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# The complex geographies of ethnic residential segregation: Using spatial and local measures to explore scale-dependency and spatial relationships

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Ethnic residential geographies have become increasingly spatially complex. While urban diversity is by far the dominant pattern in the UK, over the last two decades suburban and rural areas have experienced a modest but steady growth of ethnic minority populations. Yet despite these emerging patterns, a bias persists whereby most studies of ethnic residential segregation are concerned solely with metropolitan places. While spatial and local measures enable a more sophisticated analysis of the intricate geographical and scalar variations in residential segregation than traditional "global" approaches, there have been surprisingly few analyses of the local dimensions of ethnic residential patterning, and these have tended to be metro-focused. This study analyses small area ethnic segregation in England and Wales using a spatially-weighted approach for 2011 Census data across all (small) areas, rather than just cities. To briefly summarise, the results demonstrate (1) the non-uniform scale effects of segregation between each ethnic group; (2) spatial "thresholds" at which segregation can be found, which challenge established wisdom about the relative levels of segregation between ethnic groups; (3) the high spatial variability in segregation levels; and (4) how segregation dimensions and group proportions are not strongly related in all neighbourhoods, providing justification for their use in conjunction. Exploring segregation across a national context, the research develops understandings of ethnic group interactions between spaces and across scales, and advances hitherto underdeveloped debates about the complexity of the conceptual and empirical distinctions that can be made between the dimensions of segregation.

**KEYWORDS**
diversity, ethnicity, neighbourhood, residential segregation, scale, urban–rural

## 1 | INTRODUCTION

As ethnic diversity increases so too does the complexity of its residential geographies. While urban diversity is by far the dominant pattern in the UK, over the last two decades suburban and rural areas have experienced a modest but steady growth of ethnic minority populations (Catney, 2016a), a trend mirrored in small-town and rural USA (Lee & Sharp, 2017; Lichter, 2012). For Britain, the mechanisms behind the spatial diffusion of ethnic diversity are fairly well-documented in

the migration literature: dispersal from inner-city clusters – reflecting upward socio-spatial mobility (Catney & Simpson, 2010), increased inter-racial tolerance (Storm, Sobolewska, & Ford, 2017) and wider trends in internal migration across the life-course (Coulter, van Ham, & Findlay, 2016; Finney, 2011); and new, direct, immigration flows to non-metropolitan destinations – in part due to low-skilled labour demand (Jentsch, De Lima, & MacDonald, 2007) and asylum seeker dispersal policies (Hynes & Sales, 2010). While these processes have diversified the ethnic composition of non-metropolitan places (Catney, 2016a), the segregation literature has not kept pace with that of migration scholars, and a bias persists whereby most studies of ethnic residential segregation are concerned solely with urban areas. The new residential spaces of ethnic diversity are thus omitted in empirical analyses which stop at the city boundary, with an implication that minority populations outside urban neighbourhoods are a less urgent topic for scholarly investigation.

This study analyses small area segregation for England and Wales using a spatially-weighted approach (Wong, 2003) using data for all areas, rather than just cities. Exploring segregation *across* a national context allows for a more integrated appreciation of the changing geographies of ethnic diversity. This is important because the impact on residential concentration of the suburbanisation and counterurbanisation of ethnic minority populations (Finney & Simpson, 2009) is not well understood, and a spatially-detailed exploration of ethnic segregation across the urban–rural spectrum is yet to be undertaken. Spatial assimilation theory suggests that such decentralisation would result in reduced residential segregation, however US-based research has suggested that these processes may be more complex. While there has been dispersal from immigrant settlement areas (Lichter, Parisi, Grice, & Taquino, 2007), the geographic trajectories of immigrant groups are spatially-stratified, do not conform to traditional conceptions of urban–suburban diffusion (reflecting in part the polycentricity of cities), and vary by group and cohort of arrival (Wright, Ellis, & Parks, 2005). The suburbanisation of Black populations in US cities, for example, may be associated with a spatial *displacement* of segregation, rather than a reduction (Lichter et al., 2007).

