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Household location and income: a spatial analysis for British cities[1]

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Abstract

Using information on the exact location of urban households in Britain for the period 2009-2013 we explore the validity of standard urban land use models by estimating the extent to which distance of residence from the city centre is a function of income. This is the first study of its kind for British cities. After controlling for household characteristics and access to transport, as well as city and time effects, and taking account of both spatial and serial correlation, we find a strong positive association between household's income and distance from the city centre. We also estimate the income elasticity of demand for land and find that this is not large enough to support the view that richer households locate further from the city centre mainly because they prefer larger dwellings. Finally, we find that while poorer households live closer to the city centre, they have experienced increasing real incomes over the period relative to those who live further away. This supports the view that cities in Britain attract poor people rather than generate poverty.

JEL classification: I32, R23

Keywords: urban poverty; cities; segregation by income

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1. Introduction

The majority of the poor in Great Britain currently live in urban areas. Within cities there are distinct spatial patterns to deprivation; for example our data reveals that, in the period 2009-2013, the average monthly real income of households living within 0 to 5 percentile distance of the city's Central Business District (CBD) was £1,399, significantly lower than for our sample of all urban households (£1,557)[2].

Why do poor households tend to live in the inner cities? Is household location in cities determined mostly by income? Is it the case that British cities tend to make households poorer? Or is it rather the case that cities are good locations for the poor because, for example, they have better access to public services?

In this paper we use data from the UK Household Longitudinal study ("Understanding Society") to study the relationship between household income and location of residence in the nine largest British metropolitan areas (excluding London) over the period 2009 to 2013[3]. The analyzed cities are Birmingham, Bristol, Glasgow, Manchester, Leeds, Liverpool, Newcastle, Nottingham, and Sheffield. We deliberately exclude London from the study because both its size and structure are very different from the rest of British cities.[4] Within these cities we locate the exact position of households via their grid reference, and then calculate their distance from the CBD. To estimate our models we use the spatial panel estimator of Hsiang (2010), which is based on the generalised method of moments (GMM) estimator for spatial data proposed by Conley (1999), and extends this to account for serial correlation in longitudinal data.

To our knowledge this is the first study that explores the relationship between household location and income in Britain using an economic framework. In fact, it is one of the very few papers that analyses this question in any other country except the US. Further, our study is one of the few that employ individual level analysis, and this is enabled by use of

[2] Average income figures quoted throughout this paper are mean monthly equivalised real net household income in 2012/2013 prices.

[3] We refer to metropolitan areas and cities interchangeably in the paper.

[4] With a population of over 8 million in 2011, London is by far the largest UK city; the total population for the nine cities in our sample is just over 4 million. With such a large share of the urban population, including London would likely drive the main results of the paper. Excluding London from cross-city urban comparisons in the UK has been often done in the literature; see, for example, Rae (2013).

secure data on exact household location, which is rarely used in economic analyses. As well as the theoretical importance of this topic for urban economics, our findings also inform the policy debate on urban poverty in Britain.

The paper is structured as follows. In Section 2 we provide a brief review of the literature that has studied the relationship between income and household location in cities, most of them in the US. In Section 3 we sketch the theoretical model advanced in Glaeser et al (2008) to explore different explanations of household location within a city. The data are described in Section 4. The econometric method, main empirical results and robustness checks are discussed in Section 5. Finally, Section 6 concludes the paper.

2. Literature Review

Glaeser et al. (2008) study the location of the urban poor in US cities. Their first main result is that there is a disproportionately larger incidence of poverty near a city's CBD than farther away from it. One possible explanation for this pattern is provided by standard urban land use models (Alonso, 1964; Mills, 1967; Muth, 1969). In these models, rich households wish to consume higher amounts of land, i.e. they would like to locate in larger houses than poorer ones and therefore choose to live where land is cheaper, i.e. further away from the CBD. However, introducing time costs associated with commuting in the model leads to an ambiguous effect of income on location choices, as shown in Beckman (1974), Hochman and Ofek (1977), Henderson (1977) and Fujita (1989). This is the result of the fact that rich households have to choose between the utility they obtain from living in a large dwelling far away from the CBD and the income loss associated with the long commute to their home. Becker (1965) shows that the prediction that rich households locate further away from the CBD than poor ones holds only if the income elasticity of demand for land is greater than one.

In their analysis, Glaeser et al (2008) estimate income elasticities of demand for land in US cities between 0.1 and 0.5, and thus they conclude that the standard monocentric city model cannot explain the pattern of urban poverty observed in U.S cities. An alternative argument, based on the model by LeRoy and Sonstelie (1983), is that the poor choose to live in the CBD because they have access to better public transportation than in the suburbs. Glaeser et al's (2008) calibrated version of this model provides strong evidence in favour of this hypothesis. However, a recent paper by Gutierrez-i-Puigarnau et al (2014) provides results that contradict much of the previous (largely US based) literature; they show that for Denmark, conditional on the workplace location, the income elasticity of commuting distance is negative and in the order of -0.18. This result could be due to the demand for amenities, which in European cities tend to be clustered in city centres (Brueckner et al 1999). However it could also be specific to Denmark and the result of the highly regulated rental housing market there.

One important difference between our work and this previous literature on commuting is that we study distance to the CBD, not to the workplace. While this may be seen as restrictive, households that locate close to the CBD may do so for many reasons other than being close to their workplace (for example the availability of public transportation and better amenities). More importantly, in our sample 32% of the heads of household do not work, and this mean figure ranges from 26% to 41% across our cities. Focussing on both employed and not-employed households is an important distinction between our paper and the previous literature on commuting, where, by definition, only working households are considered.

A further explanation for the spatial distribution of incomes is put forward by Brueckner and Rosenthal (2009) who argue that the rich may decide to live in or near the CBD because they value new construction more than the poor, and this construction often takes place in the CBD. [5] Ng (2008) builds a model in which heterogeneity in household's valuation of amenities determines their location. Persky (1990) tests how well three different urban models explain the pattern of income inequality in Chicago' suburbs and finds that the model that emphasizes local status (Frank, 1985) is the one that fits the data the best.

[5] See also McKinnish, Walsh, and White (2010) on gentrification using US micro data.

In the UK, the relevant literature has largely focused on the spatial concentration of poverty and deprivation without testing any specific theoretical model (Rae, 2009; Galster, 2005). As in the US, this has also been a major policy concern and focus of the urban planning debate in the UK (DETR, 2000), among other reasons because concentrations of deprivation have negative externalities due to the existence of 'neighbourhood' effects (Galster et al., 2007). As mentioned above, it is well documented that UK deprivation is overly concentrated in cities (Rae, 2012). This remains true even after the recent gentrification of city centres (Rosenthal and Ross, 2015) facilitated both by the construction boom in high-quality apartments that has characterised cities like Bristol and Manchester, and to a lesser extent the rest of the cities we study here, and the enormous growth in student numbers in cities resulting from the expansion of higher education (Tallon and Bromley, 2004). However, a recent report from the Smith Institute argues that the wealth gap between the inner and outer parts of cities is narrowing, as poverty is growing fastest in the suburbs (Hunter, 2014). In order to shed light on this topic we do what no work has done to date, and explore the relationship between household income and urban location[6], in order to test whether the theoretical models of urban economics outlined in the next section are useful in a British context.

3. Theoretical Framework

In this section we present a simplified version of the models first developed by Alonso (1964), Mills (1967), and Muth (1969).[7] Consider a city where all the jobs and amenities are located in the CBD. Households commute to the CBD to either work, consume goods and/or services or enjoy amenities. For simplicity, let us assume the CBD is collapsed to a single point at the city centre, and that the city has a dense network of radial roads. The city contains two different types of households: the rich, with income y_R and the poor, with income y_P, where $y_R > y_P$. The two household types have the same preferences over the two consumption goods, which are housing (q) and a composite good (c), with the latter

[6] Rae (2012) studies the location of deprivation disaggregated by 'travel-to-work-area' in London, Birmingham, Liverpool and Manchester but no theoretical models are tested and the focus is on deprivation rather than income per se.

