data on deaths and population by age, sex, year of death and LSOA of residence in a Bayesian hierarchical model to estimate posterior age- year- and sex-specific death rates for each LSOA, which we converted to life expectancy at birth with lifetable methods.

Second, we used data on house prices by postcode, date of sale, and property size, type and land tenure in a hierarchical model to estimate house prices at Output Area (OA) level, subsequently summarised to LSOA level, and year.

Third, we used a regression analysis to summarise change in life expectancy in relation to change in house prices from 2002 to 2019, separately for each decile of 2002 price. The regressions are not interpreted as causal associations, because both house prices and health may be affected by changes in the sociodemographic and environmental characteristics of LSOAs as shown schematically in Appendix Figure 1, and by secular economic, epidemiological and technological trends.

Fourth, we calculated the correlation between change in price and change in sociodemographic characteristics of the resident population of LSOAs or population turnover, to investigate the role of change in the resident population of each LSOA, as a potential mechanism underlying the price-life expectancy relationship.

Data

Deaths: We extracted de-identified data for all deaths in London from 2002 to 2019 (909,097 death records) from the UK Small Area Health Statistics Unit (SAHSU) research database; data were provided to SAHSU by the Office for National Statistics. These data are records of all deaths in England, together with information on sex and age at death. We did not use 16 death records (0.002%) for which sex was not recorded. Deaths were stratified into the following age groups: 0, 1–4, 5–9, 10–14, ..., 80–84 and ≥85 years. The LSOA of residence was determined using the postcode of residence at death registration.

Population: Mid-year population estimates by LSOA, age group, year and sex were obtained from the Office for National Statistics (ONS). In 3267 (0.099%) of age-LSOA-year combinations, the number of deaths exceeded population. In 88% of these combinations the deaths exceeded population by only one or two, and 96% of these combinations were in people aged 80 years and older. In these cases, the population was set equal to the number of deaths.

House prices: All home sales in England are recorded in the Land Registry with information on sales price. The Land Registry does not include information on property size. The real estate website Rightmove (www.rightmove.co.uk) provides the same information as the Land Registry for all sales; for those that were listed for sale on Rightmove by subscribing estate agents, it also links the Land Registry data to information about number of bedrooms. Rightmove data are regularly updated. We downloaded data from Rightmove for all London postcodes through an automated search using a web crawler, which submitted postcodes to Rightmove to extract sales data. We obtained 2.1 million sales records for years 2002–2019, which is 94.9% of the total number of sales in the Land Registry database. Data on the number of bedrooms was available for 1.2 million (58.2%) homes; the remainder were either never listed on Rightmove or their listing was removed. On average, homes with known and unknown number of bedrooms had similar prices (ratio of median prices = 1.01).

The house price data contained the following information: postcode, date of transaction, price, type of house (flat, terraced, semi-detached, detached house), status of land ownership (freehold (owns the property and the land upon which the property is built), leasehold (owns the property but not the land, which is leased)), whether the property is an existing property or newly constructed, and number of bedrooms. We excluded sales where the number of bedrooms was nine or more (n = 326, 0.03%) as this is not a homogenous group, with some of these properties (with low sale prices) made up of multiple individually rented units and others being large single household properties (with high sale prices). We also excluded those sales for which prices were lower than the median price in the quarter by over six standard deviations (n = 36, <0.01%) with some sale prices of £500, £750 or £1000; these are likely to have been transacted at a nominal figure rather than at full market value. We excluded one sale (<0.01%) with missing status of land ownership so that all data were complete. We used postcode to map homes to 24,131 (96.4% of 25,031) OAs in London which belonged to 4830 LSOAs (>99% of 4835). The median number of sales in each LSOA was 246 over the entire analysis period, with a median per year in each LSOA of 13. The 900 (3.6%) OAs with no sales over this period tended to be places with higher proportions of rented housing, especially rented social housing.[11]

Measures of socioeconomic status: We used data on the following measures of socioeconomic status from the English Indices of Deprivation.[12] We used data for these measures for 2004 (because data for 2002 were not available) and 2019 to examine the characteristics of the population that changed from 2002 to 2019 as prices of housing changed.

- Income deprivation (referred to as poverty hereafter): proportion of LSOA population claiming income-related benefits due to being out-of-work or having low earnings;
- Employment deprivation (referred to as unemployment hereafter): proportion of the working age population of the LSOA involuntarily excluded from the labour market due to unemployment, sickness or disability, or caring responsibilities; and
- Education, skills and training deprivation (referred to as low education hereafter): lack of attainment and skills—including education attainment levels, school attendance and language proficiency indicators—in the LSOA population both for adults and for children and young people.

We did not use data on race, ethnicity or occupation because, over the study period, they were available at small area level only in the census year of 2011. We also used estimates of population turnover, defined as the proportion of households in each LSOA in 2019 who were different from those who had lived there in 2002, from the Consumer Data Research Centre.[13] The Consumer Data Research Centre estimates these proportions by using the names of households members, individually and in combination, and addresses and dates of records from electoral and consumer registers and land registry sales data.

Statistical analysis

Statistical methods for estimating life expectancy (Bayesian hierarchical model) and house prices (hierarchical model) at the small-area level are described in Appendix Text 1. We summarised change in life expectancy in relation to percent change in price using linear regressions at LSOA level, the smallest unit with life expectancy estimates. We used the median of all constituent OAs for each LSOA's price. The intercept of this regression measures the average increase in life expectancy irrespective of price change, and the coefficient of the price term shows the extent of change in life expectancy with increasing house prices. The regressions included interactions between decile of price in 2002 for both the intercept and the coefficient of price change term. The interactions with baseline price allow life expectancy and price change associations to vary by areas that started off as relatively less or more expensive.

