Effects of population density changes on the value of amenities in the United Kingdom:
Evidence from the Rail Plan for the Midlands and the north of England

Dr. Laila AitBihiOuali, Imperial College London

Table of Contents

Executive Summary

This report quantifies the impact of an increase in population density on the value of amenities in the United Kingdom in order to assess the impact potential transport infrastructure projects. Using state-of-the-art statistical models and panel data, this analysis relies on a methodology *à la* Glaeser to account for the two main influences on the value of amenities, (i) rent and (ii) wages. The dataset used to perform this empirical analysis is the United Kingdom Household Longitudinal Survey (UKHLS) dataset, which collects information for over 40,000 UK households. This allows the computation of elasticities for cities of interest in the Midlands and the North.

Each type of specification uses a different measure of density. The population density and the mean effective density are successively used as a proxy for density. Both measures yield similar results: estimates record a positive impact of an increase in density on the value of amenities for a given area. Estimates indicate that the quality of life is higher in denser areas: this implies that, overall, density is a net amenity.

Estimates indicate that the population density is positively associated with the value of amenities, which is in line with previous studies of urban amenities. This result is stable to the inclusion of socio-demographics, time and location controls. This means that amenity effects appear to not be driven by the composition of the households, nor by the location effects or the time at which respondents are interviewed. Moreover, this indicates that the negative effects of an increase in population density in the form of higher congestion, increased pollution concentration, inequality, adverse health effects and reduced well-being, are offset and over-compensated for by a series of consumption benefits. The corresponding elasticity of amenities with respect to the population density is of 0.015 on average for the full sample. Although this gives an important first set of interpretations, it is important to use a complementary measure of density that allows for inter-zonal effects. Assuming three areas A, B and C, inter-zonal effects between these areas occur as follows: the value of the amenity in zone A (both rents and wages) are a function of the density if zone A, but it is also a function of individuals' access to the density in other zones (B and C). In a second step, the mean effective density is used as a measure of density.

Overall, estimates suggest that elasticities of amenities to mean effective density range between 0.005 and 0.112, which is in line with the literature. Results indicate an elasticity of 0.109 for the full sample, an elasticity of 0.104 for Midlands and the northern England cities, and an elasticity of 0.112 for the subgroup of comparative cities. Cities in the Midlands and the North are less dense than the comparative cities, which probably explains the difference in responses: for a given increase in the mean effective density, the MED post transport infrastructure would remain smaller in the Midlands and northern England compared to the comparative cities. Although the MED increased the same way, the number of agents accessible per unit of time or per cost unit is smaller in the Midlands and the North. This in turn implies smaller incentives for the provision of consumption amenities as the accessibility of these areas remain smaller. This also has an impact on wages in that it attracts less individuals and less high-skilled individuals, which in turn decreases the likelihood of having higher paying jobs in the area.

Impedance effects are larger for northern England and Midlands' cities, which means that individual responses to a decrease in general travel costs are subject to more frictions. Estimates indicate that the impedance factor is $\alpha = 0.5$ for comparator cities and $\alpha = 1.5$ for cities in the Midlands and the North of England. Finally, results suggest that if low impedance levels are reached in the Midlands and northern England cities, then an additional increase in the mean effective density can lead to larger increases in amenities.

I. Introduction

The purpose of this project is to perform an amenity valuation analysis for the Midlands and the north of England. This project aims to contribute to the quantification of agglomeration benefits that could be generated by the implementation of new transport infrastructure (e.g., rail schemes such as those part of the integrated Rail Plan for the Midlands and the north).

Infrastructure projects of a large scale, (*e.g.*, the Rail Plan for the Midlands and the north) lead to an increase in rail capacity, which in turn can increase the effective density of cities involved in the rail projects. Two consequences arise from these projects: firstly, the productivity benefits of cities increase, and secondly, the amenity benefits (*i.e.*, quality of life benefits, such as access to leisure facilities) are expected to increase.

The amenity valuation strategy suggested for this analysis builds upon the theoretical framework presented in Glaeser, Kolko and Saiz (2001) and proposes an empirical strategy that can lead to precise amenity benefits quantifications for cities in the Midlands and the North. This empirical methodology relies on United Kingdom household panel data.

Using state-of-the-art statistical models enables the computation of the value of amenities with respect to the city density. Computing these elasticities is useful to assess whether city density is associated with an increased demand for city driven by higher valuation of city amenities. Additional simulations can be performed based on different scenarios of projected density changes as the current pandemic context could result in substantial changes in residential choices. The purpose of this project is to provide a step by step analysis that will fill an evidence gap given that the current literature is out of date and does not compute effects for the Midlands and the north of England.

This analysis relies on a methodology *à la* Glaeser which enables us to account for the two main influences on the value of amenities, that are (i) rent and (ii) wage dynamics. This analysis follows a panel fixed effects specification and builds upon an econometric framework that is widely used in the urban economics literature. The dataset used to perform this empirical analysis is the United Kingdom Household Longitudinal Survey (UKHLS) dataset, which collects information for over 40,000 UK households. The dataset records information on respondents for all regions of England, Wales and Scotland. This allows the computation of elasticities for a large number of cities in the Midlands and the north of England. The UKHLS dataset contains information on the following categories of variables, namely housing prices and characteristics, household sociodemographic characteristics, economic outcomes and location information. Information is collected both at the LSOA and MSOA levels to give an account of the responses to changes in density at a precise geographical level.

Given that the purpose of this project is to perform an amenity valuation analysis for the Midlands and the north of England, this analysis is performed over two subgroups of cities: (i) cities of interest in the Midlands and the North of England and (ii) UK comparator cities. These two groups will be helpful to understand how responses to changes in density can differ from one area to another.

Each type of specification uses a different measure of density. More precisely, the population density and the mean effective density are successively used as a proxy for density. Both measures yield significantly comparable results: estimates record a positive impact of an increase in density on the value of amenities for a given area. These results are in line with previous findings in the literature. Estimates indicate that the quality of life is higher in denser areas: this implies that, overall, density is a net amenity. Overall, estimates suggest that elasticities of amenities to density range between 0.005 and 0.112, which is in line with previous findings from the literature. Differences in the value of elasticities compared to those found in the literature can be attributed to the fact that, to the knowledge of the author at the time of the study, there was no analysis computing amenity elasticities to density using UK data. To interpret these results in more detail, the specification with the best goodness-of-fit is chosen. For this specification, we find an elasticity of 0.109 for the full sample, an elasticity of 0.104 for Midlands and the northern England cities, and an elasticity of 0.112 for the subgroup of comparative cities.

Cities in the Midlands and the North are less dense than the comparative cities, which is likely to be at the source of the difference in responses: for a similar variation of MED in both areas (e.g., 10% increase) triggered by a transport infrastructure, the new MED levels are still smaller in the Midlands and northern England compared to the comparative cities. This implies that the number of agents accessible per unit of time or per cost unit is smaller in the Midlands and the North. Therefore, there are smaller incentives for the provision of consumption amenities as the accessibility of these areas remain smaller in the Midlands and the North. This also has an impact on wages in that it attracts less individuals and less high-skilled individuals, which in turn decreases the likelihood of having higher paying jobs in the area.

Impedance effects are larger for northern England and Midlands' cities, which means that individual responses to a decrease in general travel costs are subject to more frictions. Finally, results suggest that if low impedance levels are reached in the Midlands and northern England cities, then an additional increase in the mean effective density can lead to larger increases in amenities.

II. Methodology

1. The Glaeser approach

The seminal paper by Glaeser, Kolko and Saiz (2001) presents a theoretical framework that disentangles the drivers of the demand for cities in the U.S. The underlying mechanism of the demand for cities is the following: individuals place a higher value in urban amenities because cities can offer them numerous consumption opportunities only accessible in cities (*e.g.*, opera, sports matches), increased social interactions, qualitative schools, etc. All of these contribute positively to the individuals' quality of life.

Glaeser et al. (2001) develop a theoretical framework that models individual housing location choices. Let us assume that individuals are mobile across locations. Agents can choose where they live between several cities either in rural or in urban areas. Individuals' aim is to pick the location that will maximise their welfare. Glaeser et al. (2001) uncover the determinants of the rent premium in cities compared to rural areas. The corresponding relationship is encompassed by the following relationship between housing prices, productivity and amenities:

$$UrbanAmenityPremium + UrbanProductivityPremium = UrbanRentPremium \quad (1)$$

As mentioned in Glaeser, Kolko and Saiz (2001) "the urban productivity premium can be directly measured with wages" (p.6). Thus, we can rewrite (1) as:

$$UrbanAmenityPremium + UrbanWagePremium = UrbanRentPremium \quad (2)$$

From Glaeser and Mare (2001), we know that the urban premium represents the gap between urban and non-urban prices. Therefore, we can rewrite (2) as:

$$(UrbanAmenity - RuralAmenity) + (UrbanWages - RuralWages) = (UrbanRent - RuralRent)$$

$$\Leftrightarrow (UrbanAmenity + UrbanWages) - UrbanRent = (RuralAmenity + RuralWages) - RuralRent \quad (3)$$

Equation (3) shows that, if both urban wages and urban amenities increase, urban housing prices also increase[1]. The underlying mechanism is as follows: due to the improved quality of life and higher wages, cities become more attractive (Roback, 1982).

It is important to mention that this strand of literature studies the relationship between urban and rural areas. This explains these studies often refer to *premiums* in their common terminology when mentioning costs. Premiums represent the gap in prices between rural and urban areas. However, the aim of this amenity benefit valuation project is to uncover urban development dynamics that are only encompassed by the relationship between urban variables (*cf.*, the left-hand side of equation (3)). Therefore, the methodology suggested in this present document moves away from the concept of *premiums* to provide a tailored response for the purpose of this study.

As presented in equation (3), housing prices reflect both wages and amenities associated with living in a large city. Under the standard assumptions that people are mobile and maximize their welfare, housing prices will fully offset wages and amenities at the *spatial equilibrium* (Glaeser and Gottlieb, 2009). The spatial equilibrium can be defined as the moment when all economic agents (*i.e.*, individuals in

[1] All other things being equal.

households) in the country have decided on the location where they will live and work: this implies that the supply equals the demand in all areas in respectively the labour and housing markets, as the supply and demand found an agreement on the price of housing and the price of labour (*i.e.*, wage). Following the concept of spatial equilibrium, places with low amenities and low wages should have low housing prices, and vice versa. The underlying mechanism is as follows: high amenities in an area are offset by higher prices. Black (1999) provides an example using school quality as an amenity: for a given house and setting wage levels constant, an increase in the quality of the local school results in an increase in housing prices.

Our starting premise is that all markets are cleared, and the U.K. is at a spatial equilibrium. This assumption is reasonable given that (i) individuals are mobile within the U.K., and (ii) housing prices are flexible, and (iii) we start at a point in time prior to the completion of the transport infrastructure[2]. At the spatial equilibrium, all prices are cleared and the following holds[3]:

$$E(UrbanAmenity) + E(UrbanWages) - E(UrbanRent) = 0 \tag{4}$$

Thus, we can express the level of Urban Amenity as:

$$E(UrbanAmenity) = E(UrbanRent) - E(UrbanWages) \tag{5}$$

2. Amenities and Population Density: Literature Review

An increase in population density generates individual costs in the form of higher congestion and lower average road speeds. Besides the congestion effects, the cost of density comes in the form of increased pollution concentration, inequality, adverse health effects and reduced well-being. However, these costs of density are more than compensated for through two main channels. The underlying mechanism behind

[2] Note that the presence of additional transport infrastructure might change individual location choices.
[3] The average urban amenity is set equal to the difference between average rents and average wages, which is why we use expectations in equations (4) and (5).

the positive association between amenities and population density can be divided into two channels (see Ahlfeldt and Pietrostefani, 2019 for a review).