[7] We follow the exposition of these models provided in Brueckner (2011).

representing any consumption good other than housing. The cost of commuting to work at the CBD is increasing in the distance x from the CBD and it has two components: a monetary cost t, which increases linearly with distance and is assumed to be the same for the two groups, and a cost related to the opportunity cost of time. Assuming that an extra mile of commuting distance reduces available work time by a fraction δ and that the rich have higher wages than the poor $(w_R > w_P)$ then the foregone income is larger for richer households.[8] The household budget constraint for the rich is then given by $c_R + pq_R = y_R - x(t + \delta w_R)$ and for the poor is given by $c_P + pq_P = y_P - x(t + \delta w_P)$. On a (q, p) diagram then the slope of the two price schedules are $-\frac{t+\delta\omega_R}{q_R}$ and $-\frac{t+\delta\omega_P}{q_P}$, respectively. At the same housing price p, the higher income of the rich implies that they consume more housing $(q_R > q_P)$, making the slope of the price schedule flatter for the rich group at that point. However, since wages are also higher for the rich, it is unclear which of the two slopes is larger. Essentially, the rich group faces the following trade-off: on the one hand, they wish to enjoy a large dwelling and so they benefit from living far from the CBD, where housing costs are lower. On the other hand, commuting is more expensive for them than for the low-income group, because their opportunity cost of time is higher. Therefore, the location of rich and poor households in the equilibrium of the model can be characterized by two different patterns, depicted in Figure 1. In the plot on the left, the rich outbid the poor in the suburbs and therefore they end up living further away from the CBD. The opposite happens in the plot on the right. As stated above, Becker (1965) shows that the first scenario holds if and only if the income elasticity of demand for land is greater than one. Ultimately, this is an empirical question that we analyze in Section 5.

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[8] This model implicitly assumes that the utility obtained from leisure is the same for both groups. Adding leisure to the standard monocentric model would allow us to distinguish between the utility obtained from leisure by rich and poor households. However, to our knowledge, the only attempt to do so is a recent paper by Rappaport (2014). His model however does not provide closed form solutions and considers only one income group. For these reasons, we leave the incorporation of leisure in our analysis as a promising avenue for future research.

4. Data and descriptive statistics

We use data from the first four waves of Understanding Society (University of Essex, 2015). Understanding Society is a longitudinal survey of around 40,000 households in the UK. Interviews for the first wave took place in 2009/10, with subsequent waves in 2010/11, 2011/12 and 2012/13. The sample of households was designed to be representative of the UK population in 2008. All adults in each household are interviewed (as well as children aged 11 to 15) and the data contain rich information on the social and economic circumstances of households. As well as basic geographic information, such as which Government Office Region a household is located in and whether the area is classified as urban and rural[9], the Secure Data Service (SDS)[10] also provide access to detailed geographical location for each household via grid reference.[11] The Easting and Northing pair of coordinates that make up a grid reference provide the exact location for each household to a 1 metre resolution.

Our analysis covers the nine largest British metropolitan areas (Birmingham, Bristol, Glasgow, Manchester, Leeds, Liverpool, Newcastle, Nottingham, and Sheffield), excluding London. Households in these metropolitan areas were selected by matching their grid reference to the postcode area code[12] via the National Statistics Postcode Directories, and then selecting only those households that were classified to be in an urban area; thus for example those households in, say, the Sheffield (S) postcode area that are deemed to be rural are excluded from our sample[13].

The Understanding Society data is constructed at the individual level; with all individuals in each household being interviewed. We construct a panel dataset at the household level by

[9] Urban and rural classifications are given by the National Statistics Rural and Urban Classification of Output Areas at www.ons.gov.uk/ons/guide-method/geography/products/area-classifications/index.html

[10] Details on the Secure Data Service can be found at ukdataservice.ac.uk/use-data/secure-lab

[11] The British National Grid is the common referencing format for all geographic data in Great Britain. A location is described using two coordinates (Easting, Northing) which give its distance East and North of the origin, a fixed point to the west of the Scilly Isles.

[12] The UK uses a system of alphanumeric postcodes to identify postal delivery areas. A postcode is made up of four components (area, district, sector and unit). The area code is the letter prefix that denotes city, for example B for Birmingham and LS for Leeds; there are 124 postcode areas in the UK, one for each city.

[13] The district part of the postcode immediately follows the area code, and these are numbered consecutively, largely in a concentric pattern from district 1 (the city centre); thus for example S1 is the city centre of Sheffield and this is surrounded by S2-S5, outside this S6 to S13, and so on, so that postcode districts such as S32 and S33 are rural areas distant from the city centre.

using both household level variables, such as household income and housing tenure, and individual level variables for the 'head of household' (HoH), such as age, education, health and labour market status. We define a unique HoH for each household using the methodology outlined by the Institute for Social and Economic Research (Taylor, 2010: App 2-3).[14] Since the main goal of the paper is to analyze the link between household income and location, and one of the main determinants of income will be employment status, we use only those households where the HoH is of standard working age i.e. between 18 and 65 years-old.

Our two key variables of interest are household income and distance from the CBD. Income is measured as the household's real equivalised net income in the month preceding the interview, with all figures adjusted to 2012/13 prices[15]. This variable is constructed from a set of questions, asked to all adults in the household, which cover information on all income sources. Figure 2 shows the distribution of income for our data, which clearly displays the skewness in this distribution with a mean of £1557 and a median of £1366.[16] Table 1 shows the number of households and mean income by city and wave; the first column shows the population of each city according to the 2011 census. The total number of households in our sample decreases from 3451 in wave 1 to 2628 in wave 4 due to sample attrition[17]. Mean monthly income rises steadily from £1522 to £1576 over the same period. The Gini coefficients for income inequality are similar in all of our cities, ranging from 0.28 in Liverpool and Newcastle to 0.32 in Manchester. They all show a slightly lower level of inequality than the figure for the whole of the UK, which was 34% in 2012 (Cribb et al, 2013).

[14] The HoH is the individual who claims primary responsibility for household costs. Where this is shared by two or more people of different sexes, the oldest man is defined as the HoH. If all individuals claiming this responsibility are of the same sex, the HoH is the oldest person. If two same-sex individuals of the same age claim responsibility, we randomly assign one of them to be HoH.

[15] Equivalence weights are from the modified OECD equivalence scale where the first adult in the household receives a weight of 1, all other adults receive a weight of 0.5, and all children a weight of 0.3. Net income data is net of direct taxes and national insurance contributions, and inclusive of state benefits and tax credits. All income figures are adjusted to 2012/2013 prices using the Retail Price Index available at www.ons.gov.uk

[16] We omit clear outliers (10 observations with monthly net equivalised incomes greater than £14,000), and 81 observations with income less than or equal to zero.

[17] The survey is also 'topped up' in wave 2 by the reintroduction of the British Household Panel Survey (BHPS) sample of households. The BHPS was the predecessor survey that Understanding Society builds on.

To calculate distance from the CBD, we first locate this area in each of our cities. Bowden (1971, p.121) describes attempts to define the CBD as a 'perplexing task', and no consensus exists on how this should be done. Brown (1987) argues that the CBD is often defined subjectively to include the principal shopping streets, and many studies seem to rely on planners' local knowledge to draw a boundary around the CBD[18]. We have chosen two alternative definitions of the CBD that are consistent with previous urban economics applications. Firstly, we define a city's CBD as the location of its main railway station. Nathan et al (2005) use a similar definition in their study of city centre living.[19] Secondly, as an alternative we use the location of the main Marks & Spencer (M&S) retail establishment in the city. This definition is in line with real estate valuation approaches which view M&S as a key retail location which increases footfall to adjacent stores (see Schiller, 2001). While our measures of the CBD are arguably rough, they are in line with the previous literature and the available data do not allow us to provide more rigorous measures of the city centre.[20]

We transform the Easting, Northing grid reference coordinates for each household, and the postcode for each main railway station and main M&S store, into latitude and longitude[21] and then use the Stata routine *geodist* to calculate the Euclidean distance (in km) between each household and the corresponding CBD. The correlation between household distances from the station and main M&S store is very high ($r = 0.997$, $p<0.001$), so in what follows we focus on the results produced using only the main railway station; and the results for M&S are discussed in our robustness section (5.3). From Figure 3, which shows the histogram of distances (in km) between each household and the corresponding CBD[22], it is apparent that most of the mass of the distribution is at short distances from the city centre.