The association of change in LSOA life expectancy with change in house prices may represent a causal relationship, e.g., because a rise in price provides those who own homes to have the means to improve the quality of their homes and purchase more goods and services.[6] Alternatively, the rise in price may reflect improvement in the environment and amenities available to the residents which are beneficial to health.[14] Finally, or additionally, price rise may be a marker for changes in the people who live in the area and who may be able to afford more expensive homes while having different health due to factors unrelated to housing.[14] These relationships are schematically shown in Appendix Figure 1. Establishing the contributions of these mechanisms requires linked data that track the place of residence for the entire population, as well as changes to the quality of homes and neighbourhood environment and amenities. Such detailed linked data do not exist in England and most other countries. To investigate the extent that price change is accompanied with changes in the characteristics of LSOA populations, we report the Spearman's (rank) correlations of change in price with the following characteristics which measure the change in the resident population, separately for each decile of price in 2002:

- Change in total population and population density of the LSOA;
- Change in share of the LSOA population in the age groups 0–14, 15–29, 30–69 and 70+ years;
- Change in rank of LSOA in terms of measures of deprivation including poverty, unemployment and low education;
- Change in households living in the LSOA during the period 2002–2019 as measured by population turnover as defined above.

The three deprivation variables were only available as ranks, and in order to use a consistent measure of correlation, and account for potential non-linear associations, we used Spearman's rank correlation for all variables. Summaries of the population and population turnover variables are given in Appendix Table 3; deprivation variables were ranks and therefore excluded from the table.

Role of funding source

The funders played no role in the writing of the manuscript or the decision to submit it for publication.

Results

Life expectancy at birth for London increased from 80.9 (95% credible interval (CrI) 80.8–81.0) years in 2002 to 85.4 (CrI 85.3–85.5) years in 2019 for women, and from 76.1 (CrI 76.0–76.2) years to 81.6 (CrI 81.5–81.7) years for men. Life expectancy inequality (defined as the difference between 2.5th and 97.5th percentiles of LSOA life expectancies) was 19.1 (CrI 18.4–19.7) years for women and 17.2 (CrI 16.7–17.8) years for men, in 2019 which is a substantial increase from 11.1 (CrI 10.7–11.5) years for women and 11.6 (CrI 11.3–12.0) years for men in 2002. The corresponding estimates for life expectancy inequality in 2019 calculated using MSOA level analysis were 10.8 (CrI 10.3–11.3) years for women and 11.0 (CrI 10.5–11.6) years for men.[1]

Life expectancy in 2019 was highest in LSOAs in central London districts of Kensington and Chelsea, Westminster, City of London and Camden, in the southwest (Richmond upon Thames and Kingston upon Thames) and parts of the northwest (e.g., parts of Harrow and Barnet), with life expectancy in many LSOAs surpassing 90 years. Low life expectancy was spread in LSOAs throughout the city but was more common in outer east and southeast London.

There was large variation across London in how much life expectancy increased from 2002 to 2019, ranging from <2 years in 537 (11.1%) LSOAs for women