Firstly, private costs are reduced due to shorter trips in denser areas where quick transport modes are available, essentially through public transport (buses, metros). Additional quantitatively relevant benefits arising from density also include cost savings in the provision of local public services, preserved green spaces, a larger access to a more diverse set of consumption amenities[4] and reduced energy use, which creates a sizeable social benefit in addition to the aforementioned private cost savings. Moreover, agglomeration benefits on the consumption side due to larger and more accessible consumption variety are quantitatively important and amount to more than one-third of agglomeration benefits on the production side through wages (Ahlfeldt and Pietrostefani, 2019).

However, this does not prove that density is desirable in itself: more people should want to live in amenable areas, although local housing supply restrictions may impede them. Moreover, in the long run, higher amenities are expected to be offset by higher prices. Combes, Duranton and Gobillon (2019) find that for France, a 10% larger population in a small city leads to a 0.3% increase in expenditure for its residents to remain equally well off. For a city with the same population as Paris, the same 10% increase in population implies a 0.8% increase in expenditure. These figures are 'all else constant', including the urban area of cities.

Another way to get a better understanding of the dynamics of density and amenity starts with referring to the definition of amenities. In the present analysis which relies on a methodology *à la* Glaeser, we assume perfect mobility and competition in all markets, with all benefits and costs in urban areas being compensated by wages and rents (Rosen, 1979; Roback, 1982). From this set of assumptions based on theoretical models' findings, amenities are then defined in Equation (2) as the difference between rent and wages. Therefore, it is interesting to explore the impact of density on both rents and incomes to understand further the mechanisms explaining the positive relationship between amenities and density.

In the urban economics literature, the average elasticity of rent with respect to population density is of 0.15, and the average elasticity of labour productivity with respect to density equals 0.04 (see Ahlfeldt and Pietrostefani (2019) for a review). Following the structure of amenities (rent – income) in the present

[4] Among the consumption amenities referred above are leisure activities such as parks, historic sites, museums, venues such as restaurants, stadiums (for sports and other events), etc.

analysis, this shows that it is expected to find a positive relationship between amenities and density. Collier and Venables (2018)'s further corroborate this expectation: in their study of the distribution of the urban surplus, they find that rent might capture between one- and two-thirds of total surplus, the rest accruing to individuals through wages.

To better understand the mechanics at stake, it is possible to successively look at the impact of density on (i) rent and on (ii) income levels.

A. Impact of density on rent:

Higher densities imply that it is more expensive to provide space, which in turn pushes rents up. Therefore, larger cities are theoretically expected to be denser and have higher rents, with the latter resulting from an increase in construction costs and housing provision costs.

However, if mobility is not perfect and/or there is heterogeneity in the preference for locations, rents will not only reflect demand-side conditions (here, amenities), but also supply-side conditions, because local demand is downward-sloping (Arnott and Stiglitz, 1979). Increases in density – or the policies that enforce increased density – may then also increase rents because the cost of supplying space is higher. By implication, observed rent increases do not necessarily reflect demand-driven capitalization effects exclusively, but potentially to some extent spatial differences in the slope of the supply curve (Hilber and Vermeulen, 2016; Hilber, 2017). Distinguishing these scenarios is notoriously difficult, but it is informative to compare the quality-of-life effect inferred from wages and rents to the aggregate amenity effects across categories. If the accounting was precise and complete and demand was perfectly elastic, we would expect the aggregate amenity effect to equal the quality-of life effect.

Nonetheless, it is important to also mention that neighborhood quality within metropolitan areas can vary substantially. This is likely to have less to do with natural amenities than with residents and the artificial amenities that they produce (Ahlfeldt and Pietrostefani, 2019)[5].

[5] This relies on an empirical analysis led using U.S. data.

B. Impact of density on income levels

An increase in cities' productivity creates an economic surplus in that area relative to other places, which partly explains the wage gap bias (and whether it goes upwards or downwards from one area to another)[6]. An increase in cities' productivity also endogenously generates further job opportunities which in turn makes cities even more dense. In addition, it boosts the creation of consumption amenities that increase wages as it attracts workers that are paid more.

Diamond (2016) argues that, while rising skill premiums started the process of educated workers concentrating in dense urban settings, their presence then generated additional endogenous amenities, which she argues are central to reconciling observed changes in wages, rents, and the skill composition of residents across cities in the U.S. between 1980 and 2000. In highly granular empirical work, Couture and Handbury (2019) provide direct evidence about the importance of local amenities to explain the return of young educated workers to higher density residential areas in American cities. In turn, the increased concentration of educated workers appears to foster the development of new local amenities. This recent work is in tension with more traditional estimations of the relationship between amenities and city size building on Roback (1982), which suggest only a weak relationship between city population and amenities (Albouy, 2008).

3. The concept of Effective Density

One of the main characteristics of the economic activity is that it is often concentrated spatially (Duranton and Puga, 2004). The concentration of firms is observed in most cities, albeit with a different magnitude depending on the city (Melo et al., 2009). Transport infrastructure has a significant impact on these concentration effects, since additional transport infrastructure leads to effective increases in density levels. **Effective density** can be defined as the number of agents accessible per unit of time or per cost unit (Graham and Gibbons, 2019).

[6] The wage gap bias can be defined as the difference in average wages between cities, with wages in denser cities (namely capital cities) being on average higher than wages in less dense cities.

Transport infrastructure brings about two types of benefits that come from the change in effective density levels:

(i) **Direct user benefits**: they are directly induced by a decrease in the general cost of travel. These direct user benefits are yielded by both old and new users of the transport infrastructure. Transport infrastructure decreases transport costs per mile travelled, which is likely to increase the number of individuals that can access further areas.

(ii) **Wider Economic Impacts**: new transport infrastructure leads to a closer integration of both firms and workers through economies of scale. These effects are not directly caused by time savings nor transport demand. The wider economic impacts of creating additional transport is that it increases the level of interaction in the economy: this effect is coined as the 'wider economic impacts' (Graham and Gibbons, 2019). More precisely, transport infrastructure reduces interaction costs (i) between firms, (ii) between workers, and (iii) between firms and workers. This, in turn, leads to productivity gains.

The previous section explained how transport infrastructure changes population densities, which in turn impacts the value of amenities in a given area. This section presents a strategy to account for the influence the degree of spatial interaction between two zones. The effective density (i.e., the number of agents accessible per unit of time or per cost unit) can be largely impacted by the presence of additional transport infrastructure. Wider economic benefits of agglomeration generated by new transport infrastructure increase the effective density levels, which pushes up the access to the economic mass. This, in turn, can influence the value of amenities. Therefore, it is necessary to include a measure of the effective density to complement this analysis and to account for changes in amenities induced by the agglomeration economies that are generated by new transport infrastructure.

In this study, the access to the economic mass is computed using Mean Effective Densities (MED), following the methodology suggested in Gibbons and Graham (2009).

We assume that the full area of interest (in the present study, the UK) is divided into N zones indexed by i and j, i=[1;N] and j=[1;N]. The Mean Effective Density (MED) is denoted ρ_i for zone i and can be defined as follows:

$$\rho_i = \frac{1}{n} \sum_{j=1}^{N} m_j f(d_{ij}) \qquad (1)$$

where m_j is a measure of the economic mass in zone j: in this study, we use the number of employed individuals as a measure of the economic mass. The function $f(d_{ij})$ is the impedance function: this is a decreasing function of the cost of travelling from zone i to zone j. The impedance function is a function of the distance between two zones i and j: it determines how accessible a destination is based on the distance and travel costs associated with reaching zone j from zone i.

The form of the function $f(d_{ij})$ follows Graham and Gibbons (2009), but there are several other forms to represent distance decay (Rice et al., 2006; Graham et al, 2009). This form has been chosen over all others because of its standard nature. This form is the most commonly used in practice: it has namely been recommended in the UK Cost Benefit Analyses to estimate agglomeration elasticities.

Moreover, this specific measure has been selected as it accounts for inter-zonal effects. Assuming three areas A, B and C, inter-zonal effects between these areas occur as follows: the value of the amenity in zone A (both rents and wages) are a function of the density if zone A, but it is also a function of individuals' access to the density in other zones (B and C). The form used in this analysis is presented in Equation (2) below. It follows an efficient form with only a single parameter, α. Parameter α is used as a exponent and shows the importance of proximity and the decay of agglomeration effects with an increase in distance.

$$\rho_i = \sum_{j=1}^{n} \frac{m_j}{d_{ij}^{\alpha}} \quad (2)$$

The impedance decay function in Equation (2) is composed of two variables, d_{ij}, that is the distance between zones i and j, and α, the impedance decay parameter. The impedance decay parameter determines the sensitivity of the MED to changes in impedance. The value of the parameter α is important as it determines the influence that a change in costs has on accessibility between two zones. More precisely, the smaller the value of the impedance parameter α, the higher the sensitivity of the MED to reductions in transport costs. Moreover, the exponential form of Equation (2) indicates that an impedance reduction (decrease in α) has a larger impact on the mean effective density than the pure distance effect (*i.e.*, whether two zones are closer or further from one another). In other words, a smaller impedance parameter implies that transport improvements have a larger impact on the effective density of an area, namely in substantially improving the connectivity between two areas that are more dynamic from an economic point of view and rather large.

In the model, several values of α will be tested to assess to what extent responses to changes in costs affect the magnitude of responses to transport infrastructure. The set of impedance parameters tested in this study is the following: $\alpha = \{0.5\,;\ 0.6\,;\ 0.7\,;\ 0.8\,; 0.9\,;\ 1\,; 1.1\,; 1.2\,; 1.3\,;\ 1.4\,;\ 1.5\}$. The smaller the value of α, the bigger the effect of transport infrastructure on effective density. The larger the value of α, the larger the distance decay effect.

4. Amenities and Population Density: Empirical Model

Building new infrastructures (*e.g.*, HS2 or Crossrail) improves regional attractivity through better transport and employment opportunities. As a consequence, both population density and amenities increase: therefore, population density is expected to be linked to urban amenities. Empirically, we define Urban Amenity as a function of population density and other local characteristics:

$$UrbanAmenity = f(density, X) \tag{6}$$

This relationship builds upon the framework developed in several studies (Rappaport, 2008; Albouy, 2016). Equation (6) will be estimated using a Fixed-Effects panel specification. The choice of this type of model is motivated by the necessity to account for individual household heterogeneity over time.

The fixed effects specification contains household and time fixed effects that clear out trends and heterogeneity in individual perceptions. This allows for a direct estimation of the amenity elasticity with respect to the city density. Elasticities can be computed for all areas of interest, thus leaving room for simulation for each specific city that will be targeted by the transport infrastructure project. This is a crucial element enabling the quantification of urban amenity prices based on expected changes in the density in the areas of interest. Additional simulations can be performed based on different scenarios of projected density changes as the current pandemic context could result in substantial changes in residential choices.

Two types of specifications are used in this analysis, with each specification using a given density measure: the first set of specifications use population density as a measure of density, whereas the second set of specifications use the mean effective density (MED) as a measure of density. All specifications follow the same general form. Accounting for that information and using (5) and (6), it is possible to formally write the main reduced-form econometric specification as follows:

$$UrbanRent_{i,t} - UrbanWages_{i,t} = \beta density_{i,t} + \gamma X_{i,t} + \delta_i + \eta_t + \varepsilon_{i,t} \tag{7}$$

where:

$UrbanRent_{i,t}$: rent paid by household i at year t.

$UrbanWages_{i,t}$: wage perceived by household i at year t.

$density_{i,t}$: this represents the measure of density in the area where household i lives at year t. Two measures of density are used in this report: (i) population density, and (ii) mean effective density (MED). All measures of density are in logs in order to facilitate the computation and interpretation of results as elasticities.

β: the elasticity of amenity with respect to density.

$X_{i,t}$: vector of local characteristics of household i at year t such as family composition, marital status and employment status.

γ: vector of coefficients linked to each socio-demographic variable which composes the vector $X_{i,t}$.

δ_i: household fixed effects.

η_t: year fixed effects.

$\varepsilon_{i,t}$: statistical error term for household i at year t.