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[18] In a recent paper Kantor et al. (2014) quite arbitrarily choose the city centre of New York to be Times Square and that of Los Angeles to be Pershing Square.

[19] Also, as recently stated in The Economist, *"Cities now measure their appeal by their stations. Businesses cluster around them: at King's Cross, a once-grimy part of north London, a postcode has been created for all the new buildings around the station, which was redeveloped in 2013. John Lewis, an upmarket department store, will open in the mall above New Street (which is indeed called "Grand Central") along with 60 other shops."* www.economist.com/node/21597904

[20] Some other papers have used alternative definitions of a city's centre based on its market potential or travel-to-work areas (see, for instance, Ahlfeldt et al., 2014) or consider the possibility of cities with multiple CBDs (Giuliano and Small, 1991; Ahlfeldt and Wendlend, 2014).

[21] Conversion between different geographical identifiers is carried out via gridreferencefinder.com/batchConvert/batchConvert.php.

[22] We exclude from our analysis 40 households who were clear outliers in that their distance from the CBD was more than 40km. These were all located in and around Sleaford in Lincolnshire; these households have

In the analysis that follows we also consider a number of other variables which are described here. As well as income we also consider whether each household is in poverty. The Child Poverty Act 2010 establishes that a household in the UK lives in poverty if its income is below 60 percent of the national median equivalised net income (Townsend and Kennedy, 2004). We use estimates of national median incomes from the Institute for Fiscal Studies[23]. These figures suggest median monthly net incomes (in 2012/13 prices) of £2021 for wave 1 of our data, £1964 for wave 2, £1908 for wave 3 and £1905 for wave 4. This suggests a poverty incidence of 43% in wave 1, 38% in wave 2, 34% in wave 3 and 37% in wave 4, and 38% overall. These figures are high compared to national estimates, which are usually around 20-25% (see for example Carr et al, 2014), but our sample is very different to the population as whole. Firstly we focus on large cities, and this is where social housing tends be concentrated; those in social housing are twice as likely to be in poverty as individuals who own their own home (Carr et al, 2014). Secondly, regionally the South East has the lowest percentage of individuals living in poverty, but London is excluded from our analysis and none of our other large cities are located in the South East. In the robustness section we also consider some alternative definitions of poverty.

Another relevant variable in our analysis is the labour market status of the head of household.[24] An important difference between the UK and the US (where most of the evidence on cities and poverty has emerged from) is that in the UK unemployment (and other welfare) benefits are more generous and therefore it is plausible that a significant fraction of poor households may choose to live far from the CBD even if they do not work.[25] To account for this we create a dummy variable "not-employed" that takes a value of zero if the head of the household is either employed or self-employed, and one otherwise (this includes: unemployed; retired; long-term sick & disabled; looking after family or home; in full-time education; on a government training scheme; or unknown). According to this

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Nottingham postcodes but are not generally viewed as part of the urban area of Nottingham because they are closer to the smaller city of Lincoln (both Sleaford and Lincoln are in the county of Lincolnshire, whereas Nottingham is in Nottinghamshire).

[23] The Institute for Fiscal Studies use data from the Family Resources Survey to produce estimates of weekly median equivalised net income in 2012/13 prices (www.ifs.org.uk/tools_and_resources_/income_in_uk).

[24] Using data for English regions, Patacchini and Zenou (2006) find empirical evidence suggesting that both the local cost of living and local labour market tightness have a positive and significant effect on jobless average search intensity.

[25] In the U.S, due to the low benefits, the poor have a strong incentive to live near the CBD to try to find a job, among other reasons.

classification, our sample has 32% of urban households where the head is “not-employed”. In our robustness section we compare results for the full sample, with those where the head of household is in employment.

Table 2 presents descriptive statistics for all our relevant variables at different distances from the CBD. Apart from the variables introduced above, income, poverty and the percentage of households where the head of household is not employed, we provide information on the following: percentage of heads of households with at least higher education; percentage of households with children aged below 16*;* age and sex of the household head; health status of the household head, measured as the proportion who are in poor health[26]; number of rooms in the house; percentage of owner occupiers (defined as owning the house outright or with a mortgage); percentage of households who own a car.

Household income tends to rise as distance from the CBD increases. The table also reveals that heads of households closer to the city centre are more likely to be not employed, are younger, are less likely to have children aged under 16, are less likely to own their accommodation, are more likely not to own a car and their accommodation has fewer rooms. The proportion of household heads in poor health tends to decrease with distance from the CBD, apart from in those households closest to the CBD. The percentage of households with at least higher education seems to decrease as distance from the CBD increases.

Figures 4a to 4i show maps for each of our nine cities. We use information on a household's distance to the CBD as well as its income. In order to preserve anonymity, we proceed by calculating the median income of households living at different percentile distances from the CBD and assign this income to each household living at this distance[27]. Some interesting patterns emerge reflecting the heterogeneity of British cities. In Birmingham, Leeds and Nottingham there is a clear monocentric pattern, where the poorest households live close to the CBD with wealthier households located further away; this is also true for Liverpool, with the caveat that the city is bordered on the west by the River Mersey. In Glasgow this

[26] Health status is a five point self-reported scale; we define poor health here as those heads who report being in 'poor' or 'fair' health, as opposed to good, very good or excellent.
[27] Specifically in these maps each point represents a household, but the marker represents the median income of the 20 nearest households.

pattern is almost reversed with an inverse relationship between income and distance from the CBD. Bristol and Manchester show clear signs of the gentrification of city centres possibly due to new apartment developments. Here we see largely a positive relationship between income and distance but with the exception of clusters of high income households near the city centre. Newcastle and Sheffield show more complex patterns which emerge from both geography and the economic development of these cities. In Newcastle the poorest households are in the city centre but these are immediately surrounded by the richest households, with other low to medium income households further out. Newcastle is unique in the UK as the site of the first (and arguably only) large-scale example of planning policies in the late twentieth century with the explicit aim of 'rebalancing' the population of disadvantaged neighbourhoods through 'positive gentrification' (Cameron, 2003). Sheffield has a monocentric pattern, but some of the poorest households are also located in the outlying ex-mining towns which surround the city.

5. Analysis and results

5.1. Household income and distance from CBD

To analyze the relationship between household income and distance from the CBD we estimate the following model:

$$logD_{it} = \alpha + \beta logY_{it} + \gamma' X_{it} + \varepsilon_{it} \qquad (1)$$

where *i* is household, *t* is wave, *D* is distance (km) from the CBD, *Y* is the household's real equivalised net income and *X* is a set of control variables that are described below. Our focus is the sign of β, where a positive value indicates that distance from the CBD increases with income. This model is estimated using the Stata panel estimator *OLS-spatial-HAC* (Hsiang, 2010), which uses the GMM approach outlined by Conley (1999) to take account of spatial correlation in the error term (ε) for all observations *i* within a given period. This estimator also allows for autocorrelation for a given household over time (*t*), since our data contain the same households for up to four waves[28]. A uniform kernel is used to weight spatial correlations, which falls from 1 to 0 at a cut-off of 50km[29].

These results are reported in Table 3 where the main finding is that a household's income is positively correlated with distance from the CBD. The associated coefficient is always significant at conventional levels of significance, regardless of which control variables are included. Without controlling for any other variable (column 1), the coefficient on log income is 0.259, suggesting that a 10% increase in income results in a household being located on average 2.6% further from the city centre. The second column includes city and wave dummies which make little difference to the coefficient on income. In column (3) we introduce a set of basic control variables for the age (and age squared), sex, education, employment and health status of the head of household, as well as whether the household has children. There is non-linear relationship between age and distance; older people live further from the CBD, but the rate of increase in distance decreases with age. Households with children and those with poor health live further from the CBD. There is no significant relationship between distance from the CBD and the sex of the head of household. The negative effect of higher education may seem counterintuitive but this may reflect the fact that household's income and education are highly correlated ($r=0.25$, $p <0.001$). Also it could be a result of preference for city centre amenities among the highly educated[30]. Those households where the head is not employed live closer to the CBD. One explanation, predicted by job search models (van Ommeren et al, 1999), is that jobs are more readily found close to the city centre. However, an alternative is that, regardless of job search, amenities used by those who are not working are more accessible in the city centre. In column (4) we introduce two additional controls; home ownership and whether the household is in poverty. Home owners live further from CBD (which is consistent with the monocentric model which predicts that housing prices decline with distance from the city

[28] Note that as many of our households do not move during the time we observe them, it is not appropriate to use a fixed effects estimator. Note also that if we collapse data for those households who do not move to one observation per household using average values across the waves for which they are present in our data, the results are very similar to those presented in Table 3; both significance and size change very little.