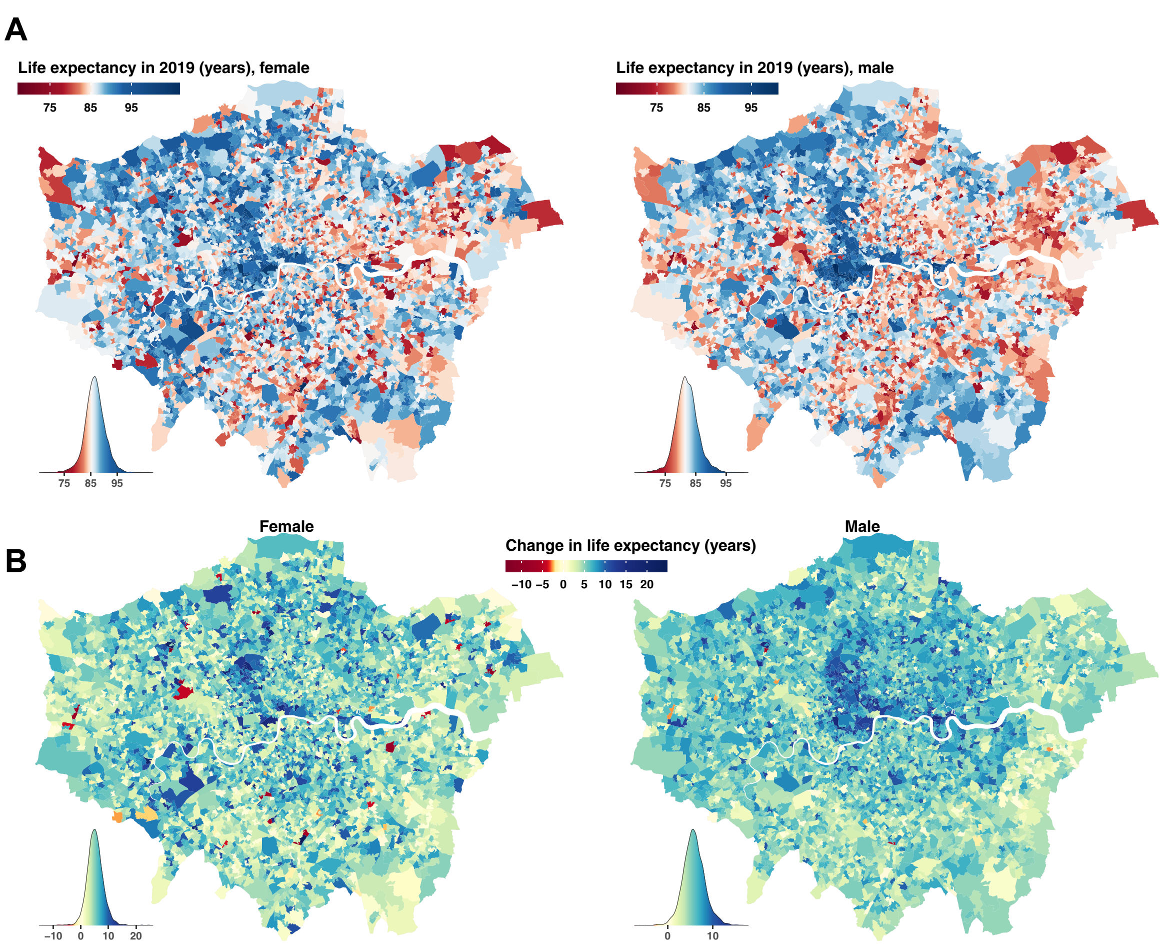

Fig. 1: Life expectancy in 4835 Lower-layer Super Output Areas (LSOAs) in London for females and males (A) in 2019 and (B) change from 2002 to 2019. In A, the areas in white have a life expectancy equal to the overall London life expectancy.

and 214 (4.4%) for men to >10 years in 220 (4.6%) for women and 211 (4.4%) for men (Fig. 1B). In 134 (2.8%) LSOAs for women and 32 (0.7%) for men, life expectancy may have declined, with a posterior probability of a decline greater than 80% in 41 (0.8%) and 14 (0.3%) LSOAs for women and men, respectively. Life

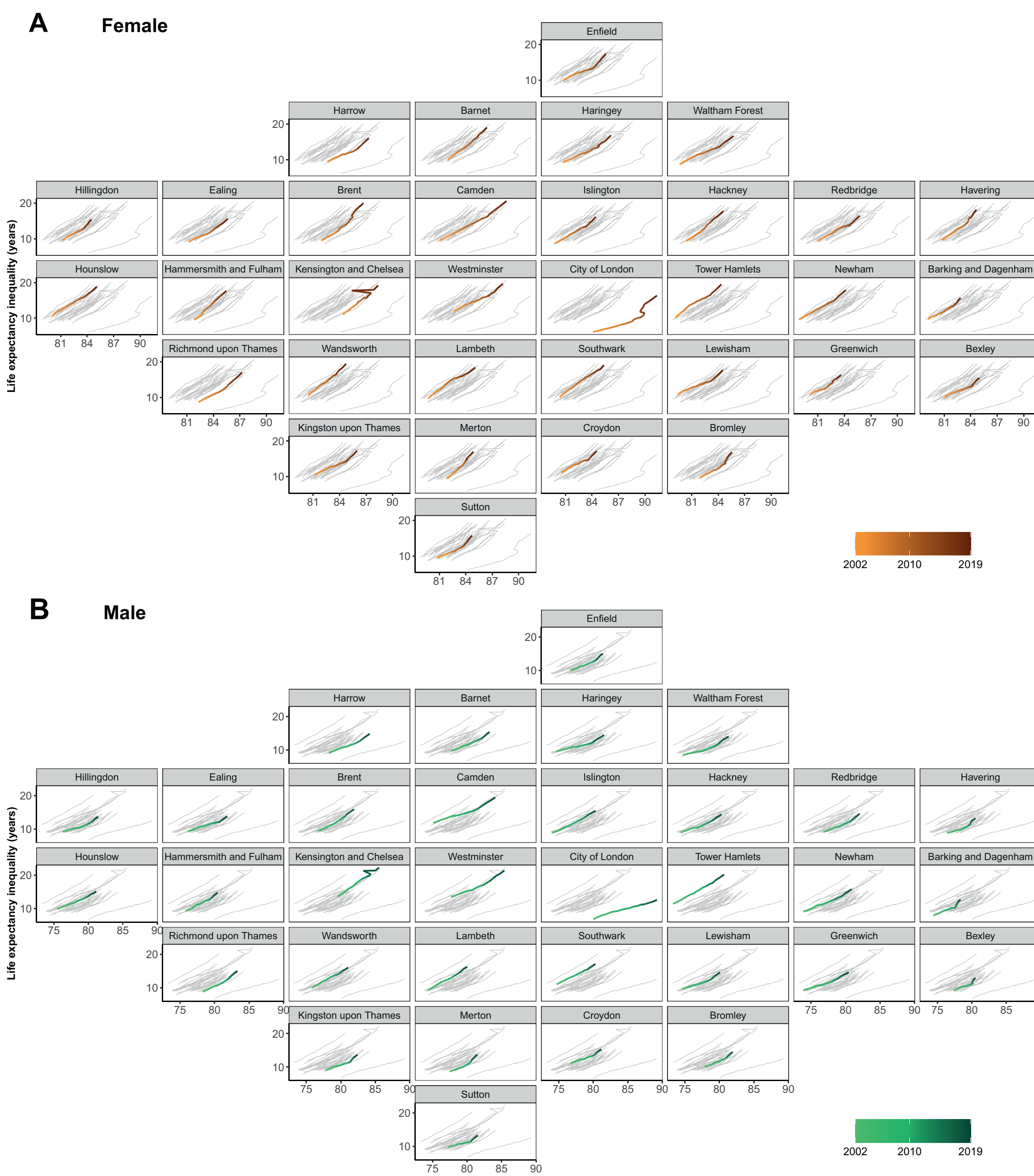

Fig. 2: Life expectancy at birth and inequality in life expectancy within London's 33 local authority districts from 2002 to 2019 for females (A) and males (B). Each panel plots life expectancy against life expectancy inequality over time for all 33 districts, and highlights the trend line for the district which is named at the top of the panel. The districts are arranged according to their approximate location in Greater London. Time is indicated by the scale of brown and green. Inequality is calculated as the difference between the 2.5th and 97.5th percentiles of the Lower-layer Super Output Area (LSOA) estimates within each local authority district. See Appendix Figure 4 for distributions in each district. The large decline in life expectancy in Kensington and Chelsea in 2017 is due to the deaths caused by the fire in Grenfell Tower.