This analysis follows a panel fixed effects specification. Therefore, it builds upon a framework that is widely used in the urban economics literature (Chen and Rosenthal, 2008; Boualam, 2014; Ahlfedt et Pietrostefani, 2019).

Note: It is important to note that rent prices can be affected by planning restrictions in each city. In this analysis, the author makes the assumption that planning restrictions are intrinsic to each city. Therefore, they can be considered as fixed effects. Thus, they are controlled for in the panel fixed effects specification.

Note: The most precise level of data available at the time of the study was at the LSOA level for the population density, and at the MSOA level for the mean effective density. Therefore, the regressions are led at the LSOA level for the first specification and at the MSOA level for the second set of specifications.

III. Data

1. United Kingdom Household Longitudinal Survey (UKHLS)

The dataset used to perform this empirical analysis is the United Kingdom Household Longitudinal Survey (UKHLS). This panel dataset contains information for over 40,000 households in the UK which was collected over a decade.

The dataset records information on respondents from all regions of England, Wales and Scotland, which allows the computation of elasticities for dense cities in the Midlands and the north of England. This makes the UKHLS a good fit for regional simulations of the amenity valuation and for the estimation of amenity responses to changes in density in areas of interest, such as East Midlands, West Midlands, Yorkshire and the Humber (among others).

The UKHLS has the main advantage of following respondents over time. The longitudinal nature of the data allows for panel data analysis that controls for unobserved heterogeneity.

The household level data contain information at the regional level and density information that enable us to recover where are the main cities (category 5) in a specific region.

The UKHLS dataset contains information on the following categories of variables:

- <u>Housing prices and characteristics</u>: rent value, number of bedrooms, number of rooms.
- <u>Household sociodemographic characteristics</u>: gender, family composition (*e.g.*, children), marital status, age, broadband characteristics.
- <u>Economic outcomes</u>: income levels, employment situation.
- <u>Location information</u>:
    - o Urban/rural area variable, which is useful to disentangle dynamics between rural vs. urban areas.
    - o Population density information: number of inhabitants where people live at a very local level. This helps building a measure of density as the normalized population in the area over the region.
    - o Household location: information available at the Lower Layer Super Output Area (LSOA) and Middle Layer Super Output Area (MSOA)[7].

These outcomes are available at the household level, which allows for the computation of Urban Amenities that follow the specification in equation (7) (cf. page 12).

[7] Further details on the definition of LSOA and MSOA available in section '2.Geospatial data level'.

2. Geospatial data level

A Lower Layer Super Output Area (LSOA) is a geographic area. LSOAs were created during the 2001 Census and are a geographic hierarchy designed to improve the reporting of small area statistics in England and Wales by the Office for National Statistics (ONS).

In Scotland, data zones (DZ) are the geographical areas of reference, that are considered in this analysis as the equivalent to LSOAs. The data zone geography covers the whole of Scotland and nests within local authority boundaries. Data zones are groups of Census output areas which have populations of between 500 and 1,000 household residents, and some effort has been made to respect physical boundaries. Data zones meet tight constraints on population thresholds (500 – 1000 household residents), they all nest into local authorities and are built up from 2001 Census output areas.

This combination of the LSOA level and Data Zone level data allow us to compute population densities at a very precise level. Population density is computed as follows:

$$Population\ density\ = \frac{Population\ in\ LSOA}{LSOA\ area\ in\ sq.km}$$

Note that for Scottish cities, population densities are computed using Data Zones as references instead of LSOAs. Or the sake of conciseness, equations often refer to LSOAs for the whole dataset, yet it is implied that the data used follows LSOA boundaries for England and Wales and Data Zone boundaries for Scotland.

The preparation of the final dataset required several steps of data homogeneisation and also the merger of several sets of information. All of the steps undertaken to build the final homogeneous dataset are detailed in **Appendix B**.

Due to the data availability, the level at which data was collected for the Mean Effective Density (MED) was at a slightly more aggregated level: for England and Wales, MED-related data was available at the MSOA level and at the IZ level for Scotland.

Middle Layer Super Output Areas (MSOA) are a geographic classification that was designed with the similar purpose with LSOAs to improve the reporting of statistics at a small scale in England and Wales by the ONS. MSOAs are built from groups of contiguous LSOAs. Their minimum population is 5000, while the average number of inhabitants within an MSOA is 7200. For Scotland, the other level at which statistics are collected is called Intermediate zones (IZ): they are a statistical geography created or the Scottish Neighbourhood Statistics (SNS) to collect information at a more local level. Intermediate Zones were designed to meet constraints on population thresholds (2,500 - 6,000 household residents), to nest within local authorities, and to be built up from aggregates of data zones (DZ). Following the update to intermediate zones using 2011 Census data, there are now 1,279 Intermediate Zones covering the whole of Scotland.

3. Cities of interest

Given that the purpose of this project is to perform an amenity valuation analysis for the Midlands and the north of England, the analysis focuses on cities in the Midlands and the North of England that are dense enough to experience agglomeration benefits on a large scale if they experience the implementation of new transport infrastructure. More precisely, areas are divided into two types: (i) cities of interest in the Midlands and the North of England and (ii) UK comparator cities. These two groups will be helpful to understand how responses to changes in density can differ from one area to another.

The cities of interest in the Midlands and the North are the following:

- Birmingham, Blackpool, Coventry, Kingston upon Hull, Leeds, Liverpool, Manchester, Middlesbrough, Newcastle upon Tyne, Nottingham, Sheffield, Stoke-on-Trent, and York

This dataset also includes information for individuals living in both the Greater Manchester and Greater Liverpool areas. Based on findings from the agglomeration benefits literature, the type of large-scale transport infrastructure under study here improves the connectivity between large areas, which is expected to alter economic opportunities, wages and rents both in the city centre and the agglomeration. Thus, this is in turn expected to change the value of amenities both for the city centre and the Greater areas. The areas are the following:

- Greater Manchester: Bolton, Bury, Oldham, Rochdale, Salford, Stockport, Tameside, Trafford, Wigan, and Manchester.

- Greater Liverpool: Knowsley, Liverpool, Sefton, St. Helens, and the Wirral.

Table 1 below presents the number of observations by for each city included in this analysis, both for cities of interest in the Midlands and the North (green) and comparator cities (yellow).

The distribution of interviews by LSOA and by Data Zone for each of the cities of interest (see **Figures A1 – A6** in Appendix) shows that the number of interviews is rather evenly spread across cities of interest. This further proves that the dataset is representative of the population and not skewed towards a particular city, which makes the UKHLS a good fit for this analysis.

Cities	Nb. Observations	Cities of Interest	Comparator Cities
Aberdeen	1,785		1,785
Birmingham	3,182	3,182	
Blackpool	566	566	
Bolton (GM)	*1,277*	*1,277*	
Brighton and Hove	632		632
Bristol	1,067		1,067
Bury (GM)	*550*	*550*	
Cardiff	1,684		1,684
Coventry	940	940	
Edinburgh	2,687		2,687
Glasgow	2,449		2,449
Kingston upon Hull	538	538	
Knowsley (GL)	*563*	*563*	
Leeds	2,295	2,295	
Liverpool	919	919	
Manchester	2,569	2,569	
Middlesbrough	274	274	
Newcastle upon Tyne	1,372	1,372	
Nottingham	1,564	1,564	
Oldham (GM)	*624*	*624*	
Rochdale (GM)	*574*	*574*	
Salford (GM)	*469*	*469*	
Sefton (GL)	*654*	*654*	
Sheffield	2,863	2,863	
Southampton	603		603
St. Helens (GL)	*753*	*753*	
Stockport (GM)	*852*	*852*	
Stoke-on-Trent	1,042	1,042	
Swindon	1,392		1,392
Tameside (GM)	*558*	*558*	
Trafford (GM)	*639*	*639*	
Wigan (GM)	*438*	*438*	
Wirral (GL)	*1,296*	*1,296*	
York	810	810	
Total	**40,480**	**28,181**	**12,299**

Table 1: Descriptive statistics – Number of observations by city (dataset: UKHLS)

4. Descriptive Statistics

Performing an analysis at the cross-regional level relies on the assumption that amenities, wages and rents significantly differ between UK regions and cities. Therefore, to show that the UKHLS data supports the model and the cross-regional analysis, it is necessary to do the right descriptive statistics that show significant differences in amenity levels between the cities of interest.

To do so, we perform analysis of variance (ANOVA) tests. ANOVAs test whether there are significant differences in the distribution of rents, wages and amenities between cities. The methodology used is as follows:

For each area of interest (*e.g.*, Aberdeen, Liverpool, Bristol), we perform an ANOVA which tests whether amenity levels in this area are significantly different from the levels observed in all other cities. For any given area, ANOVAs are computed against a comparison group of (i) the complete sample and (ii) the rest of the subgroup of interest (*i.e.*, reference cities if the city is Aberdeen, Brighton, ..., Swindon, or targeted cities if the city is Birmingham, Blackpool, ..., York).

Tables 2 and **3** have been included to demonstrate that the analysis should be performed at the cross-regional level.

Tables 2 and **3** present the p-values corresponding to each ANOVA test. The interpretation of the results in both tables can be done as follows:

- If p-values are comprised between 0 and 0.1, it means that differences in amenity levels are significant at the 10% level. These cases are highlighted in **Tables 2** and **3** (cells highlighted in blue).
- If the p-value $0<p<0.01$, then the difference between the two groups exists and is significant at the 1% level.
- If the p-value $0.01<p<0.05$, then the difference between the two groups exists and is significant at the 5% level.
- If the p-value $0.05<p<0.1$, then the difference between the two groups exists and is significant at the 10% level.

Table 2 and **Table 3** indicate significant differences for both rent, income and amenities between geographical regions. More precisely, **Table 2** indicates that there are significant differences between the cities that constitute the group of reference cities, and **Table 3** shows there are significant differences between cities in the group of targeted cities (Midlands and the North of England). Interestingly, there are less discrepancies in rents within the group of cities of the Midlands and the North compared to the group of reference cities. More broadly, these estimates prove the necessity to include estimations differentiated by geographical area.

	Amenities - ANOVA P-values		Rents - ANOVA P-values		Wages - ANOVA P-values	
	Full Sample	Within group of reference cities	Full Sample	Within group of reference cities	Full Sample	Within group of reference cities
All Reference Cities*	0.128	-	0	-	0.0008	-
City						
Aberdeen	0.7545	0.828	0.0299	0	0.7039	0.3782
Brighton and Hove	0.004	0.0029	0	0	0	0
Bristol	0.3258	0.4818	0	0	0.0002	0.0002
Cardiff	0.0544	0.0861	0.0013	0.0005	0.0937	0.427
Edinburgh	0.0007	0.0006	0.0004	0.0004	0.0003	0.0022
Glasgow	0	0	0	0	0	0
Southampton	0.7089	0.9177	0.0004	0	0.0454	0.0738
Swindon	0.7415	0.9016	0.5181	0.0002	0.9806	0.1991

*(compared to the group of Targeted Cities)

Table 2: ANOVA P-Values for (i) Comparative Cities in Full Sample and (ii) Cities in Subsample of Comparative Cities

	Amenities - ANOVA P-values		Rents - ANOVA P-values		Wages - ANOVA P-values	
	Full Sample	Within group of targeted cities	Full Sample	Within group of targeted cities	Full Sample	Within group of targeted cities
All Targeted Cities (Midlands and North)*	0.128	-	0	-	0.0008	-
City						
Birmingham	0.0001	0.0004	0.5981	0.7581	0.011	0.0728
Blackpool	0.2026	0.1812	0.7028	0.5172	0.3166	0.2403
Coventry	0.0243	0.0207	0.3224	0.2029	0.3625	0.243
Kingston upon Hull	0.0002	0.0004	0.0018	0.0149	0.0002	0.0009
Leeds	0.1385	0.0941	0.055	0.0189	0.0532	0.0206
Liverpool	0	0	0.0352	0.1476	0.0001	0.0008
Manchester	0.7214	0.9266	0.0111	0.1183	0.9183	0.543
Middlesbrough	0.0767	0.1062	0.2228	0.395	0.1129	0.1862
Newcastle upon Tyne	0.0212	0.0414	0.0094	0.0733	0.1209	0.2743
Nottingham	0	0	0.9585	0.6296	0	0.0003
Sheffield	0.571	0.7785	0.2531	0.779	0.0714	0.258
Stoke on Trent	0.0401	0.0692	0	0.0006	0.0101	0.0366
York	0.3699	0.3176	0.3031	0.2012	0.2625	0.4589
Greater Manchester	0.0001	0	0.3017	0.6327	0.0002	0
Greater Liverpool	0.2991	0.1757	0.2224	0.8556	0.1366	0.4825

* (compared to the group of Reference Cities)

<u>Table 3</u>: ANOVA P-Values for (i) Midlands and Northern Cities in Full Sample and (ii) Cities in Subsample of Midlands and Northern Cities

IV. Results and Discussion

The following section presents and interprets the results from the empirical models. This analysis resorts to two types of models that explore the impact of transport-induced density changes to the value of amenities. Each type of specification uses a different measure of density. More precisely, the population density and the mean effective density are successively used as a proxy for density. Both measures yield significantly comparable results: estimates record a positive impact of an increase in density on the value of amenities for a given area. These results are in line with previous findings in the literature.