[29] This means that observations further than 50 km apart are not correlated. Our results are robust to other cut-off distances.

[30] It is worth stressing here that the negative coefficient on higher education is not a result of the growth in student numbers in city centres. The variable represents educational qualifications already gained so does not reflect undergraduates currently studying. In addition this negative effect remains if we exclude from our sample those in full-time education (see Section 5.3).

centre) but there is no significant relationship between distance and being in poverty. The inclusion of these two variables renders the 'not employed' status of the household head insignificant, probably due to collinearity, but makes little difference to the other estimates, and the coefficient on income is reduced slightly.

In column (5) we include two variables relating to the availability of transport; whether or not the household has access to the car, and a proxy for public transport quality in the neighbourhood. This latter variable is derived from data from the Department for Transport that measures how long it takes to travel to various amenities by car and by public transport[31]. The data are available at the level of 'lower layer super output area' (LSOA); these are small neighbourhood areas. There are 32,482 LSOA in England with between 400 and 1200 households in each[32]. The data give travel times from the centre of each LSOA to the nearest amenity of each type, so these data give a good indication of travel times for each of our households. We calculate the ratio of car to public transport travel time, so that higher values suggest greater availability of public transport. We use travel to the nearest primary school as our main measure for public transport availability, since we expect primary schools to be relatively evenly distributed throughout our urban areas, but in our robustness checks in section 5.3 we also consider travel times to a number of other amenities[33].

Glaeser et al. (2008) argue that one of the reasons why the poor live near the CBD in US cities is that public transportation to work is more available there and this is important given the fact that many of the poor do not own their own car; this is also a reasonable assumption to make about British cities. In our sample of those in poverty only 57% of households have a car, whereas for those households not in poverty the proportion is 86%. Our results support Glaeser et al's (2008) argument; those with access to a car live further away from the CBD and the availability of public transport in the neighbourhood is associated with living closer to the CBD. The inclusion of these two measures results in a change in sign for the variable which measures whether or not the head of household is employed. If we do not take transport availability into account, households where the head

[31] www.gov.uk/government/statistics/accessibility-statistics-2013
[32] The Department for Transport accessibility data that we use for our public transport availability measures is only available for England so households in Glasgow are excluded for this part of the analysis.
[33] In England primary schools provide education for children aged 5 to 11 years.

is not employed live nearer to the CBD, but after taking into account transport, they live further away. One explanation for this is that good public transport can reduce the time cost of travel, reducing the importance of proximity to jobs for the unemployed. Importantly, the size and significance of the coefficient associated with household income remains very similar when the public transport variable is included. This result differs from Glaeser et al (2008) who find that the public transportation explains most of the location of the poor in U.S cities.

The key finding from Table 3 is that whichever control variables we include in our model the relationship between distance from the CBD and income remains positive and significant; although its magnitude is reduced as more control variables are added. In column (5) the coefficient on log income is 0.123, suggesting that a 10% increase in income results in a household being located on average 1.2% further from the city centre. At a mean distance of approximately 8km from the CBD, a 10% increase in income is associated with households living 0.1 km further away.

5.2. Income Elasticity of Demand for Housing

As discussed above, Becker (1965) shows that the rich choose to live further away from the CBD if the income elasticity of demand for land is greater than one. To test this hypothesis, we follow Glaeser et al (2008) and estimate

$$logL_{it} = \alpha + \theta logY_{it} + \delta' Z_{it} + \nu_{it} \qquad (2)$$

As in equation (1) *i,t* index households and waves, respectively, and *Y* is the household's real equivalised net income. The dependent variable lot size (*L*) is proxied by the number of rooms in the accommodation, which is constructed from two questions that ask separately for the number of bedrooms and the number of 'other' rooms. The conditioning variables (*Z*) are the age and sex of the household head, whether or not there are children aged under 16 living in the household, and whether the resident is an owner occupier; wave and city dummies are also included[34]. The focus here is whether θ is greater than one. Again we

[34] Note that, in contrast to Glaeser et al's (2008) work for the US, race is not included in our regressions; we explored the use of a race variable but it was never statistically significant. In addition, we followed Glaeser et al's specification by using number of children in the household as a control variable. As an alternative, if we

allow for both spatial correlation and autocorrelation in the error term (ν) by estimating equation (2) using the spatial panel estimator of Hsiang (2010).

As Glaeser et al (2008) point out, one criticism of using current income in this model is that this is an error ridden measure of permanent income, and thus the estimate of θ is biased downwards. To overcome this, like Glaeser et al (2008), we instrument for income using education. The rational for this is that education is correlated with permanent income but should have no direct effect on housing consumption. Our measure of education is the highest level of educational attainment gained by the head of household, and this is represented by a set of dichotomous variables representing O-levels/ GCSEs, A levels, and degree or higher, with no formal qualifications as the base category[35].

The results, which are not reported here for conciseness, show that, whether or not we instrument for income, house size varies positively with age and is larger when there are children in the household and for home owners; house size does not vary with the sex of the household head. Our results for the income elasticity of demand for space are very similar to those of Glaeser et al (2008) for the US. When we do not instrument for income the elasticity estimate is very low, at 0.104 (in Glaeser et al the coefficient is 0.08); reducing the downward bias by instrumenting income with education increases the estimate 0.214 (0.26 in Glaeser et al). Therefore, we conclude that this estimate is too low to explain the income-distance gradient, as Becker's (1965) model would suggest.

5.3 Robustness checks

To check the robustness of our results we explore six different specifications. Firstly, we define the CBD using the location of the largest main M&S store rather than the main rail station. Secondly, we exclude full-time students from our analysis in order to explore whether our results are affected by the growth in student numbers in cities resulting from the expansion of higher education. Thirdly, we include only those households where the head is in employment. Fourthly, we restrict our sample to those households who do not

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adjust the dependent variable for household size, calculating rooms per head, the elasticity estimates are very similar to those reported in the text.

[35] These UK qualification levels largely coincide with finishing education at age 16 (O-levels/ GCSEs), 18 (A levels), and post-18 (degree or higher).

move house during the period of our analysis and are present in all four waves of our data; here we partly pre-empt the analysis undertaken below on whether or not cities make people poor. Fifthly, we consider four different definitions of poverty or low income, as an alternative to the household having less than 60% of median income; these are: being behind with rent or mortgage; being behind with council tax[36]; having problems covering all bills; and the head of household reporting that they are finding it 'difficult to get by' financially. Finally we consider six alternative public transport access measures; whereas in Table 3 this variable is the ratio of car to public transport times to primary schools, the alternative variables measure access (in the same way) to secondary schools, further education colleges, primary care health services, hospitals, employment centres (with at least 100 jobs) and town centres.

These results are reported in Table 4 where, for convenience, the first column repeats the final column (5) from our main specification in Table 3. Defining the CBD as coinciding with the main M&S store (2) makes virtually no difference the results. Excluding full-time students (3) results in only a 3% reduction in our sample. The positive income-distance gradient remains and is slightly steeper than for the full sample. The rest of the coefficients are similar, with the exception of the one associated with number of children which becomes insignificant. Employed households (4) make up 68% of our sample. The results for this sub-sample are very similar to those for the whole sample; the main difference is that access to car has a larger effect for these households. The sample of non-movers (5) make up only 41% of the full sample but they have a very similar income-distance gradient to the full sample. The effects of the control variables are also very similar; the only difference is that where these households are headed by men they tend to be further from the city centre. For the four alternative definitions of poverty[37]; those households where the head reports they are finding it 'difficult to get by' and those reporting being 'behind with their council tax' live closer to the CBD. The variables measuring whether or not household is behind with rent or bills are not statistically significant; one possible explanation for this lack of significance is that these are not standard definitions of poverty. Similarly using access to different amenities as alternative measures of public transport makes little difference to the

[36] The Council Tax in the UK is a system of local property taxation used to partly fund services provided by local government.