In addition to non-urban areas, the ethnic landscape *within* UK urban areas has also become more spatially nuanced. Ethnic diversity – a notable presence of *several* ethnic groups – has increased within cities over the last three decades (Catney, 2016a). Intra-city migration, the balance of more births than deaths, and chain immigration flows, have all reinforced existing and created new patterns of urban neighbourhood diversity. However, the intricate spatial patterning of these emerging ethnic residential geographies have yet to receive due attention. Has this increased ethnic diversity been accompanied by decreased ethnic segregation across small areas?

The aim of this paper is not to directly test the impact of mobility or demographic momentum on residential clusters, but to exemplify the need to better appreciate segregation's spatial complexity. As Lichter et al. noted a decade ago,

> to fully understand US trends in racial segregation, we must balance the current preoccupation with changing neighborhood segregation in large cities with new analyses at other geographic levels, including smaller cities and towns outside metropolitan cities and urbanized areas. (2007, p. 564)

The same can be said of the UK literature, where most studies are city-focused (Harris, 2015; Johnston, Poulsen, & Forrest, 2015) and, with some notable exceptions (e.g. Johnston, Jones, Manley, & Owen, 2016), have ignored the scalar variations in residential segregation. Yet this is an issue which is arguably at its most timely.

"Spatial" and "local" segregation measures (defined in the next section) offer unique insights into the geographical characteristics of ethnic residential segregation. Several scholars have developed and applied spatial and local indices (e.g. Feitosa, Câmara, Monteiro, Koschitzki, & Silva, 2007; Harris, 2014; Morrill, 1991; Reardon & O'Sullivan, 2004; Wong, 1997; and see the overview by Wong, 2016), demonstrating the ways in which segregation can vary across space and by scale, and hence the importance of accounting for its local variation. Yet these more geographically-sensitive measures are far from commonplace in segregation studies, have focused on urban areas and are virtually absent from the British literature. In this paper, 2011 Census data for England and Wales are used to advance the spatial measurement literature by providing a comprehensive study *across* the urban–rural spectrum and not just for metropolitan areas. Geographical and scalar variation, and the relationships between dimensions of segregation by scale, are explored. In turn, this work expands the UK evidence base, which is so far founded largely on aspatial measurement and/or is reliant on superimposed administrative geographic boundaries which have limited or no resonance with the reality of residential experiences "on the ground".

## 2 | SPATIAL AND LOCAL SEGREGATION

Most analyses of segregation are based on measures that represent one or more dimension of segregation (Massey & Denton, 1988) and provide one-number summaries for the whole study area (for example, a country or city). Most of these

measures are *aspatial*. To give an example, the standard form of the index of dissimilarity (*D*) uses counts of two population groups (e.g. White and Black African) within each zone (e.g. a ward or census tract), and measures unevenness in the two groups *across* the study area. However, no account is taken of neighbouring zones; as such, this "global" measure implicitly ignores the possibility of connections *between* neighbouring zones. Artificially imposed boundaries (such as a metropolitan boundary or the edge of census administrative units) are treated as hard physical or social barriers between two areas (Wong, 2003). The well-known "checkerboard problem" encapsulates this issue and shows how global indices produce the same index values for different spatial configurations of the same zone populations (see the discussion in O'Sullivan & Wong, 2007).

"Spatial" measures of segregation offer a solution by incorporating information on the populations in neighbouring zones (defined in multiple ways, including adjacent zones or those within some predefined distance) and thus, more appropriately, generate different results for different spatial arrangements of the same population values (e.g. Wong, 2003). Yet both global aspatial and spatial measures provide only one figure for the whole study area. Local indices go further to provide a value for *each* individual (small) zone (e.g. a census ward), rather than their collective (e.g. wards in a city) (e.g. Feitosa et al., 2007; O'Sullivan & Wong, 2007). Thus, local measures are mappable and can be used to explore the geographic patterning and scale of residential segregation *across* the study area – a valuable attribute given that segregation is an inherently spatial phenomenon. The aspatial, spatial and local unevenness (the Index of Dissimilarity, *D*) and exposure (Index of Exposure, $_mP_m^*$) measures used in this study are defined in Supporting Information, S1. The spatial and local measures are computed using distance-decay functions, whereby close-by zones have a greater influence in calculations of indices than those further away.