1. Results using Population Density as a measure of density

Table 4 below presents estimates from the initial fixed effects model. Estimates indicate that the population density is positively associated with the value of amenities (Column (1)), which is in line with previous studies of urban amenities. Results are stable in magnitude across Columns (1)-(3), which indicates that results are stable to the inclusion of socio-demographics, time and location controls. This means that amenity effects appear to not be driven by the composition of the households, nor by the location effects or the time at which respondents are interviewed.

VARIABLES	Specification (1)	Specification (2)	Specification (3)
Log Population Density	144.9***	134.5***	127.1***
	(48.23)	(47.23)	(46.78)
Controls			
Sociodemographic Controls	Yes	Yes	Yes
Time Controls	No	Yes	Yes
Location Controls	No	No	Yes
Observations	39,854	39,854	39,854
R-squared	0.068	0.086	0.093

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Panel regression model estimates – Impact of the population density on amenities (UKHLS data, own calculations)

These estimates indicate that the quality of life is higher in denser areas, which implies that overall, density is a net amenity (Ahlfeldt and Pietrostefani, 2019). More precisely, the positive coefficients related to population density in **Table 4** indicate that the negative effects of an increase in population density in the form of higher congestion, increased pollution concentration, inequality, adverse health effects and reduced well-being, are offset and over-compensated for by a series of consumption benefits. These benefits are essentially constituted of (i) private costs savings and (ii) savings in the consumption of public services.

Firstly, additional transport infrastructures in denser areas reduce private costs through an increased access to public transport. In addition, denser areas generate cost savings in the provision of local public services (*e.g.*, green spaces), a larger set of diverse consumption amenities, reduced energy use. This, in turn, generates substantial social benefits, namely in the form of lower carbon emissions. It is important to precise that higher amenities (mainly consumption amenities) that are present in denser areas are expected to be offset by higher prices in the long run (Combes, Duranton and Gobillon, 2019).

The positive effect of density on amenities results from the combined influence of density on both rent and income levels. Firstly, an increase in density pushes rent prices up since it becomes more expensive to provide additional space. Therefore, construction and housing provision costs increase[8]. Secondly, the increase in population density is positively associated with income levels. Higher productivity levels in denser areas are at the root of cities' economic surplus. Additional transport infrastructure increases individuals' access to consumption amenities in cities. This, in turn, increases wages as it attracts workers that are paid more (Couture and Handbury, 2019). The mechanism is as follows: an increase due to larger and more accessible consumption variety are quantitatively important and amount to more than one-third of agglomeration benefits on the production side – *i.e.*, essentially observed through wages (Ahlfeldt and Pietrostefani, 2019). Rising skill premiums in denser areas not only started the process of educated workers concentrating in dense urban settings, but also generates endogenous local amenities (Diamond, 2016).

[8] The impact of density changes on rents is not only driven by the demand, but also represents changes in the slope of the supply curve (Hilber and Vermeulen, 2016; Hilber, 2017). It can reasonably be expected that the coefficient encompasses both demand and supply dynamics. For the purpose of this analysis, the interpretation will mainly focus on demand-driven dynamics.

Table 4 indicates that an increase in the population density in a given LSOA is associated with a significant increase in the value of amenities in the same area. Although this gives an important first set of interpretations, it is important to use a complementary measure of density that allows for inter-zonal effects. Assuming three areas A, B and C, inter-zonal effects between these areas occur as follows: the value of the amenity in zone A (both rents and wages) are a function of the density if zone A, but it is also a function of individuals' access to the density in other zones (B and C).

Moreover, the magnitude of responses to changes in transport infrastructure are likely to depend on the extent to which decreases in travel costs improve the level of connectivity between areas. The changes in connectivity with respect to variation in travel costs can be defined as impedance effects. Computing mean effective density accounts for impedance effects using impedance parameters (for more details, see Equation (2), p.9). Therefore, using the mean effective density as a measure of density is helpful to understand individual responses with respect to both (i) a change in density levels and (ii) a change in impedance effects, while also accounting for distance decay effects between zones.

Finally, seminal studies suggest only a weak relationship between city population and amenities (Roback, 1982; Albouy, 2008), which highlights the need for a measure of the relationship between the effective economic density and amenities. The corresponding elasticities are presented in **Table C.1** in **Appendix C**, based on the most detailed specification (Column 3, **Table 4**).

2. Results using the Mean Effective Density as a measure of density

	Outcome of interest: Amenity Value (Full Sample)										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
VARIABLES	alpha=0.5	alpha=0.6	alpha=0.7	alpha=0.8	alpha=0.9	alpha=1.0	alpha=1.1	alpha=1.2	alpha=1.3	alpha=1.4	alpha=1.5
MED	9,911***	6,731***	4,528***	3,042**	2,071**	1,453*	1,063*	815.2*	654.3**	545.9**	469.8**
	(3,039)	(2,289)	(1,747)	(1,328)	(1,001)	(751.5)	(565.6)	(430.1)	(332.6)	(262.5)	(211.8)
Change in amenity for a 10% increase in MED	944.66	641.56	431.56	289.90	197.38	138.44	101.29	77.70	62.36	52.03	44.78
Observations	40,445	40,445	40,445	40,445	40,445	40,445	40,445	40,445	40,445	40,445	40,445
R-squared	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092	0.092
AIC	671519.5	671520.2	671523.2	671527.3	671531.4	671534.3	671535.6	671535.2	671533.3	671530.2	671526.2
BIC	672036	672036.6	672039.6	672043.8	672047.8	672050.8	672052.1	672051.6	672049.7	672046.6	672042.7

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
MED: Mean Effective Density

Table 5: Amenity Value Panel regression model estimates – Impact of the mean effective density on the value of amenities (UKHLS data, own calculations)

Table 5 presents estimates obtained from the panel model whose specification is detailed in Equation (7). Results suggest that the mean effective density is positively and significantly associated with the level of amenities in a given MSOA. From the estimates in **Table 5**, we can deduct elasticities of amenities to change in the mean effective density. The coefficients linked to the MED are in logs, which allows us to compute the corresponding elasticities. using the following formula:

$$Elasticity \ = \beta_{logMED} \ * \ ln(1.1)$$

Elasticities are computed as the change in amenity levels for a 10% increase in MED. Elasticities vary quite substantially depending on the level of the impedance parameter.

The impedance function is a function of the distance between two zones i and j: it determines the accessibility of a destination based on the distance and travel costs associated with reaching zone j from zone i. The higher the impedance coefficient, the smaller the sensitivity of the mean effective density to reductions in transport costs. **Table 5** and **Table 6** present results from a set of specifications computed for a series of impedance coefficients α, which produces a large set of coefficients.

Using goodness-of-fit methods is useful to disentangle these coefficients and determine which specification fits best the data and should be interpreted in priority. The Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) are the two measures that help us in the selection of the model that fits best the data. The model which best explains the data is the one with the lowest AIC and BIC values.

Based on **Table 5**, the best fitting model that is be interpreted in more detail is the specification with the impedance parameter $\alpha = 0.5$. Results suggest that for a change in the mean effective density of 10%, amenities increase by almost £950 on average in the full sample including all the UK cities. **Table 6** presents estimates of the regressions led over the subsample of cities from the Midlands and the North.

	Outcome of interest: Amenity Value - Targeted Cities (Midlands and North)										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
VARIABLES	alpha=0.5	alpha=0.6	alpha=0.7	alpha=0.8	alpha=0.9	alpha=1.0	alpha=1.1	alpha=1.2	alpha=1.3	alpha=1.4	alpha=1.5
MED	11,860***	8,707***	6,402***	4,717***	3,494***	2,615***	1,986***	1,537***	1,216***	984.2***	815.9***
	(3,076)	(2,157)	(1,554)	(1,143)	(855.2)	(650.4)	(503.0)	(396.1)	(317.7)	(259.6)	(216.0)
Change in amenity for a 10% increase in MED	1130.37	829.83	610.20	449.56	333.02	249.20	189.26	146.48	115.86	93.80	77.76
Observations	28,153	28,153	28,153	28,153	28,153	28,153	28,153	28,153	28,153	28,153	28,153
R-squared	0.146	0.146	0.146	0.147	0.147	0.147	0.147	0.147	0.147	0.147	0.147
AIC	454112.9	454100.4	454090.6	454083.5	454078.9	454076.1	454074.6	454073.6	454072.8	454071.8	454070.2
BIC	454508.7	454496.2	454486.3	454479.3	454474.7	454471.9	454470.4	454469.4	454468.6	454467.5	454466

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
MED: Mean Effective Density

Table 6: Amenity Value Panel Regression Estimates – Impact of the mean effective density on the value of amenities, Midlands and the North (UKHLS data, own calculations)

To interpret the results found in **Table 6**, we select the model with the impedance parameter that best fits the data. The lowest values of the AIC and BIC are found for $\alpha = 1.5$. The fact that the impedance parameter is higher for the subsample of the Midlands and northern cities implies that a change in travel costs has a smaller impact on the density, which in turn implies a smaller increase in amenities.

According to the results in **Table 6**, with an impedance parameter of $\alpha = 1.5$, a 10% change increase in MED implies a change in amenity of almost £80. This result is about 10 times smaller than the one found for the full sample.

3. Heterogeneity of responses by geographical area

Evidence has been brought that within cities and metropolitan areas, the neighborhood quality is subject to substantial variation. This is less likely to be caused by natural amenities and more likely to be due to artificial and consumption amenities (Ahlfeldt and Pietrostefani, 2019). This motivates the computation of additional estimated that test for the presence of heterogeneous responses by city.

Table 7 shows elasticities of the amenity by geographical area of interest. Detailed estimates for each city and for each impedance parameter are presented in **Table C.2** in **Appendix C**. Overall, results in **Table 7** suggest that elasticities of the mean effective density by geographical area ranges between 0.005 and 0.112, which is in line with previous findings from the literature.

To interpret these results in more detail, the specification with the highest goodness-of-fit is chosen: based on the estimates in **Table 5**, the specification with $\alpha = 0.5$ stands out as the one that fits best data. For this specification, we find an elasticity of 0.109 for the full sample, an elasticity of 0.104 for Midlands and the northern England cities, and an elasticity of 0.112 for the subgroup of comparative cities.

The results are in line with estimates found in previous studies, which find respectively an average elasticity of rent with respect to population density of 0.15, and an average elasticity of labour productivity with respect to density of 0.04 (Ahlfeldt and Pietrostefani, 2019). Following the structure of amenities (rent – income) in the present analysis, this shows that it is expected to find a positive relationship between amenities and density of around 0.1. Collier and Venables's work (2018) further corroborate this expectation: in their study of the distribution of the urban surplus, they find that rent might capture between one- and two-thirds of total surplus, the rest accruing to individuals through wages.