[37] For conciseness the results for alternative poverty and public transport definitions are not reported here.

results reported in Tables 3 and 4. As a further check on the robustness of our results we estimate the land elasticity model of equation (2) for the sub-samples of non-movers and excluding full-time students; the results are very similar to those reported for the full-sample above.

In summary our results are robust to variation in the estimation sample, definition of city centre and to alternative definitions of a number of our explanatory variables. The finding of a significant positive relationship between distance from the CBD and household income remains.

5.4 Do cities make people poor?

Our results have so far revealed that poorer households live closer to the city centre. With our longitudinal data we are also able to address the question of whether British cities tend to make households poorer or whether they simply attract people who are poor. Here we follow households who have not changed residence during the analysis period 2009-2013 and analyse how their income has changed over this time period. The concept of spatial equilibrium implies that, in a frictionless world, households are equally happy in all locations and hence have no incentives to move. However, another possibility in the real world is that households do not move because they are constrained and immobile, and thus not able to satisfy their preferences on location. We can get some idea of which hypothesis is more likely by exploring their views on their current housing situation. The Understanding Society survey contains two informative questions in this regard; whether or not the respondent would prefer to move house, and whether or not they expect to move in the next year. For our full sample of n= 12,096, 41% would prefer to move and 14% expect to do so. For our non-mover sample of n = 4,793 a similar proportion (39%) would prefer to move but only 7% expect to do so. This gives some support to the second hypothesis that the non-movers are more constrained and this explains their geographic immobility. A look at some key descriptive statistics can partly explain why this might be the case. The two samples have almost identical proportions of households in poverty, with a car and with children. However, non-mover households are less likely to have a head who is not in employment (26% vs. 32%), and are more likely to be home owners (68% vs. 60%). Therefore non-mover households may be constrained by both labour market and housing market circumstances (Manning, 2003).

Table 5 follows household's income for the non-movers at different distances from the CBD over the four waves of our sample. This table reveals that on average urban dwellers who did not move saw virtually no change in their real net income over the period, average monthly income was £1605 in wave 1 and £1621 in wave 4. However, these figures mask some variation for households according to distance from the CBD. For those households who live close to the CBD (between the 1st - 5th and 5th - 25th percentile distance), real incomes increased. For households further from the CBD real incomes have fallen, with the exception of those in the furthest percentile distance who saw a small increase. Given that we have already shown that younger households live closer to the city centre it is tempting to argue that the growth in income is therefore a result of life stage, with younger people experiencing faster income growth. However, this is a sample of people who did not move during the four waves we observe them, and this confounds the age-distance relationship because younger people are more mobile. The average age of people in each of the first three distance bands in Table 5 is 45 years, increasing to 46 for the next two bands and 48 for those who live furthest from the CBD. Hence age is not a complete explanation for this phenomenon. These results provide prima facie evidence that rather than cities making people poor, they tend to attract poorer people who then experience faster income growth than those who live further away. However, it is worthy of note that real incomes in the nearest percentile distance (£1404) are still only 85% of those in the furthest percentile (£1652) in wave 4.

6. Conclusions

In this paper we present the first study that has explored the relationship between income and the location of urban households in Britain. Our findings show that the poorest households tend to live closer to the CBD than the rest of urban dwellers. Moreover, after controlling for several household characteristics and access to transport (as well as city and time effects), we find a strong significant, and robust, positive relationship between household's income and distance from the CBD. We test whether the income elasticity for the demand for housing is large enough to conclude that richer households live further away from the CBD to consume larger dwellings. Our results show that this elasticity is much lower than one and so preference for space cannot fully explain our findings on the income-location pattern. These results are very similar to those of Glaeser et al. (2008) for the US; and they contrast with those of Brueckner et al (1999) who argue that the US pattern, for those with higher wages to choose to live further from the CBD, is reversed in Europe where amenities are concentrated in historic city centres. However, unlike Glaeser et al (2008) we do not find that public transport availability can explain the spatial distribution of income.

Finally, using a subsample of households who did not change residence over the time period analysed, we find some evidence that households who live closer to the CBD are the ones who have experienced the largest increases in real income over the period. This suggests that one can reject the hypothesis that cities tend to make households poor, and may even conclude that cities are good for the poor. However, importantly for urban planning debates, those who live near the CBD are still poor relative to those who live further away.

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Table 1: Number of households and mean income by city and wave

City	2011 population	Wave 1 Households	Wave 1 Income[1]	Wave 2 Households	Wave 2 Income[1]	Wave 3 Households	Wave 3 Income[1]	Wave 4 Households	Wave 4 Income[1]
Birmingham	1073045	706	1399	564	1497	507	1462	481	1509
Bristol	428234	247	1647	234	1557	207	1697	210	1628
Glasgow	629501	358	1699	383	1824	334	1668	303	1704
Leeds	751485	285	1353	235	1439	199	1518	175	1539
Liverpool	466415	261	1629	237	1711	213	1690	194	1685
Manchester	503127	411	1604	366	1602	319	1612	290	1668
Newcastle	280177	372	1485	345	1568	310	1563	300	1549
Nottingham	305680	403	1547	398	1443	374	1472	347	1490
Sheffield	552698	408	1478	412	1503	381	1518	328	1515
Total	4990362	3451	1522	3174	1566	2844	1569	2628	1576

[1] Income is measured as monthly equivalised net income (£) in 2012/13 prices.

<u>Table 2</u>: Descriptive statistics at different distances from the CBD, for household (HH) and head of household (HoH).

Percentile distance from CBD	Number of households	Distance from CBD (km)	Mean monthly HH income (£)[1]	HH in poverty[2] (%)	HoH not employed (%)	HoH has Higher Education (%)	Children in HH (%)	Average age of HoH (years)	HoH is male (%)	Hoh in poor health (%)	Number of rooms in home	HH owns home (%)	HH has a car (%)
< 5	601	< 1.82	1399	47.7	43.7	38.1	25.2	32	59.7	19.1	3.5	23.6	48.1
5-25	2415	1.82 - 3.96	1377	49.6	37.3	39.1	41.7	40	54.4	23.0	4.4	50.6	66.1
25-50	3023	3.96 - 6.63	1567	39.6	31.5	37.8	41.7	44	56.7	22.7	4.6	60.5	75.0
50-75	3027	6.63 - 10.72	1657	33.3	30.2	32.8	39.9	45	57.6	23.4	4.7	66.0	78.6
75-95	2422	10.72 - 2.70	1620	31.9	28.1	32.7	37.6	45	61.5	19.7	4.7	70.3	82.9
>95	608	> 22.70	1613	30.5	27.3	26.9	34.3	46	67.9	19.9	4.8	69.2	86.3

Notes: [1] Income is measured as monthly equivalised net income (£) in 2012/13 prices. [2] A household is defined as in poverty is if its income is below 60 percent of the national median equivalised net income.

<u>Table 3</u>: Household income and distance from the CBD.

Dep. var. Log distance	(1)	(2)	(3)	(4)	(5)
Household income	0.259***	0.258***	0.123***	0.105***	0.123***
	(0.003)	(0.004)	(0.016)	(0.012)	(0.014)
Age			0.034**	0.039***	0.043***
			(0.005)	(0.004)	(0.004)
Age squared			-0.000***	-0.000***	-0.000***
			(5.2-05)	(3.9e-05)	(4.0e-05)
Sex			0.023	0.006	0.001
			(0.022)	(0.020)	(0.021)
Higher education			-0.137***	-0.167***	-0.183***
			(0.017)	(0.018)	(0.019)
Children			0.091***	0.077***	0.044**
			(0.018)	(0.017)	(0.018)
Not employed			-0.081***	-0.008	0.046**
			(0.021)	(0.021)	(0.019)
Health			0.023***	0.016**	0.016**
			(0.006)	(0.007)	(0.008)
Home owner				0.198***	0.150***
				(0.026)	(0.029)
In poverty				-0.041	-0.015
				(0.026)	(0.021)
Access to car					0.187***
					(0.015)
Public transport access					-0.434***
					(0.066)
City and wave dummies	no	yes	yes	yes	
Observations	12,096	12,096	12,082	12,082	10,691
R-squared	0.860	0.864	0.873	0.874	0.876

*,**,*** denote significance at the 10%, 5% and 1%, respectively. Estimation is via the Hsiang (2010) spatial panel estimator for stata (*ols_spatial_HAC.ado*). Glasgow is omitted from the sample in column (5) because there is no compatible public transport data available.