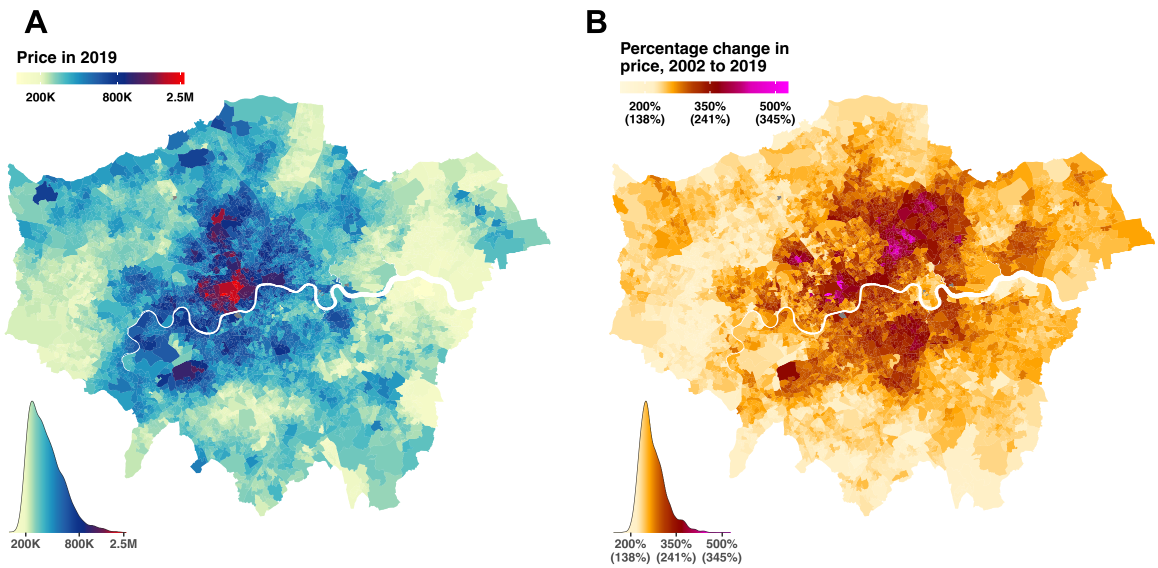

Fig. 3: House prices in 4830 Lower-layer Super Output Areas (LSOAs) in London (A) in 2019 and (B) relative (percent) change from 2002 to 2019. Price is shown for a two-bedroom leasehold existing (not newly constructed) flat sold in the spring season. Two-bedroom leasehold flats were the most common type of sale during the study period with 19.7% of sales. These estimates are compared with the price of three-bedroom freehold terraced houses, the second most common type, in Appendix Figure 6. We did not make price estimates in 5 LSOAs (<0.01%) where no sales were recorded during the study period, shown in grey in the map. In (B) the numbers in brackets show percent change adjusted for inflation, as measured by Consumer Price Index.

expectancy increased more in LSOAs in central and inner east and south London than in outer areas. The rate of increase in life expectancy was smaller after 2010 compared to the earlier years for both sexes (Appendix Figure 3), and the number of LSOAs in which life expectancy may have fallen was larger, especially from 2010 to 2014. The slow-down or reversal of LSOA life expectancy after 2010 is consistent with the pattern seen throughout England's MSOAs,[1] which may be partly due to increase in poverty due to low-wage employment and cuts in services in the austerity era.[1,15] However, the progressive worsening of life expectancy gain and loss from 2010–2014 to 2014–2019 which was seen in other parts of England did not happen in London (Appendix Figure 3).

There was substantial variation in the size of life expectancy increase over short distances. As a result of this spatial heterogeneity, life expectancy inequality increased not only in London as a whole, but also in every district in London alongside increasing average life expectancy (Fig. 2 and Appendix Figure 4). By 2019, female and male life expectancies had a 2.5th–97.5th percentile range that was >12 years in every district, and >20 years in three districts for men and two for women. In 2002, within district inequality had been >12 years in only two districts for men and none for women. At the same time, the difference between districts with the highest and lowest life expectancy increased from 5.9 (CrI 5.2–7.7) years in 2002 to 8.5 (CrI 5.9–11.9) years in 2019 for females, and from 6.8 (CrI 5.9–8.7) years to 10.9 (CrI 8.2–14.2) years for males indicating that the rise in life expectancy inequality took place both within and between districts. In 2019, the percentage of total variation in life expectancy across LSOAs due to within-district variation was 88% for women and 83% for men with 12% for women and 17% for men due to between-district variation.

In 2019, the cost of a two-bedroom flat varied by 6.1 (95% confidence interval (CI) 5.5–6.9) folds between the 2.5th (CI 169,000; 148,000–188,000; all prices rounded to the nearest GBP 1000) and 97.5th (CI 1,028,000; 912,000–1,168,000) percentiles of LSOAs (Fig. 3). Price was highest in central, inner north and southwest London and lowest in outer east, west and south London. From 2002 to 2019, every LSOA experienced an increase in home price with the 2.5th and 97.5th percentiles of the relative (percent) increases at the LSOA level being 201% (CI 194%–209%) and 389% (CI 372%–407%), respectively. There was only weak correlation between price in 2002 and price change (correlation coefficient = 0.19). For example, while price almost quadrupled in many LSOAs in already-expensive central London districts such as Westminster and City of London, the rise was generally smaller in southwest London districts (Richmond upon Thames and Kingston upon Thames), which had started from similar prices. At the same time, house prices also increased by three to six folds in some areas which