To a certain extent, the concept of 'quality of life' could be assimilated to that of amenities. Interestingly, Ahlfeldt and Pietrostefani (2019) find that an average of 0.04 for the quality-of-life elasticity to density. This is in line with the measure used: in this paper, density is often measured as population density, which yields smaller effects than those obtained for the mean effective density. This difference in results is attributable to the fact that a 10% increase in population density is more likely to induce smaller responses in terms of rent and wages compared to a change in mean effective density. Moreover, previous studies that are part of the academic literature, there is also some variation in the collected quality-of-life elasticity estimates including both negative (Chauvin et al., 2016) and positive effects (Albouy and Lue, 2015). Differences in the value of elasticities compared to those found in the literature can be attributed to the fact that, to the knowledge of the author at the time of the study, there was no analysis computing amenity elasticities to density using UK data.

		Elasticities by Geographical Area				
		Full sample	Greater Manchester	Greater Liverpool	Cities of interest (Midlands and North)	Comparative cities
Alpha	0.5	0.109	0.103	0.107	0.104	0.112
	0.6	0.074	0.070	0.072	0.070	0.076
	0.7	0.050	0.047	0.049	0.047	0.051
	0.8	0.034	0.032	0.033	0.032	0.034
	0.9	0.023	0.022	0.022	0.022	0.023
	1	0.016	0.015	0.016	0.015	0.016
	1.1	0.012	0.011	0.011	0.011	0.012
	1.2	0.009	0.008	0.009	0.009	0.009
	1.3	0.007	0.007	0.007	0.007	0.007
	1.4	0.006	0.006	0.006	0.006	0.006
	1.5	0.005	0.005	0.005	0.005	0.005

Table 7: Amenity Value Panel Regression Estimates – Impact of the mean effective density on the value of amenities, Midlands and the North (UKHLS data, own calculations)

Table 7 indicates that for $\alpha = 0.5$, responses to a change in density are smaller for cities in the Midlands and the North. Cities in the Midlands and the North are less dense than the comparative cities, which probably explains the difference in responses. Suppose we select two cities: an average city from the group of comparative cities (city 1), and an average city from the Midlands and the north of England (city 2). Based on the descriptive statistics, the mean effective density is smaller in the Midlands and the north compared to the comparative cities. We assume that MED_1 and MED_2 the mean effective densities in city 1 and city 2 respectively, implying that:

$$MED_1 < MED_2$$

The elasticity of amenities assesses the impact of an increase in the mean effective density. Assuming a 10% increase in mean effective density, we would then get the following:

$$\Leftrightarrow\ MED_1 + 10\%\, MED_1 \ <\ MED_2 + 10\%\, MED_2$$

This implies that for a same intensity and increase in the mean effective density, the MED post transport infrastructure is still smaller in city 1 compared to city 2. This implies that although the MED increased the same way, the number of agents accessible per unit of time or per cost unit is smaller in city 1 compared to city 2. Moreover, the smaller increase in MED in Midlands and northern cities implies that a generally lower increase in accessibility, which in turn implies smaller incentives for the provision of consumption amenities. This smaller increase in mobility and accessibility across areas also implies smaller cost savings in terms of transport costs. This also has an impact on wages in that it attracts less individuals and less high-skilled individuals, which in turn decreases the likelihood of having higher paying jobs in the area.

Moreover, it is important to recall that **Table 6** suggested that the impedance effects are larger for northern England and Midlands' cities, which means that individual responses to a decrease in general travel costs are subject to more frictions.

Finally, it is important to assess the heterogeneity of responses to changes in density at the city level. **Table C.2** in **Appendix C** presents elasticities of amenities to the mean effective density by city. These elasticities range between 0.005 and 0.112, an interval of a slightly larger range than the one observed for regions. This makes sense since the previous estimates (**Table 7**) are averaged over larger areas. **Table C.2** in **Appendix C** presents a large number of estimates. Therefore, for the sake of interpretability, we focus on estimates obtained for the impedance parameter $\alpha = 0.5$, that is the one with the highest goodness-of-fit for the dataset used.

Note that the elasticities computed for the population density (**Table C.1**) are of a smaller range than those computed for the MED (**Table 8**): amenity responses to a 10% increase in population density are likely to be smaller than amenity increases caused by a 10% increase in MED. An increase in the MED represents a change in the economic mass of an area, which constitutes a larger boost in consumption amenities than a simple increase in population density.

Estimates in **Table 8** indicate a rather important level of heterogeneity between cities within each group. All estimates in **Table 6** are computed using $\alpha = 0.5$, which means that the impedance effects are rather low. These results convey the important message that if low impedance levels are reached in the Midlands and northern England cities, then an additional increase in the mean effective density can lead to larger increases in amenities. In other words, returns to investments are expected to increase with further investments in the Midlands and the North.

One last important conclusion brought about by all estimates is that the impedance factor that should be taken into account is $\alpha = 0.5$ for comparator cities and $\alpha = 1.5$ for cities in the Midlands and the North of England.

		Elasticities by Geographical Area
	Alpha	0.5
Targeted Cities	Birmingham	0.139
	Blackpool	0.080
	Coventry	0.094
	Greater Liverpool	0.107
	Greater	0.103
	Kingston upon Hull	0.243
	Liverpool	0.787
	Leeds	0.094
	Manchester	0.143
	Middlesbrough	0.135
	Newcastle upon	0.142
	Sheffield	0.105
	Stoke-on-Trent	0.128
	York	0.098
Comparative Cities	Aberdeen	0.097
	Brighton	0.093
	Bristol	0.097
	Cardiff	0.087
	Edinburgh	0.094
	Glasgow	0.229
	Southampton	0.105
	Swindon	0.095

Table 8: Amenity Value Panel Regression Estimates – City effects (UKHLS data, own calculations)

V. Conclusion

This report provides a quantification of the impact of population density changes on the value of amenities in the United Kingdom. Infrastructure projects (such as the Rail Plan for the Midlands and the north) essentially lead to an increase in rail capacity, which in turn can increase the effective density of cities involved in the rail projects. Two consequences arise from these projects: firstly, the productivity benefits of cities increase, and secondly, the amenity benefits (*i.e.*, quality of life benefits, such as access to leisure facilities) are expected to increase.

Using state-of-the-art statistical models and panel data, this report computes the variation in the value of amenities with respect to the city density. The purpose of this project is to provide a step by step analysis that will fill an evidence gap given that the current literature is out of date and does not compute effects for the Midlands and the north of England.

This analysis relies on a methodology *à la* Glaeser which enables us to account for the two main influences on the value of amenities, that are (i) rent and (ii) wage dynamics. This analysis follows a panel fixed effects specification and builds upon an econometric framework that is widely used in the urban economics literature. The dataset used to perform this empirical analysis is the United Kingdom Household Longitudinal Survey (UKHLS) dataset, which collects information for over 40,000 UK households. The dataset records information on respondents for all regions of England, Wales and Scotland. This allows the computation of elasticities for cities of interest in the Midlands and the North, which have been selected because their density is high enough to allow for agglomeration effects after the implementation of new transport infrastructure. The UKHLS dataset contains information on the following categories of variables, namely housing prices and characteristics, household sociodemographic characteristics, economic outcomes and location information. Information is collected both at the LSOA and MSOA levels to give an account of the responses to changes in density at a precise geographical level.

This characteristic makes the UKHLS a good fit for regional simulations of the amenity valuation, because the estimation of amenities based on expected changes in density in areas of interest, such as East Midlands, West Midlands, Yorkshire and the Humber (among others). The UKHLS has the main advantage of following respondents over time. The longitudinal nature of the data allows for panel data analysis that controls for unobserved heterogeneity. Also, the household level data contain information at the regional level and density information that enable us to recover where are the main cities in a specific region.

Given that the purpose of this project is to perform an amenity valuation analysis for the Midlands and the north of England, areas are divided into two types: (i) dense cities in the area of interest (Midlands and North of England) (ii) UK comparator cities. These two groups will be helpful to understand how responses to changes in density can differ from one area to another.

Each type of specification uses a different measure of density. More precisely, the population density and the mean effective density are successively used as a proxy for density. Both measures yield significantly comparable results: estimates record a positive impact of an increase in density on the value of amenities for a given area. These results are in line with previous findings in the literature. Estimates indicate that the quality of life is higher in denser areas: this implies that, overall, density is a net amenity. More precisely, the positive coefficients related to population density suggest that the negative effects of an increase in population density in the form of higher congestion, increased pollution concentration, inequality, adverse health effects and reduced well-being, are offset and over-compensated for by a series of consumption benefits. These benefits are essentially constituted of (i) private costs savings and (ii) savings in the consumption of public services.

Firstly, additional transport infrastructures in denser areas reduce private costs through an increased access to public transport. In addition, denser areas generate cost savings in the provision of local public services, more consumption amenities and reduced energy use. This, in turn, generates substantial social benefits, namely in the form of lower carbon emissions. The positive effect of density on amenities also results from the combined influence of density on both rent and income levels.

An increase in density pushes rent prices up since it becomes more expensive to provide additional space. Therefore, construction and housing provision costs increase. Secondly, the increase in population density is positively associated with income levels. An increased accessibility to cities increases wages as it attracts workers that are paid more. Rising skill premiums in denser areas not only started the process of educated workers concentrating in dense urban settings, but also generates endogenous local amenities.

Estimates indicate that the population density is positively associated with the value of amenities, which is in line with previous studies of urban amenities. This result is stable to the inclusion of socio-demographics, time and location controls. This means that amenity effects appear to not be driven by the composition of the households, nor by the location effects or the time at which respondents are interviewed. Moreover, this indicates that the negative effects of an increase in population density in the form of higher congestion, increased pollution concentration, inequality, adverse health effects and reduced well-being, are offset and over-compensated for by a series of consumption benefits. The corresponding elasticity of amenities with respect to the population density is of 0.015 on average for the full sample. Although this gives an important first set of interpretations, it is important to use a complementary measure of density that allows for inter-zonal effects. Assuming three areas A, B and C, inter-zonal effects between these areas occur as follows: the value of the amenity in zone A (both rents and wages) are a function of the density if zone A, but it is also a function of individuals' access to the density in other zones (B and C).

Overall, estimates suggest that elasticities of amenities to density range between 0.005 and 0.112, which is in line with previous findings from the literature. Differences in the value of elasticities compared to those found in the literature can be attributed to the fact that, to the knowledge of the author at the time of the study, there was no analysis computing amenity elasticities to density using UK data. To interpret these results in more detail, the specification with the best goodness-of-fit is chosen. For this specification, we find an elasticity of 0.109 for the full sample, an elasticity of 0.104 for Midlands and the northern England cities, and an elasticity of 0.112 for the subgroup of comparative cities.

Cities in the Midlands and the North are less dense than the comparative cities, which probably explains the difference in responses. This implies that for a same increase in the mean effective density, the MED post transport infrastructure is still smaller in the Midlands and northern England compared to the comparative cities. This implies that although the MED increased the same way, the number of agents accessible per unit of time or per cost unit is smaller in the Midlands and the North. This in turn implies smaller incentives for the provision of consumption amenities as the accessibility of these areas remain smaller. This also has an impact on wages in that it attracts less individuals and less high-skilled individuals, which in turn decreases the likelihood of having higher paying jobs in the area.

Moreover, impedance effects are larger for northern England and Midlands' cities, which means that individual responses to a decrease in general travel costs are subject to more frictions. Finally, results suggest that if low impedance levels are reached in the Midlands and northern England cities, then an additional increase in the mean effective density can lead to larger increases in amenities. In other words, returns to investments are expected to increase with further investments in the Midlands and the North.

References

Ahlfeldt, G.M. and Pietrostefani, E., 2019. The economic effects of density: A synthesis. *Journal of Urban Economics*, *111*, pp.93-107.

Albouy, D., 2008. *Are big cities bad places to live? Estimating quality of life across metropolitan areas* (No. w14472). National Bureau of Economic Research.