<u>Table 4</u>: Household income and distance from the CBD: Robustness checks.

Dep. var. Log distance	(1) Table 3. Col (5)	(2) M&S CBD	(3) Ex. FT students	(4) Employed	(5) Non-movers
Household income	0.123***	0.118***	0.143***	0.138***	0.110***
	(0.014)	(0.016)	(0.015)	(0.009)	(0.015)
Age	0.043***	0.045***	0.036***	0.038***	0.049***
	(0.004)	(0.004)	(0.004)	(0.001)	(0.006)
Age squared	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(4.0e-05)	(4.4e-05)	(4.1e-05)	(1.7e-05)	(6.3e-05)
Sex	0.001	-0.010	0.014	-0.007	0.045**
	(0.021)	(0.019)	(0.022)	(0.018)	(0.018)
Higher education	-0.183***	-0.194***	-0.178***	-0.207***	-0.177***
	(0.019)	(0.020)	(0.019)	(0.022)	(0.022)
Children	0.044**	0.049***	0.021	0.018	-0.007
	(0.018)	(0.018)	(0.017)	(0.013)	(0.010)
Not employed	0.046**	0.037*	0.098***		0.068***
	(0.019)	(0.020)	(0.023)		(0.010)
Health	0.016**	0.014*	0.027***	0.027***	0.024**
	(0.008)	(0.008)	(0.006)	(0.007)	(0.011)
Home owner	0.150***	0.157***	0.145***	0.141***	0.136***
	(0.029)	(0.030)	(0.031)	(0.030)	(0.038)
In poverty	-0.015	-0.024	0.004	-0.021	-0.018
	(0.021)	(0.021)	(0.022)	(0.029)	(0.032)
Access to car	0.187***	0.192***	0.186***	0.285***	0.177***
	(0.015)	(0.017)	(0.017)	(0.036)	(0.025)
Public transport access	-0.434***	-0.447***	-0.436***	-0.409***	-0.378***
	(0.066)	(0.068)	(0.072)	(0.077)	(0.060)
City and wave dummies	yes	yes	Yes	Yes	Yes
Observations	10,691	10,691	10,344	7,267	4,401
R-squared	0.876	0.873	0.880	0.886	0.889

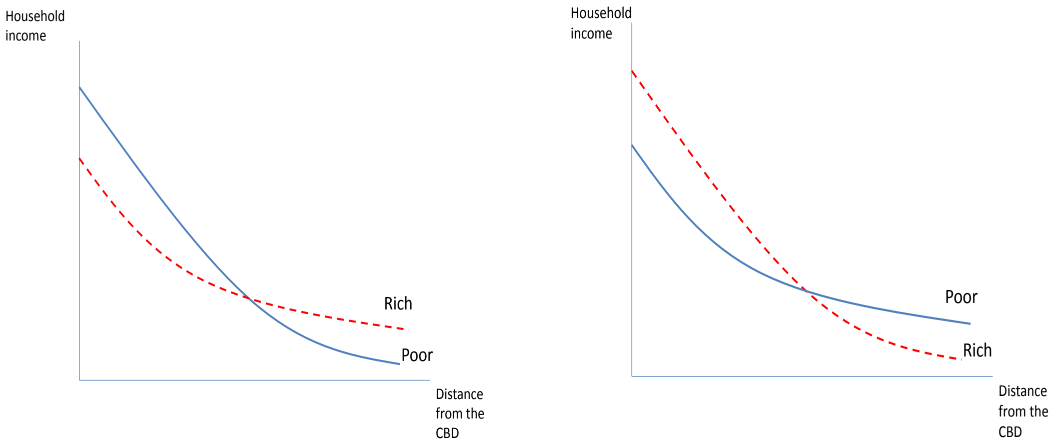
*,**,*** denote significance at the 10%, 5% and 1%, respectively. Estimation is via the Hsiang (2010) spatial panel estimator for stata (*ols_spatial_HAC.ado*).

<u>Table 5</u>: Income evolution over time across distances from CBD. All non-mover households

Percentile distance from CBD	Income				Income Change (%)			
	wave 1	wave 2	wave 3	wave4	w1-w2	w2-w3	w3-w4	w1-w4
<5	1347	1361	1513	1404	1.04	11.17	-7.20	4.23
5-25	1472	1518	1523	1619	3.13	0.33	6.30	9.99
25-50	1644	1614	1639	1633	-1.82	1.55	-0.37	-0.67
50-75	1684	1610	1622	1637	-4.39	0.75	0.92	-2.79
75-95	1653	1660	1659	1634	0.42	-0.06	-1.51	-1.15
>95	1611	1512	1633	1652	-6.15	8.00	1.16	2.55
Total	1605	1586	1609	1621	-1.18	1.45	0.75	1.00

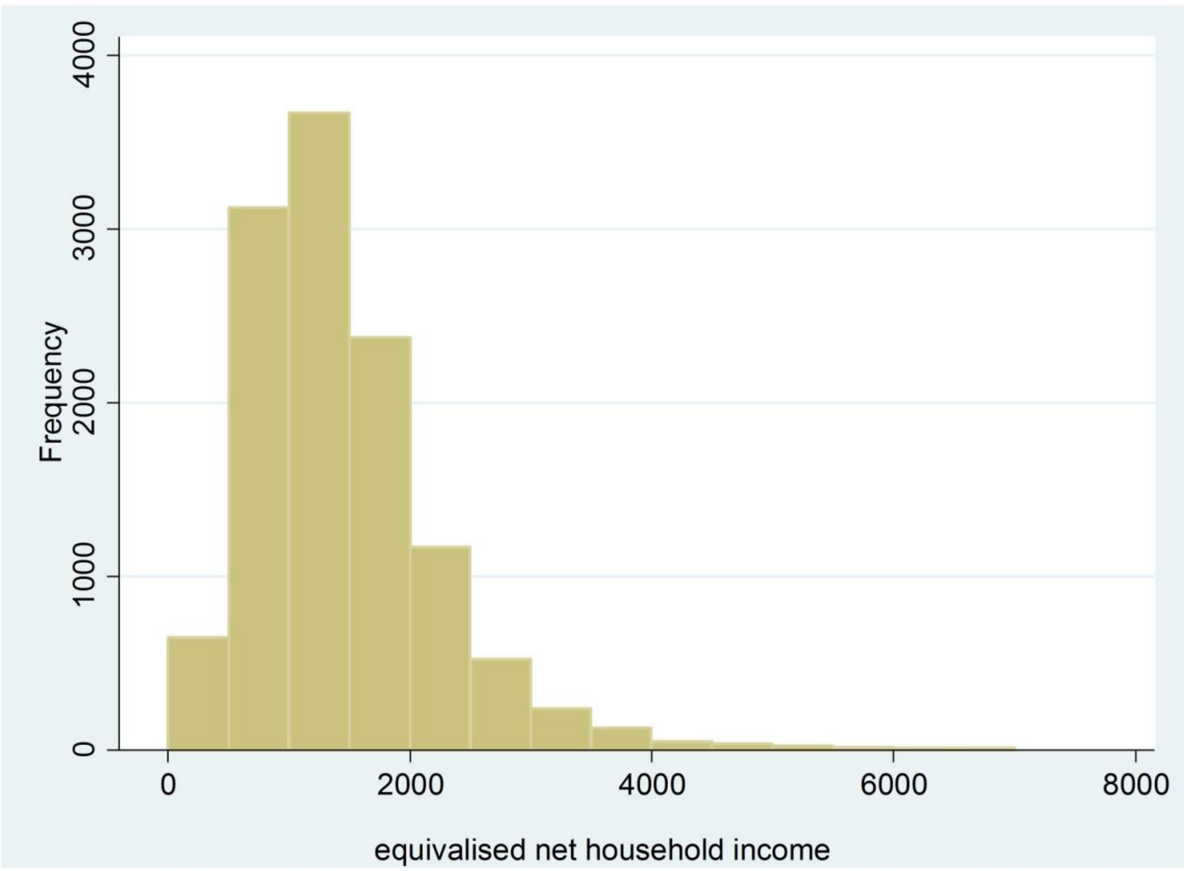
Notes: Income is measured as monthly equivalised net income (£) in 2012/13 prices.