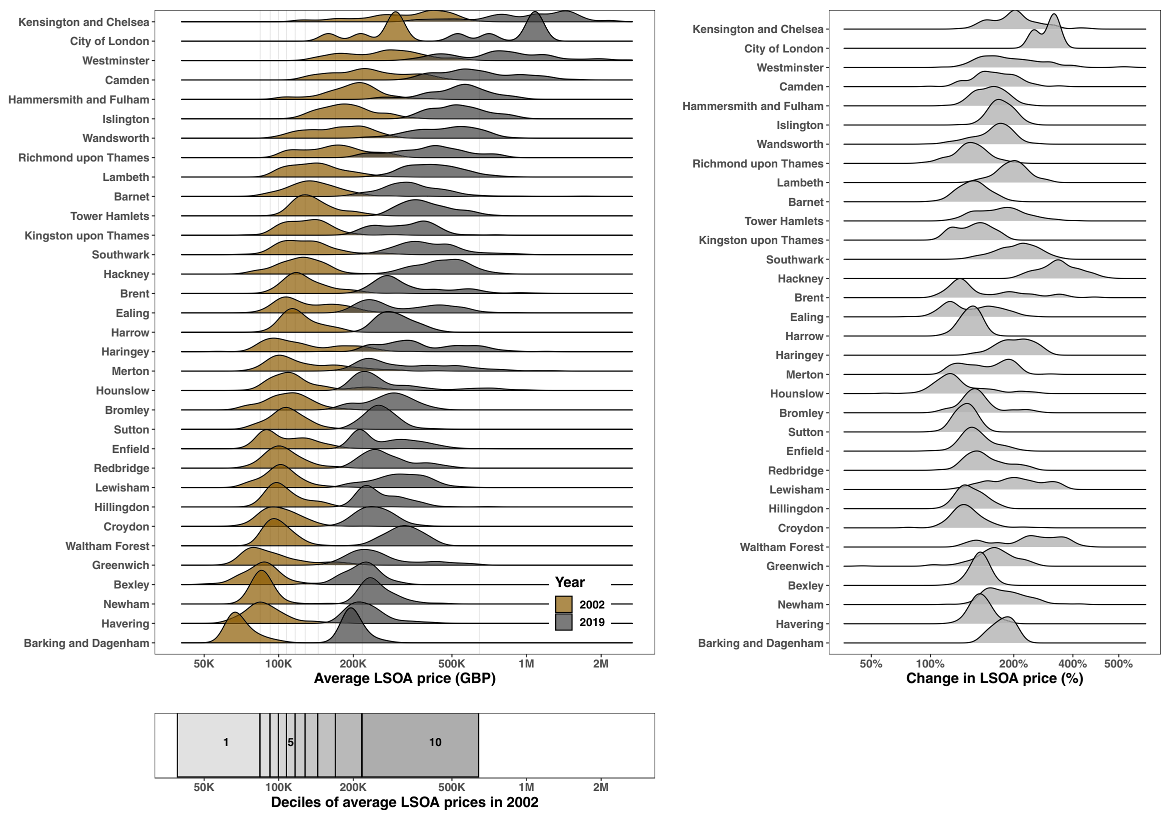

Fig. 4: Distribution of estimates of Lower-layer Super Output Area (LSOA) house price in 2002 and 2019 (left panel), and of the change from 2002 to 2019 (right panel) in 33 London districts. Districts are ordered by the median estimated price in 2002. The lower panel shows the cut-points for deciles of LSOA price in 2002. Prices are for a two-bedroom leasehold existing flat, the most commonly sold property type during the study period.

were less expensive in 2002, especially in inner east and south London, with prices approaching those in central London in 2019.

House prices, and how much they increased, also varied substantially within districts (Fig. 4 and Appendix Figure 5). The ratio of price in the median LSOA to lower-cost LSOAs (i.e., at the 2.5th percentile) varied from ~1.1 to ~2.9 in different districts; the ratio was larger (i.e., a wider left tail) in more expensive districts like Westminster and Kensington and Chelsea.[3] At the high-end of district prices (i.e., the 97.5th percentile of LSOAs), the ratio to median ranged from ~1.0 to ~3.3 with no apparent pattern in relation to district median price. In other words, the existence of locations with much higher prices than district median was as common in less expensive districts (Merton or Brent) as it was in more expensive ones (Westminster). From 2002 to 2019, most districts experienced a larger rise in the expensive LSOAs (97.5th percentile) than in the 2.5th percentile, indicating a widening of the within-district price range.

Life expectancy change from 2002 to 2019 was associated with both property prices in 2002 and how much they increased from 2002 to 2019. The 30% (females) and 20% (males) of LSOAs where house prices had been lowest in 2002, mainly in east and outer west London, on average only gained additional years of life expectancy proportionate to the rise in house prices; the regression intercept, which measures life expectancy change if house prices had not changed, was indistinguishable from zero (Fig. 5). In these LSOAs, each trebling of price was associated with 3.1 (CI 1.7–4.6) to 5.6 (CI 4.0–7.2) years of increase in life expectancy. In contrast, in the 60% (females) and 30% (males) most expensive LSOAs in 2002, life expectancy increased solely independently of price change; the increase was 6.3 (CI 4.4–8.3) years for females and 5.7 (CI 4.2–7.3) years for males in the 10% of LSOAs with the highest house prices in 2002.