Albouy, D. and Lue, B., 2015. Driving to opportunity: Local rents, wages, commuting, and sub-metropolitan quality of life. *Journal of Urban Economics*, *89*, pp.74-92.

Albouy, D., 2016. What are cities worth? Land rents, local productivity, and the total value of amenities. *Review of Economics and Statistics*, *98*(3), pp.477-487.

Arnott, R.J. and Stiglitz, J.E., 1979. Aggregate land rents, expenditure on public goods, and optimal city size. *The Quarterly Journal of Economics*, *93*(4), pp.471-500.

Black, S.E., 1999. Do better schools matter? Parental valuation of elementary education. *The quarterly journal of economics*, *114*(2), pp.577-599.

Boualam, B., 2014. Does culture affect local productivity and urban amenities?. *Regional Science and Urban Economics*, *46*, pp.12-17.

Chauvin, J.P., Glaeser, E., Ma, Y. and Tobio, K., 2017. What is different about urbanization in rich and poor countries? Cities in Brazil, China, India and the United States. *Journal of Urban Economics*, *98*, pp.17-49.

Chen, Y. and Rosenthal, S.S., 2008. Local amenities and life-cycle migration: Do people move for jobs or fun?. *Journal of Urban Economics*, *64*(3), pp.519-537.

Collier, P. and Venables, A.J., 2018. Who gets the urban surplus?. *Journal of Economic Geography*, *18*(3), pp.523-538.

Combes, P.P., Duranton, G. and Gobillon, L., 2019. The costs of agglomeration: House and land prices in French cities. *The Review of Economic Studies*, *86*(4), pp.1556-1589.

Couture, V., Gaubert, C., Handbury, J. and Hurst, E., 2019. *Income growth and the distributional effects of urban spatial sorting* (No. w26142). National Bureau of Economic Research.

Diamond, R., 2016. The determinants and welfare implications of US workers' diverging location choices by skill: 1980-2000. *American Economic Review*, *106*(3), pp.479-524.

Glaeser, E.L., Kolko, J. and Saiz, A., 2001. Consumer city. *Journal of economic geography*, *1*(1), pp.27-50.

Glaeser, E.L. and Mare, D.C., 2001. Cities and skills. *Journal of labor economics*, *19*(2), pp.316-342.

Glaeser, E.L. and Gottlieb, J.D., 2009. The wealth of cities: Agglomeration economies and spatial equilibrium in the United States. *Journal of economic literature*, *47*(4), pp.983-1028.

Graham, D.J., 2007. Agglomeration, productivity and transport investment. *Journal of transport economics and policy (JTEP)*, 41(3), pp.317-343.

Graham, D.J., 2009. Identifying urbanisation and localisation externalities in manufacturing and service industries. Pap. Reg. Sci. 88 (1), 63–84.

Hilber, C.A. and Vermeulen, W., 2016. The impact of supply constraints on house prices in England. *The Economic Journal*, *126*(591), pp.358-405.

Hilber, C.A., 2017. The economic implications of house price capitalization: a synthesis. *Real Estate Economics*, *45*(2), pp.301-339.

Maré, D.C. and Graham, D.J., 2009. Agglomeration elasticities in New Zealand, *Motu Working Paper*, No. 09-06.

Rappaport, J., 2008. Consumption amenities and city population density. *Regional Science and Urban Economics*, *38*(6), pp.533-552.

Rice, P., Venables, A.J., Patacchini, E., 2006. Spatial determinants of productivity: analysis for the regions of Great Britain. Reg. Sci. Urban Econ. 36, 727–752.

Roback, J., 1982. Wages, rents, and the quality of life. *Journal of political Economy*, *90*(6), pp.1257-1278.

Rosen, S., 1979. Wages-based Indexes of Urban Quality of Life. In: *Mieszkowski, P., Straszheim, M. (Eds.), Current Issues in Urban Economics*. John Hopkins Univ. Press, Baltimore.

Appendix

Appendix A: Distribution of interviews in areas of interest – Maps

Note: Data Zones are the Scottish equivalent of LSOAs (that are defined for England and Wales). For the sake of conciseness, the word LSOA is used for Data Zones when referring to the whole sample.

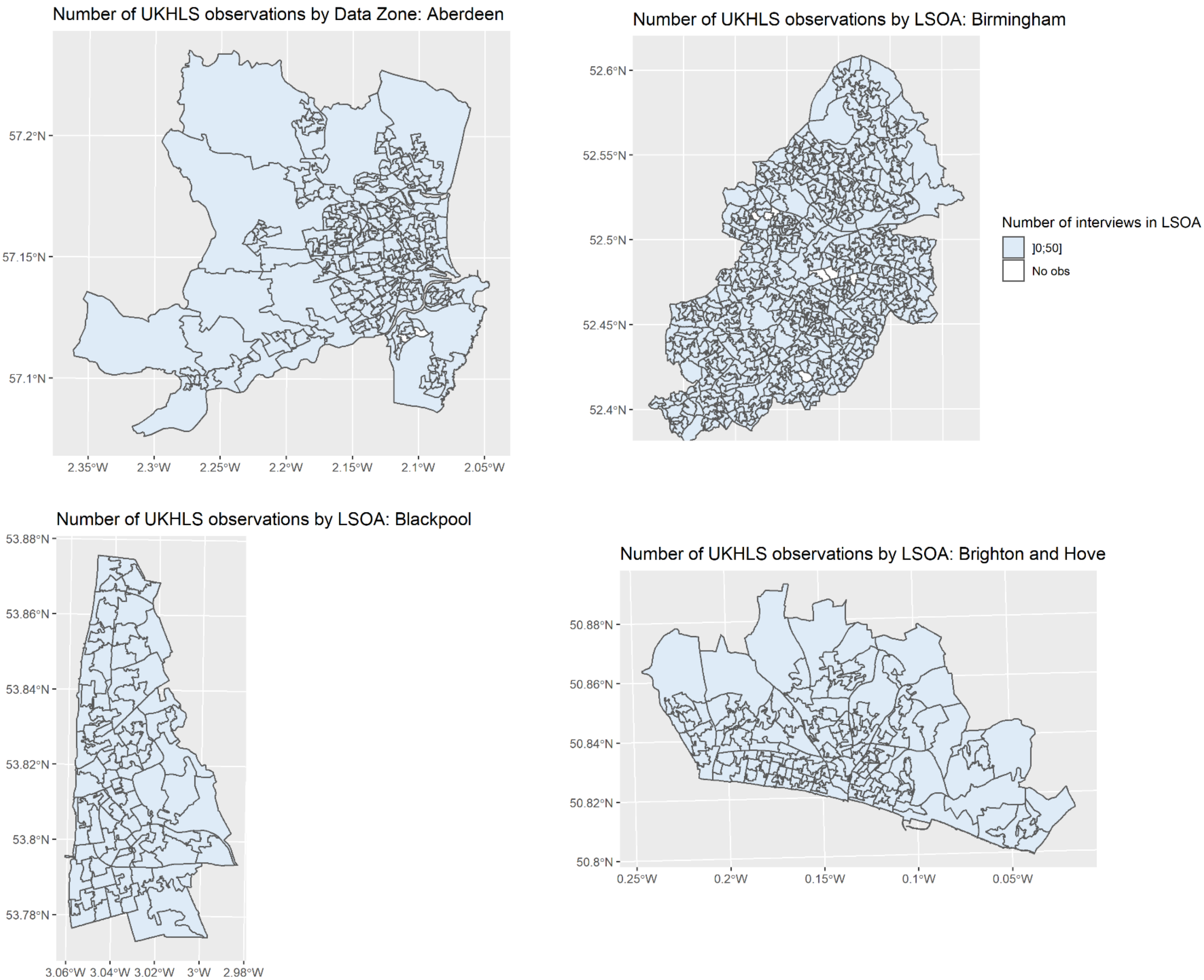


Figure A.1: Distribution of observations by LSOA – Aberdeen, Birmingham, Blackpool, Brighton and Hove

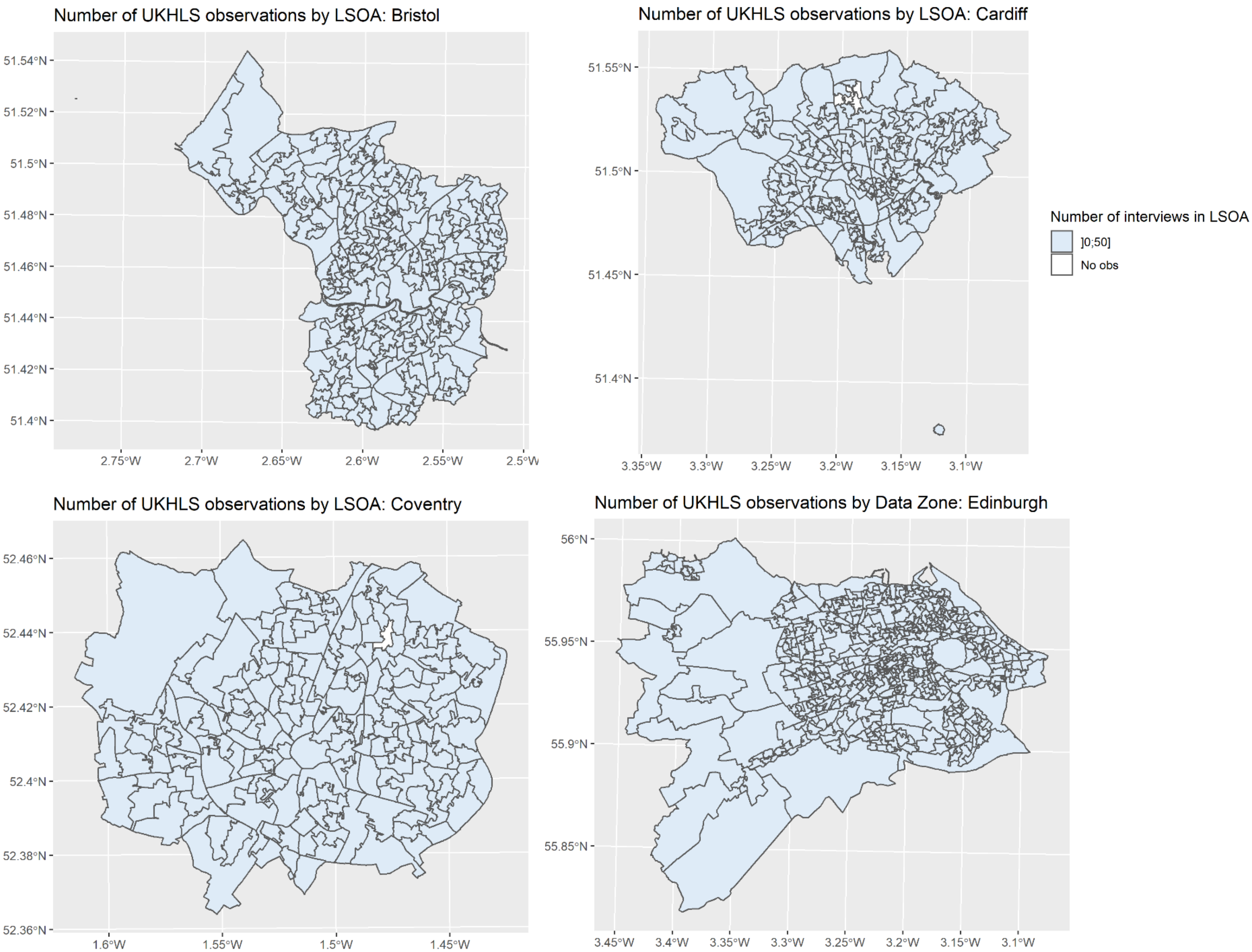
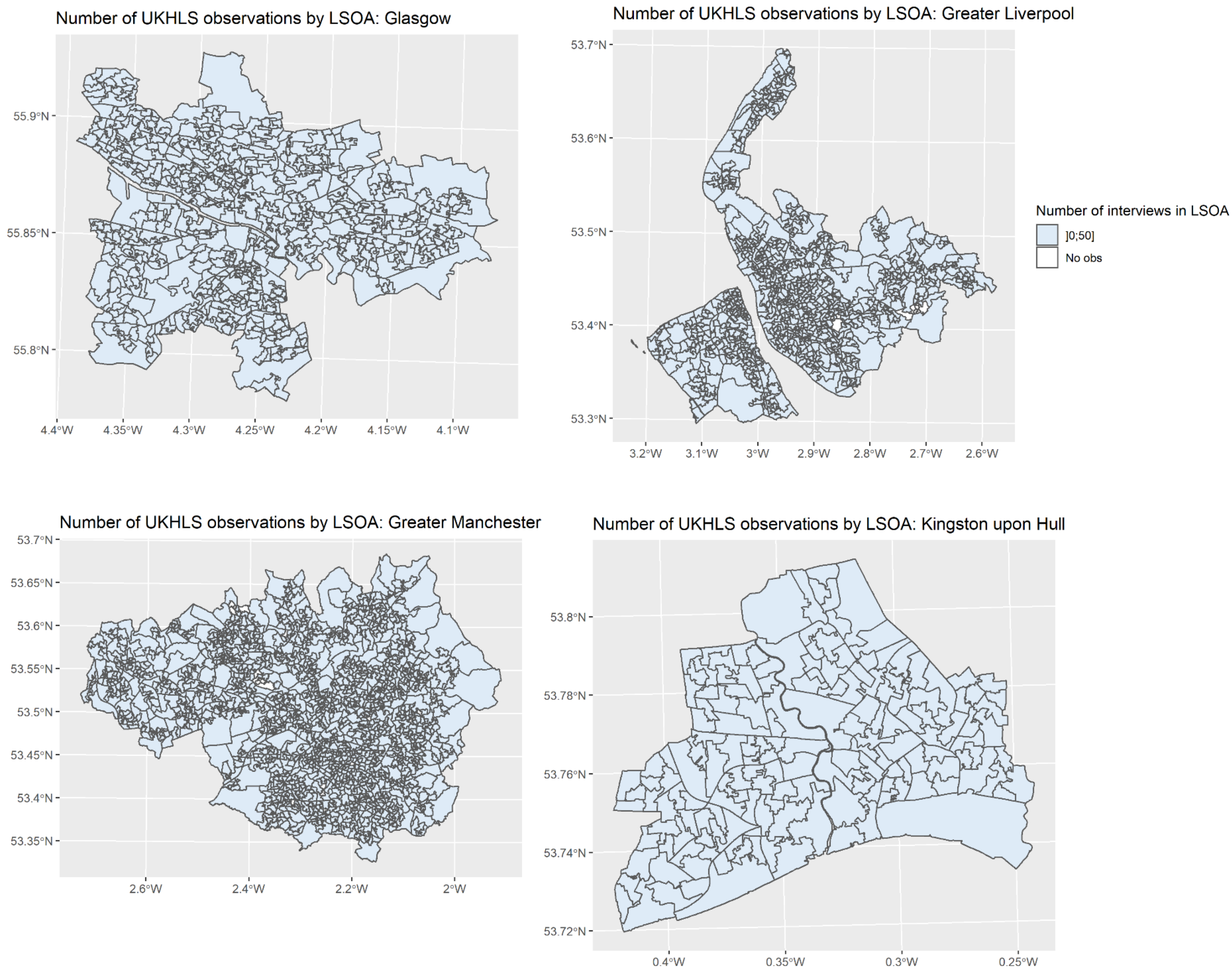