Figure 1: possible locations of the poor and the rich in the monocentric model



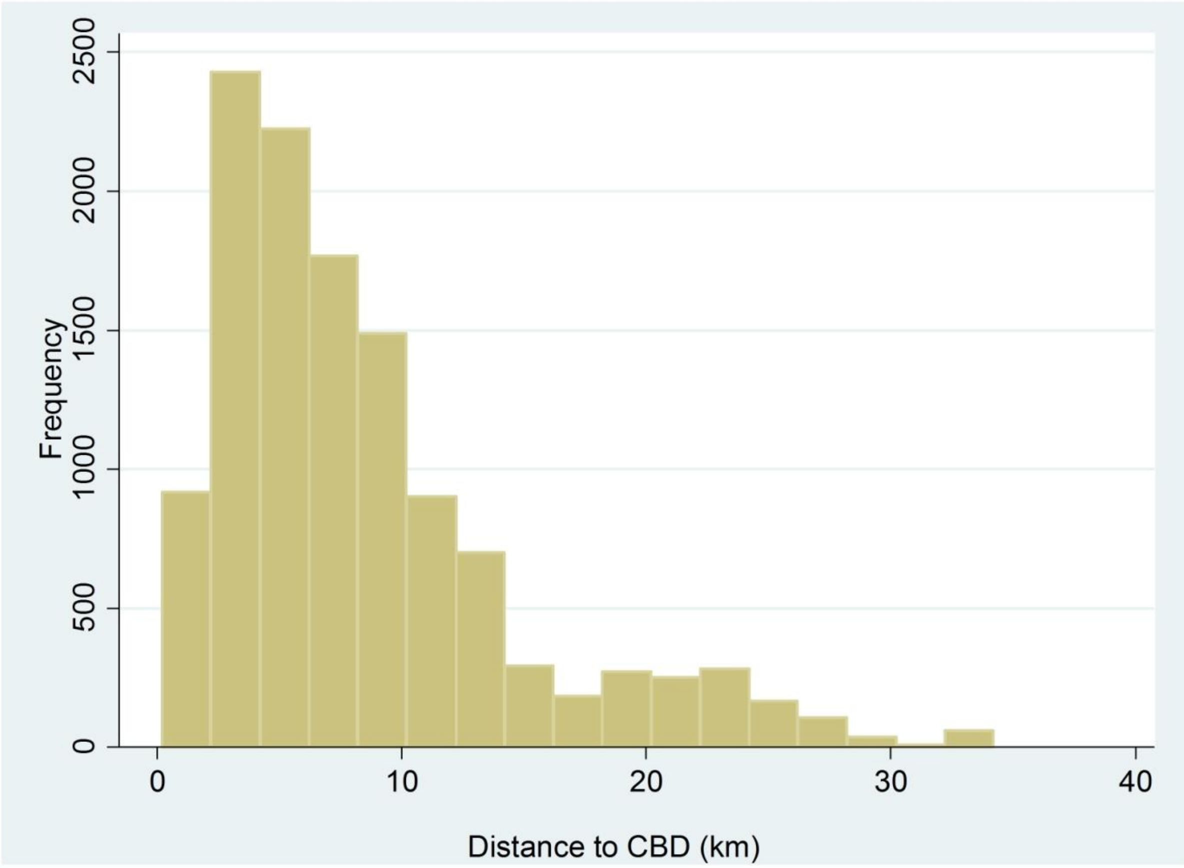
Source: Adapted from (Brueckner, 2011)

Figure 2: The distribution of household income



Notes: Income is measured as monthly equivalised net income (£) in 2012/13 prices. The graph is censored at incomes > £7000 to preserve anonymity.