Price increase was also associated with changes in the LSOA resident population and their socioeconomic characteristics (Fig. 6). The association was weaker in the 20% of LSOAs that were already expensive in 2002. Elsewhere, LSOAs with larger price increases experienced larger growth in population and had a larger share of households who had not lived there in 2002. Increase in house prices was also associated with a larger rise in the share of population in working ages

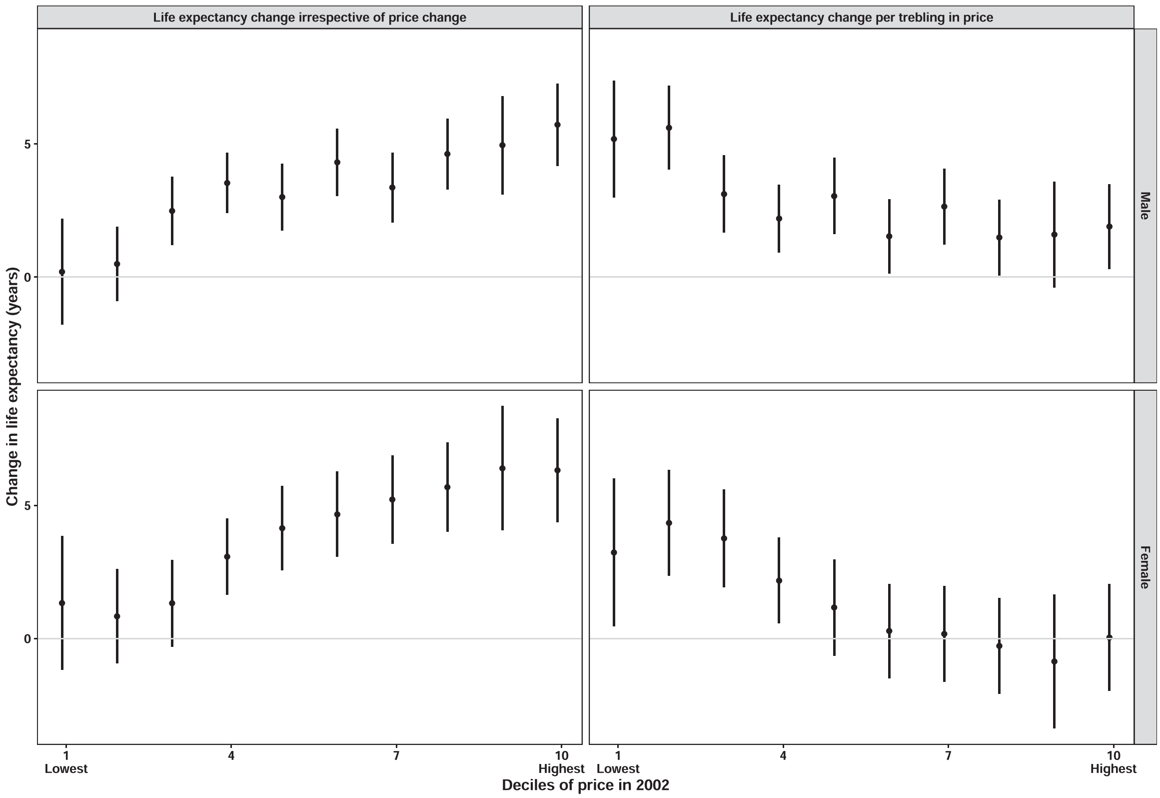

Fig. 5: The crude (unadjusted) relationship between change in house price and change in life expectancy in London for men and women. Life expectancy change irrespective of price change is the intercept of the regression of change in life expectancy on change in price, by decile of LSOA house price in 2002 as described in Methods. Change in life expectancy per trebling of price, by decile of LSOA house price in 2002, is calculated from the coefficient of price change in the aforementioned regressions.

(30–69 years), and a larger decline in the share of population in other ages. These LSOAs also improved their rankings in terms of education and skills, poverty and employment.

Discussion

Our high-resolution analysis revealed three novel and important features of life expectancy and house prices in London, a major global metropolis, in the 21st century: First, not only has life expectancy inequality increased substantially, but this increase has happened both between districts and within every district. Second, the increase in life expectancy inequality has accompanied a rise in house prices throughout London, in both the already-expensive areas and those that had lower costs at the turn of the century. Finally, change in life expectancy had different associations with price change in more expensive versus lower cost communities: where prices were high at the turn of the century, life expectancy increased substantially independently of price change, and with little change in the resident population. In contrast, in areas that started with lower prices life expectancy only increased proportional to price change, and was accompanied by a greater influx of new residents into the local area. This change in residents saw a greater proportion of the population in working ages, and socioeconomically better off, and an outflux of residents in retirement ages and to a lesser extent children, adolescents and young adults.

Life expectancy in London has previously only been reported at MSOA level as a part of analyses that covered England as a whole, either as trends over time[1] or in a single year.[16,17] When aggregated to MSOA level, the LSOA life expectancies in this work were correlated with previously published MSOA estimates[1] (correlation coefficient >0.99 and mean difference ≤0.01 years for both sexes). ONS also summarises house sales data but does not account for variations due to small number of sales in each LSOA or year, nor for different mix of properties. Some studies have documented changes in spatial patterns of poverty in London,[4,7] and have found that poverty rates have fallen in inner East London but may have risen in some outer London areas, with corresponding changes in the share of the population working in higher professional occupations. To our knowledge, no previous study has reported how life expectancy change in small-area units coincided with