Figure A.2: Distribution of observations by LSOA – Bristol, Cardiff, Coventry, Edinburgh



925

Figure A.3: Distribution of observations by LSOA – Glasgow, Greater Liverpool, Greater Manchester, Kingston upon Hull

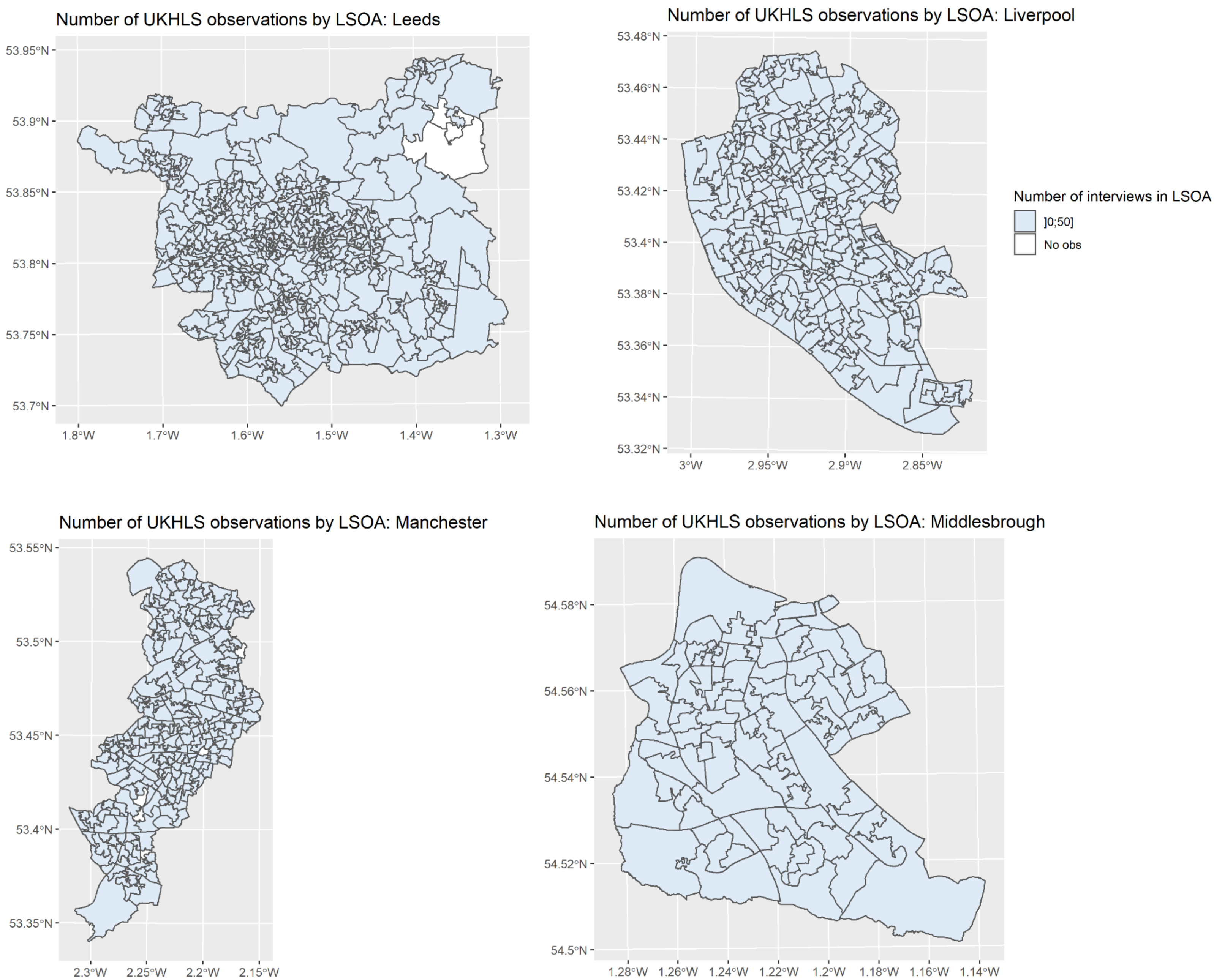
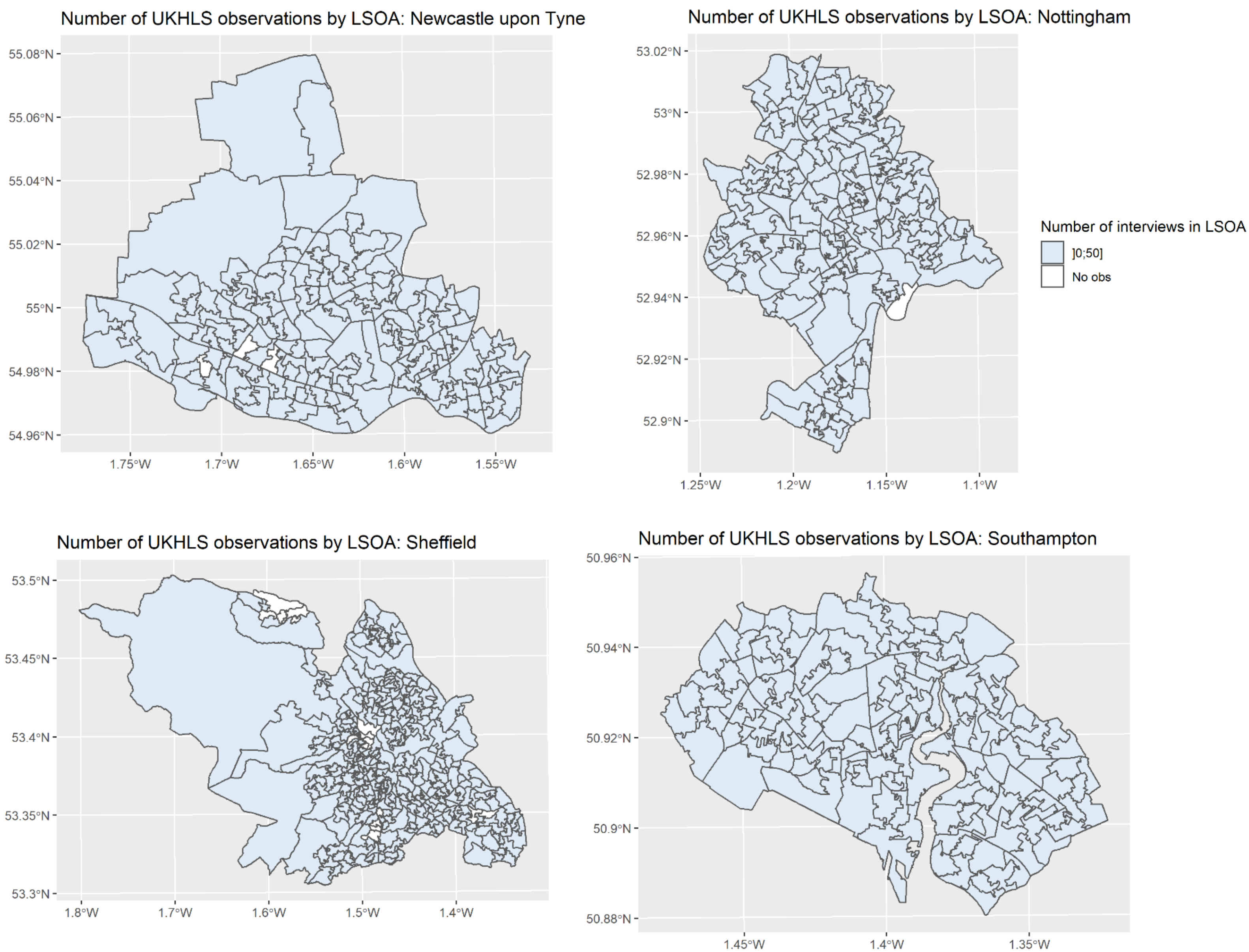


Figure A4: Distribution of observations by LSOA – Leeds, Liverpool, Manchester, Middlesbrough



<u>Figure A5</u>: Distribution of observations by LSOA – Newcastle upon Tyne, Nottingham, Sheffield, Southampton