Figure 3: Histogram of households' distances (km) to the CBD



Note: this graph is censored at distances > 34km to preserve anonymity

Figure 4a: Birmingham

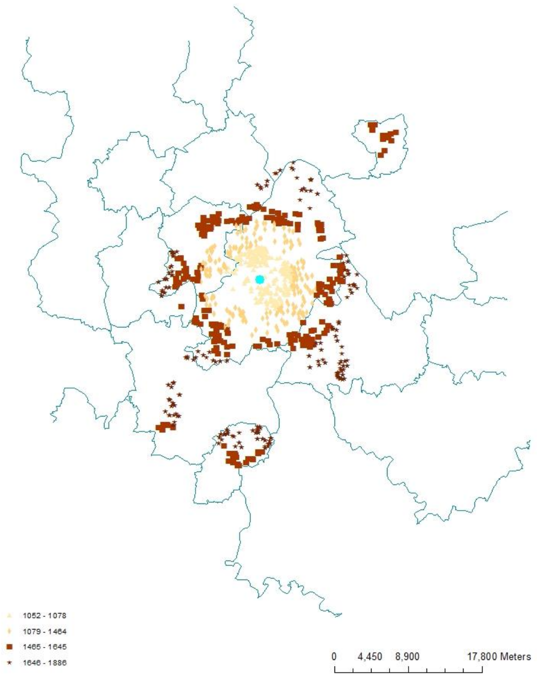


Figure 4b:Bristol

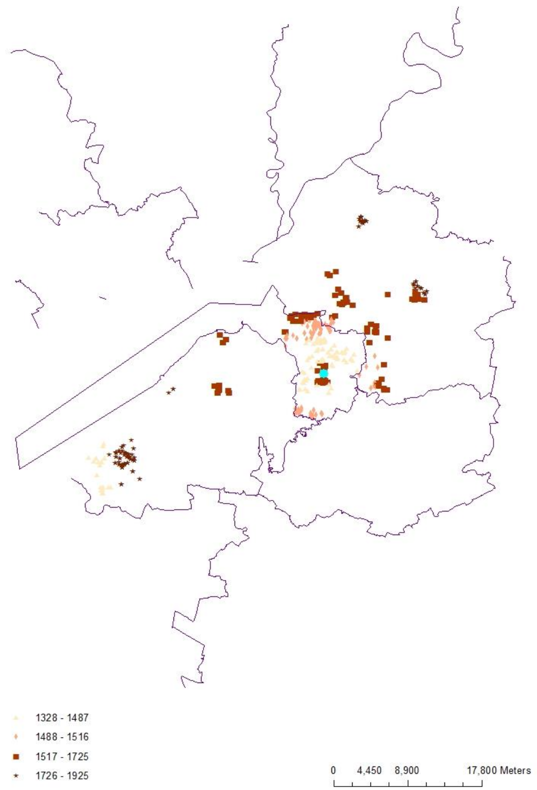


Figure 4c: Glasgow

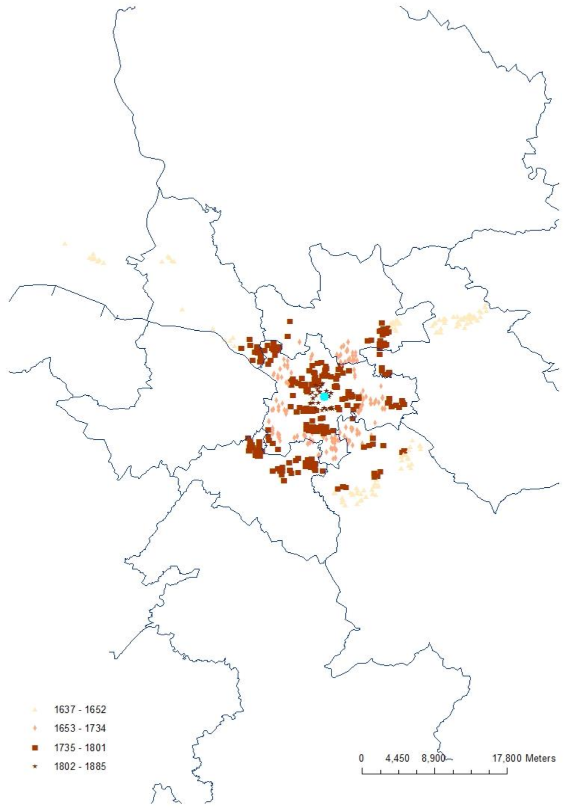


Figure 4d: Leeds

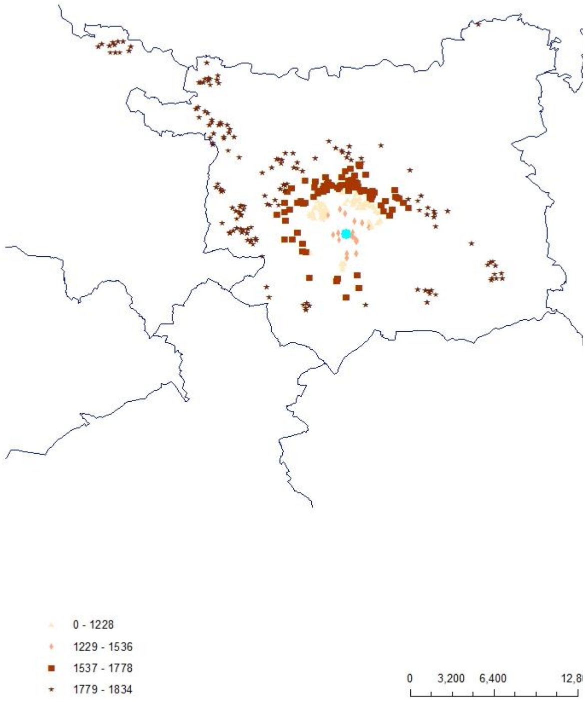


Figure 4e: Liverpool

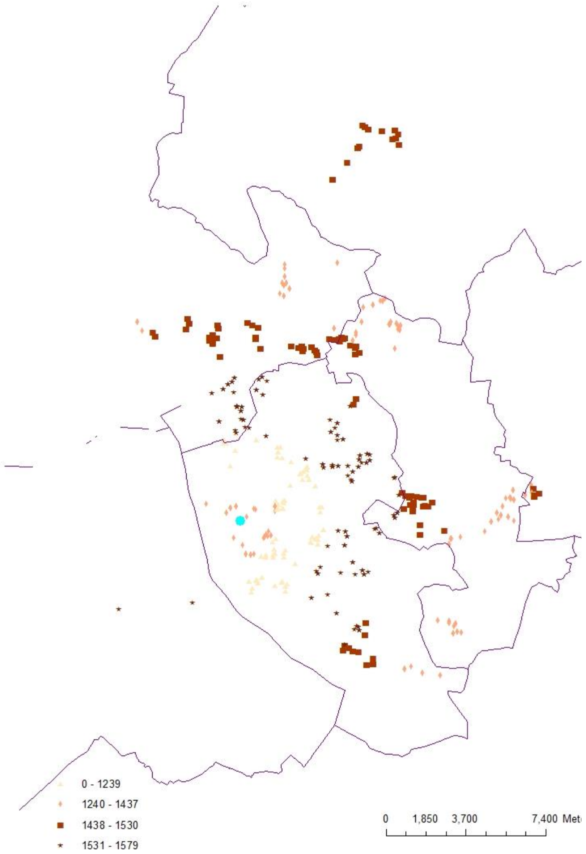


Figure 4f: Manchester

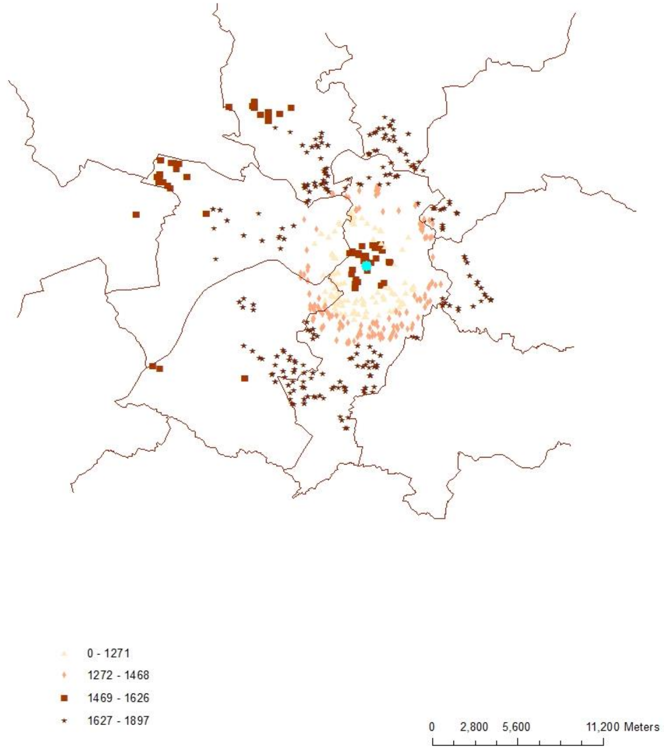


Figure 4g: Newcastle

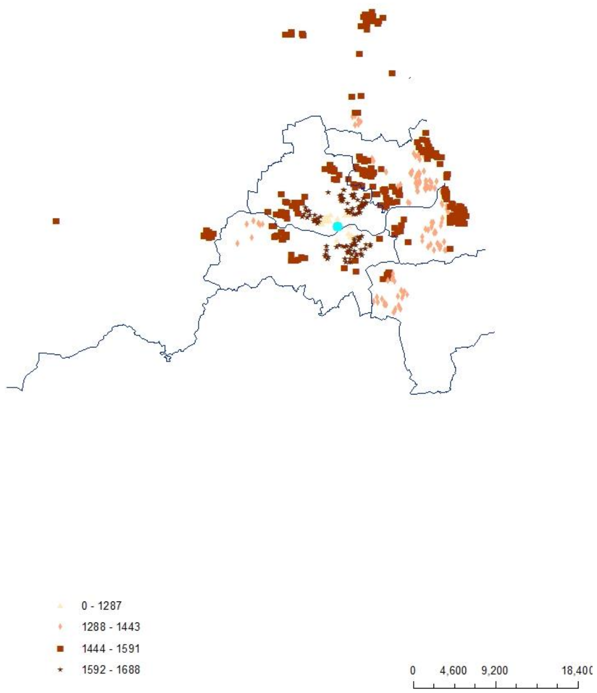


Figure 4h: Nottingham

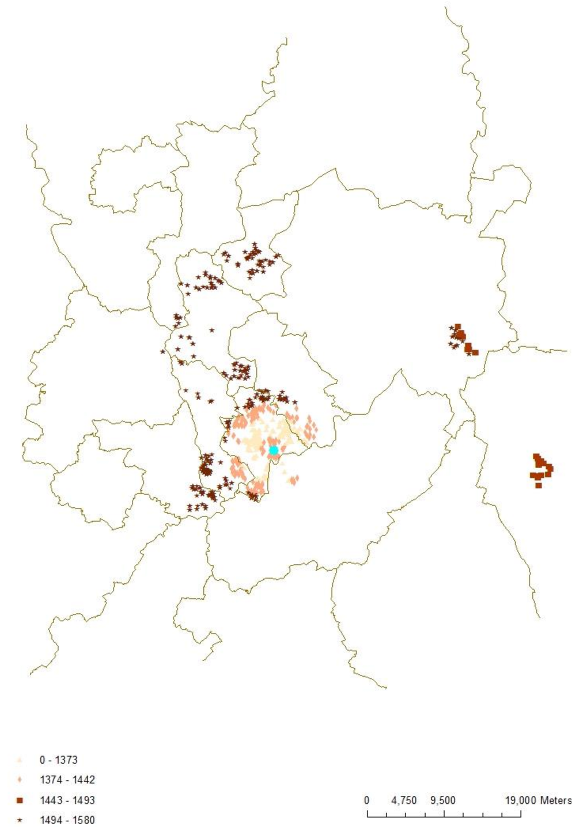


Figure 4i: Sheffield