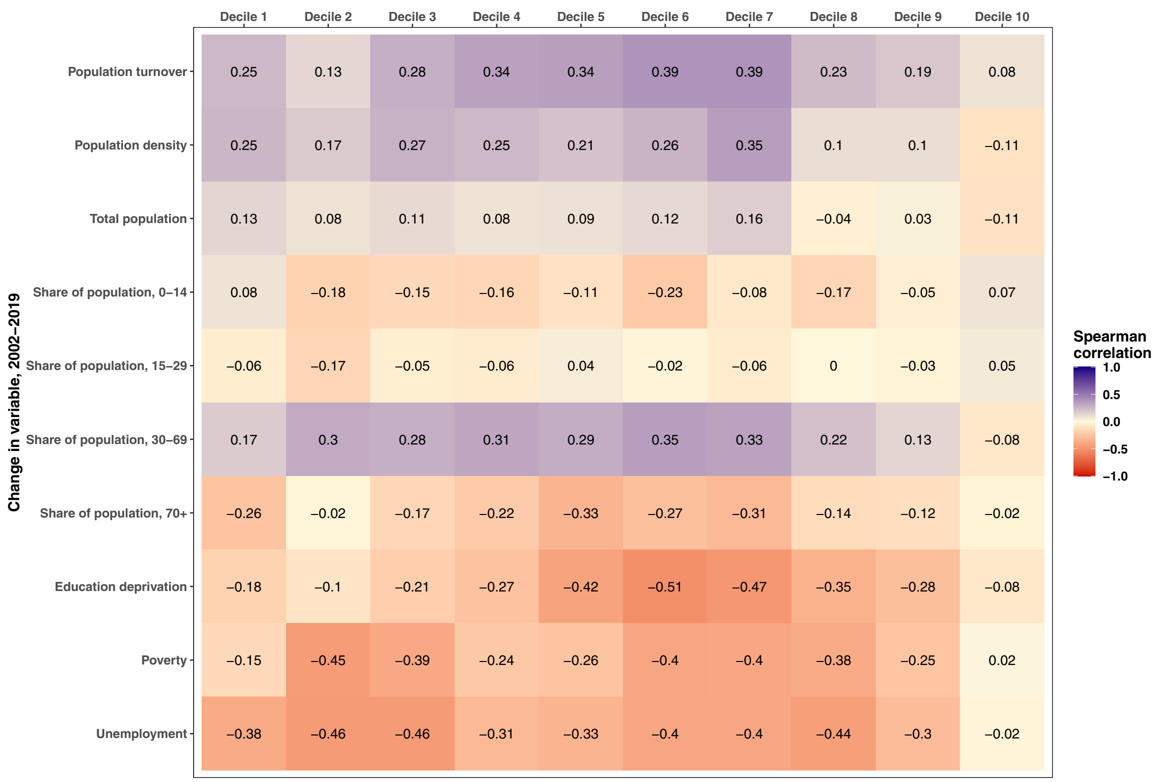

Fig. 6: Spearman correlation between change in house price and change from 2002 to 2019 in sociodemographic characteristics of the population of London Lower-layer Super Output Areas (LSOAs). LSOAs were grouped by decile of house prices in 2002 (see Fig. 4) and correlations were calculated and are shown separately for each decile. Spearman correlations are closer to 1 when the ranks of the two variables are more similar, and closer to −1 when the ranks are more opposite. Correlations close to zero imply the lack of a relationship between the ranks of the variables. Population density was calculated by dividing total population, separately for 2002 and 2019, by the LSOA area. Population turnover is a measure of change in the resident population, defined as the proportion of households in each LSOA in 2019 who were different from those who had lived there in 2002.[13]

change in house prices, and how changes in population were a potential mechanism for these interrelated dynamics.

Strengths and limitations

The main strength of our study is the presentation of very high-resolution data on life expectancy and house prices in consistent spatial and temporal units in a major global city over a period of substantial policy interest and investment in urban renewal. Carrying out the study at the LSOA level allowed us to uncover inequalities to a fuller extent. By applying hierarchical models based on patterns of mortality over age, space and time, and of house prices in relation to space, time and property size and type, we obtained robust estimates of life expectancy and house prices for small areas, together with the uncertainty in these estimates. Consistent spatiotemporal estimates of life expectancy and house prices allowed us to understand not only how life expectancy and its inequalities have changed throughout London but how these changes are distributed in relation to house prices and their changes. Combining these with data on population characteristics and movement, provided an indication of the underlying mechanisms of coupled house-price and longevity dynamics.

Our study is also affected by some limitations, which provide directions for routine data collection and further research. We did not analyse underlying causes of death, which should be the subject of further research to reveal the diseases and injuries driving the differences in life expectancy. We did not break down age beyond 85 years, which might mask some differences in old-age mortality and survival patterns. Small-area population, which is the denominator of age-specific death rates, is estimated by the ONS for intercensal years, and may be subject to error. This is especially the case in older ages when some people live and die in a long-term care facility, and may be counted towards population (denominator of death rates) in their original LSOA of residence and towards deaths (numerator of death rates) in the LSOA where the care facility is located. In four out of five LSOAs with the largest estimated decreases in life expectancy, estimated population counts were lower than the recorded death counts in the older age groups in several years of the data. Similarly, four out of the five LSOAs with the largest increases in life expectancy were adjacent to LSOAs with very large decreases implying that populations or deaths may have been allocated incorrectly. Subsequent inspection showed that postcodes coinciding with, or adjacent to, LSOAs with the largest increases and decreases contained care homes, which can lead to the place of residence or death being inconsistently recorded for some of their residents. We estimated mortality and house prices using two separate models because a joint model would be extremely complex and would require additional assumptions about how house prices are associated with age- and LSOA-specific mortality. As a result, the associations of change in life expectancy with change in house prices (Fig. 5) do not take into account the uncertainty of each input.

Using house price data via Rightmove had the advantage of providing vital information on the number of bedrooms, but the number of sales in this source was ~5% fewer than those in the Land Registry which covers all sales, and not all sales had data on the number of bedrooms. We showed that the prices of sales with and without known bedrooms were very similar. We did not analyse data on rental cost because unlike sales, which are available through the Land Registry, such data are not comprehensively collected. The available data at district level as well as in matched properties show that rent and purchase prices are highly correlated (correlation coefficient = 0.98 at the district level).[18–21] Data from the 2011 census, the only year during our analysis period for which information on percent of households who lived in rented accommodation (including social housing) was available at the LSOA level,[11] show that the proportion renting was on average higher in LSOAs with greater poverty (Spearman correlation coefficient = 0.72 for all rented housing and 0.85 for social housing). However, the relationship between the proportion of households living in rented accommodation and change in life expectancy was weak (Spearman correlation coefficient = −0.03 and 0.13 for women and men, respectively, for all rentals and −0.13 and −0.02 for social housing). The Spearman correlation coefficient between the proportion of households living in rented accommodation and population turnover was 0.72. Neither did we have data on homelessness, which is associated with severe adverse impacts on health,[22] and how it has changed over the analysis period. In analysing the association of life expectancy and price changes, we did not explicitly distinguish between the sales of existing properties and new housing stock; the share of sales which were of new properties varied between ~4% in Kensington and Chelsea and 30% in Tower Hamlets. The change in price used in our analysis is the combination of change in the price of existing properties and that of new ones, and the turnover in population reflects both movement of the existing population and influx associated with new housing stock; the correlation between the percentage of sales which were new and the turnover of the population was 0.47.