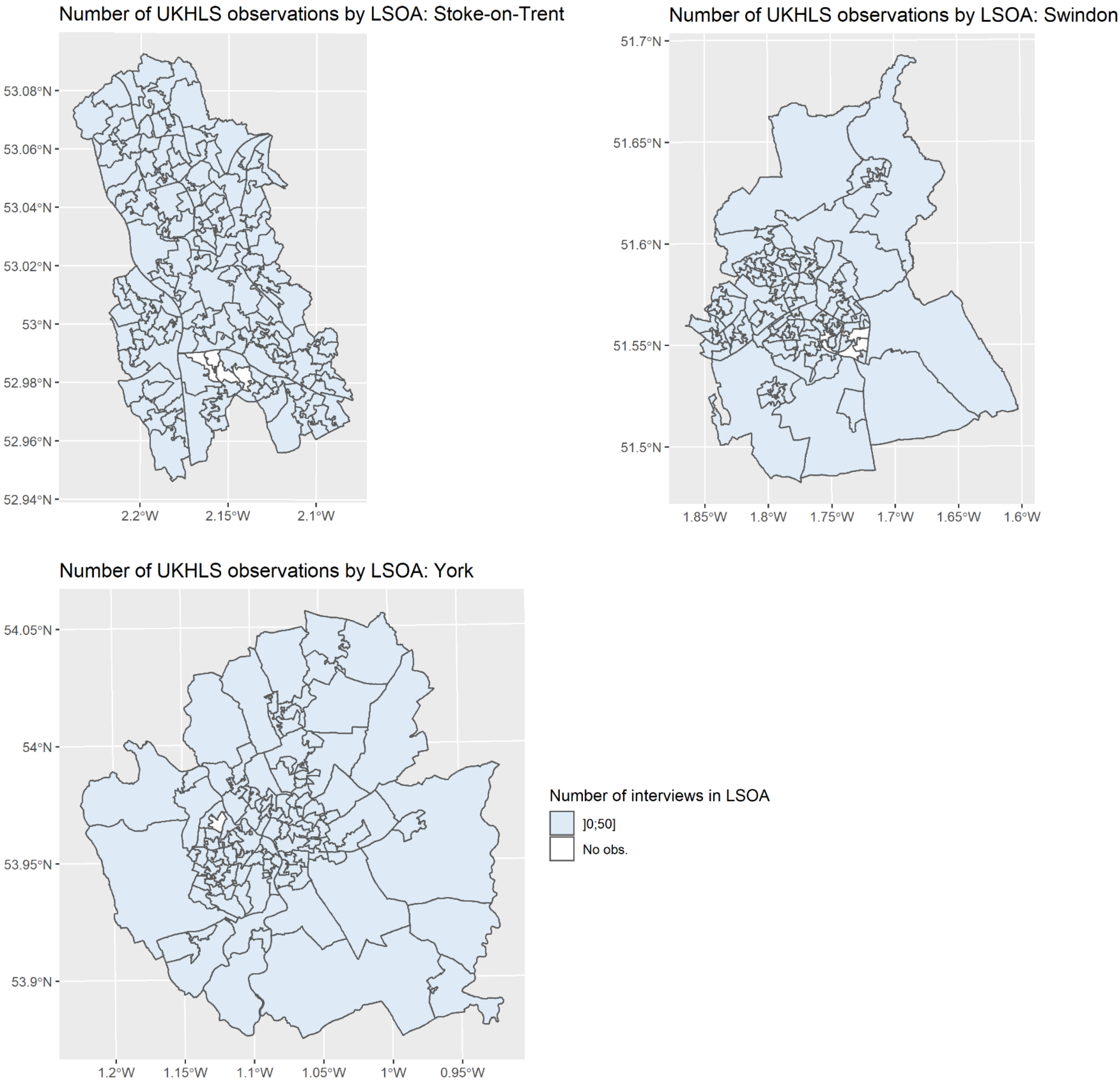
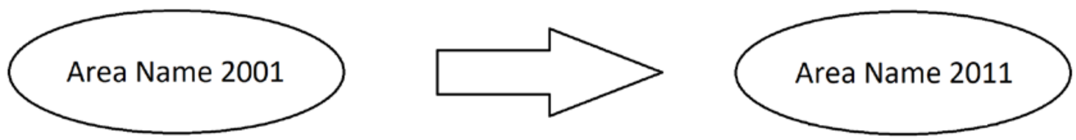


Figure A6: Distribution of observations by LSOA – Stoke-on-Trent, Swindon, York

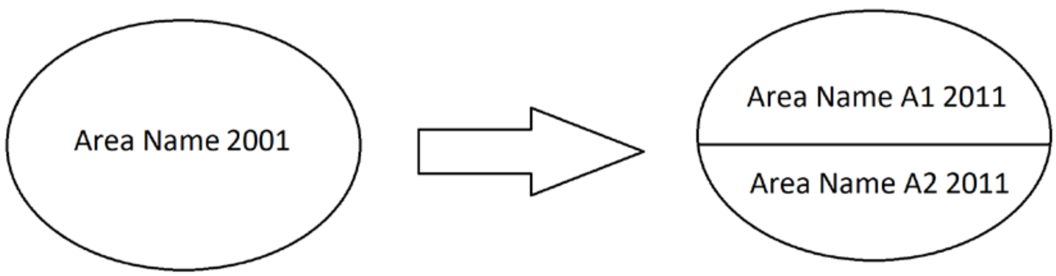
Appendix B: Data preparation – Population Density

CASE 1 : no change in the zone (or only change in name)



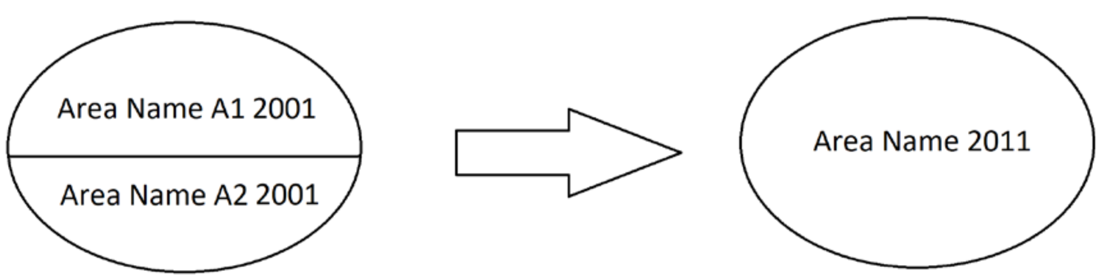
Answer:
The old name (Area Name 2001) is directly matched to the new area name (Area Name 2011), and population levels are matched accordingly.

CASE 2 : The areas have been split between 2001 and 2011



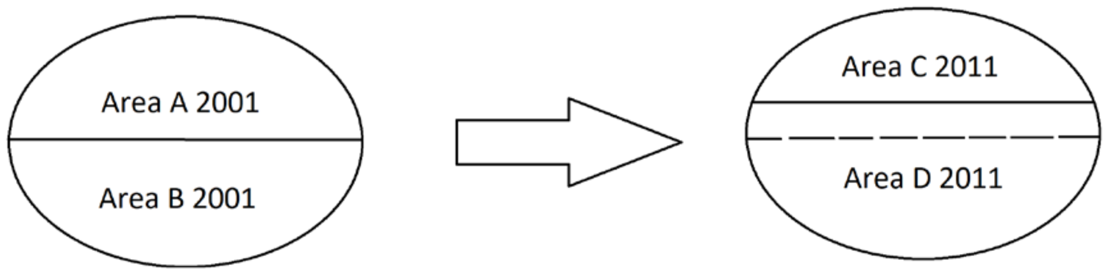
Answer:
The new name (Area Name 2001) is given the population levels of both of 2011 areas (Area Name A1 2011 + Area Name A2 2011).

CASE 3 : The areas have been merged between 2001 and 2011



Answer:
For these cases, we replace the population levels for each 2001 area by the population for the 2011 area divided by the total number of 2001 areas that compose the 2011 area.

CASE 4: Combination of splitting an area between 2001 and 2011 and merging two 2001 areas



Note : This situation was essentially observed for Scottish data zones.

Answer:

Pop Area A 2001 is defined as (Pop Area C 2001 + 1/2 (Pop Area D 2001), and Area B 2001 is defined as 1/2 (Pop Area D 2001).

Note that dividing areas by the number of areas that have been merged together is a good approximation since LSOAs have been built in a way that makes them all of a comparable size.

Appendix C: Elasticities of amenity to (i) population density and (ii) mean effective density by Geographical Area

		Elasticities by Geographical Area
	Full Sample	0.015
Targeted Cities	Birmingham	0.019
	Blackpool	0.011
	Coventry	0.013
	Greater Liverpool	0.014
	Greater Manchester	0.014
	Kingston upon Hull	0.033
	Liverpool	0.106
	Leeds	0.013
	Manchester	0.019
	Middlesbrough	0.018
	Newcastle upon Tyne	0.019
	Sheffield	0.014
	Stoke-on-Trent	0.017
	York	0.013
Comparative Cities	Aberdeen	0.013
	Brighton	0.013
	Bristol	0.013
	Cardiff	0.012
	Edinburgh	0.013
	Glasgow	0.031
	Southampton	0.014
	Swindon	0.013

Table C.1: Elasticities of amenities to changes in population density by Geographical Area – Population Density Specification

		Elasticities by Geographical Area										
	Alpha (Impedance Parameter)	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
Targeted Cities	Birmingham	0.139	0.094	0.063	0.043	0.029	0.020	0.015	0.011	0.009	0.008	0.007
	Blackpool	0.080	0.054	0.036	0.024	0.017	0.012	0.009	0.007	0.005	0.004	0.004
	Coventry	0.094	0.064	0.043	0.029	0.020	0.014	0.010	0.008	0.006	0.005	0.004
	Greater Liverpool	0.107	0.072	0.049	0.033	0.022	0.016	0.011	0.009	0.007	0.006	0.005
	Greater Manchester	0.103	0.070	0.047	0.032	0.022	0.015	0.011	0.008	0.007	0.006	0.005
	Kingston upon Hull	0.243	0.165	0.111	0.075	0.051	0.036	0.026	0.020	0.016	0.013	0.012
	Liverpool	0.787	0.535	0.360	0.242	0.164	0.115	0.084	0.065	0.052	0.043	0.037
	Leeds	0.094	0.064	0.043	0.029	0.020	0.014	0.010	0.008	0.006	0.005	0.004
	Manchester	0.143	0.097	0.065	0.044	0.030	0.021	0.015	0.012	0.009	0.008	0.007
	Middlesbrough	0.135	0.092	0.062	0.042	0.028	0.020	0.015	0.011	0.009	0.007	0.006
	Newcastle upon Tyne	0.142	0.096	0.065	0.044	0.030	0.021	0.015	0.012	0.009	0.008	0.007
	Sheffield	0.105	0.071	0.048	0.032	0.022	0.015	0.011	0.009	0.007	0.006	0.005
	Stoke-on-Trent	0.128	0.087	0.059	0.039	0.027	0.019	0.014	0.011	0.008	0.007	0.006
	York	0.098	0.067	0.045	0.030	0.021	0.014	0.011	0.008	0.006	0.005	0.005
Comparative Cities	Aberdeen	0.097	0.066	0.044	0.030	0.020	0.014	0.010	0.008	0.006	0.005	0.005
	Brighton	0.093	0.063	0.043	0.029	0.019	0.014	0.010	0.008	0.006	0.005	0.004
	Bristol	0.097	0.066	0.044	0.030	0.020	0.014	0.010	0.008	0.006	0.005	0.005
	Cardiff	0.087	0.059	0.040	0.027	0.018	0.013	0.009	0.007	0.006	0.005	0.004
	Edinburgh	0.094	0.064	0.043	0.029	0.020	0.014	0.010	0.008	0.006	0.005	0.004
	Glasgow	0.229	0.156	0.105	0.070	0.048	0.034	0.025	0.019	0.015	0.013	0.011
	Southampton	0.105	0.072	0.048	0.032	0.022	0.015	0.011	0.009	0.007	0.006	0.005
	Swindon	0.095	0.064	0.043	0.029	0.020	0.014	0.010	0.008	0.006	0.005	0.004

Table C.2: Elasticities of amenity to changes in mean effective density by Geographical Area and by Impedance Parameter – MED specification