We could only indirectly evaluate, through LSOA-level population turnover and population characteristics, whether population change is a potential mechanism that links change in house prices and life expectancy because routine death registration in England only records place of residence at the time of death. Among population characteristics, we could not obtain data on race, ethnicity and occupation. Further, there are currently limited time-series data on quality of housing, access to jobs, services and amenities, and other home and neighbourhood characteristics that affect health and precede or follow changes in house prices. To understand whether changes in the life expectancy of communities arises from changes in the health of the population, itself due to changes in their economic status and/or local environment and amenities, versus a change in the resident population requires linked datasets which are able to track over time environmental characteristics of areas together with individuals' place of residence, socioeconomic status and mortality records. Only a small number of countries such as New Zealand, Sweden and Switzerland have such fully linked data that bring together records from tax, education, census, mortality and other sources. In the absence of such data the patterns and mechanisms of the house price-life expectancy relationship would need to be studied using spatial methods, as we have done, or using studies that follow up individuals to understand the relationships among house prices, area of residence and health.[6] Finally, how health and health inequalities have changed in relation to house prices in London may have similarities as well as differences with other cities in the UK, or with other large cities throughout the world. There is a need for comparative studies to understand such similarities and differences, and their social, environmental and policy reasons.

Urban policy and public health implications

Since the turn of the millennium, London's population and economy have grown substantially. The economic growth has been highly polarised, as has been the case in metro areas in the USA,[23] with high-pay and high-skilled employment[24] alongside low-pay and insecure jobs.[25] As a result, despite city-wide growth in income, nearly one half of London's population fall in the two bottom quintiles of national income deprivation.[12] The demographic and economic growth has not been matched by an increase in housing stock.[26] Together with an uncontrolled property market, this has created house prices that are unfavourable to low-income families.[26] As a result, entire subgroups of the population have been displaced to cheaper parts of the city, with fewer amenities and worse access to jobs, quality education, healthcare and other services and amenities.[7,10,27] Many are unable to purchase (versus rent) and hence spend an increasing share of income on housing, and/or live in lower quality or smaller accommodation in the more desirable districts.[4,7,10] These trends have created either large pockets of poverty or, within certain districts, communities with low social capital[8] and access to health and other services and amenities, especially among the most vulnerable groups.[14,28–33] Comprehensive healthy housing—which encompasses both the physical structure and characteristics of the house and the community's amenities, services and social, physical and natural environment—that is affordable to those on lower incomes is increasingly rare.[34] These trends may have contributed to health inequalities both between nearby areas and across the entire city alongside other trends such as differences in the extent of neighbourhood improvement or provisions of health and social care services as council budgets were reduced as a result of austerity policies.

Successful cities are safe, affordable, and supportive of good health and wellbeing across the life course, with the benefits of good environments enjoyed by everyone. The evolution of London, and major cities in other high-income nations and emerging economies, into places where only the well-off can afford to own properties, where the balance of the city is driven by the cost of property and wealth dominates access, poses a gloomy, non-cohesive future for these cities. Although specific solutions have been proposed for London to add to the supply of housing and address the needs of the very marginalised residents, and some parts of the city have begun implementing specific plans, there has been little linkage with health and health inequalities by either the housing or the health sector. Our results indicate that unless these links are made and reflected in housing and health policy choices, as they were when cities in industrialised countries first began to take a more holistic approach to public health and health inequalities,[35] cities like London which aim to be health enhancing can instead augment societal inequalities that associate strongly with health disadvantage. As this is unfolding at a time of growing public attention and policy intention in the UK for the opposite to occur, there is a need to go beyond isolated local housing solutions and seek a more fundamental approach across government to housing, neighbourhood and health inequalities.[36]

Contributors

AZ, JEB, TR, HID, BD and EJ obtained or managed data. JEB, TR and ME developed analytical methods. JEB and TR implemented methods in consultation with ME, AZ, GL and SF. JEB, TR, YD and ME designed presentation of results and wrote the first draft of the paper. All other authors contributed to revision and finalisation of the paper. The corresponding author was responsible for submitting the article for publication. TR, HID and JEB had full access to all mortality data and AZ and JEB to all data on house prices. TR, JEB and HID checked and verified the mortality data, and AZ and JEB checked and verified the house price data. Due to data permission restrictions, not all authors were able to access the underlying data used in the study.

Data sharing statement

The Small Area Health Statistics Unit does not have permission to release data to third parties except in the form of non-disclosive statistical tables or conclusions suitable for publication. Individual mortality data can be requested through the Office for National Statistics (https://www.ons.gov.uk). Mid-year population estimates can be downloaded from https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/lowersuperoutputareamidyearpopulationestimates. English Indices of Deprivation can be downloaded from https://www.gov.uk/government/statistics/english-indices-of-deprivation-2019. Population turnover from the Consumer Data Research Centre can be downloaded from https://data.cdrc.ac.uk/node/1655. House price estimates as used in this research will be made available online upon publication of the paper.

Declaration of interests

JP-S is vice-chair of the Royal Society for Public Health and a partner at Lane Clark & Peacock, and reports personal fees from Novo Nordisk, all outside the submitted work. YD is a member of the Advisory Council for the King's Fund. All other authors declare no competing interests.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanepe.2022.100580.

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