This spatiality of segregation is further emphasised through its scale dependence. Indeed, the spatial lens through which we measure segregation has a profound effect on how we report it. In recognition of the significance of the geographic scale of segregation (e.g. Reardon et al., 2008), Johnston et al. (2016) demonstrate the variation in changes in segregation at the micro-, macro- and meso-scale in London between 2001 and 2011, using a multi-level framework which accounts for segregation across three geographical levels. They add to previous studies which have demonstrated a reduction in ethnic minority segregation in small areas (e.g. Catney, 2016b, 2017; Johnston et al., 2015) by demonstrating neighbourhood level ("micro-level" [output areas], defined on p. 392) reduction in segregation, set within more stable patterns at the "meso-scale" (middle layer super output areas), and with no change at the "macro-scale" (local authority districts). This research sheds light on the geographical variability in change in segregation levels. However, as with other studies which test the significance of scale for British ethnic distributions (e.g. Simpson, 2007), this is explored for different geographical layers within pre-imposed (census) administrative boundaries. Fowler (2016) argues that segregation is multiscalar and continuous – that it is experienced at several scales simultaneously. His observations for south Seattle resonate in many British cities, where the landscape of ethnic concentration is highly variable across small distances (Catney, 2016a; Johnston et al., 2015). An adaptable approach to defining "neighbourhood" as offered by local measurement overcomes the assumptions made via boundary definitions (reflected in the Modifiable Areal Unit Problem; Wong, 2016), and allows for a more flexible exploration of multiscale segregation. In this study, the scale of segregation is accounted for by adapting the distance weighting schemes used in computing spatial and local measures (see S1). The weighting scheme can be defined so that only neighbours in close proximity are included in calculations (small bandwidth), or such that even far away zones are included (large bandwidth).

Using local measures, the relationships between different dimensions of neighbourhood segregation can be tested, as well as between segregation and other population characteristics (for example, area deprivation). A body of work has explored the multidimensional nature of segregation, demonstrating how different measures of segregation capture quite different properties of residential distributions. Reardon and O'Sullivan (2004) and Johnston, Poulsen, and Forrest (2007) suggested that Massey and Denton's (1988) five dimensions of segregation (evenness, exposure, clustering, centralisation and concentration) could be rationalised into just two "superdimensions". Local measurement allows us to consider what information is added for each dimension at each location. How do the differing forms of segregation *and* the spatial and scalar characteristics of segregation relate? These inter-relations are potentially significant given that the experiences of segregation are not equal for every ethnic group.

While the local measurement of segregation is not new, to date it has been underutilised in UK-based analyses and has received the most attention from scholars in the USA (in particular Wong, 2002, 2003). Contributions to our understandings of ethnic group residential change using 2011 Census data have drawn on aspatial segregation index measurement or area typologies (e.g. Catney, 2016b, 2017; Johnston, Poulsen, & Forrest, 2013; Johnston et al., 2015), focusing on inter-group differences at the country or city level. There are few "national"-level analyses of local residential segregation within the constituent parts of the UK, such as those by Lloyd and Shuttleworth (2012), with a focus on the two main religious

groups in Northern Ireland, and Harris (2014) who computed a measure of "discontinuity" in an analysis of ethnicity in England. This represents a missed opportunity for ethnic/racial studies that aim to capture the residential variation in ethnic group settlement and dispersal between multiple groups, across places and between dimensions of ethnic mixing. This paper thus offers a rare exception to the literature, via an innovative analysis of different dimensions of ethnic segregation locally, at the "national" level and for multiple groups.

In light of these identifiable gaps in the existing literature, and the opportunities offered by the spatial and local measurement of segregation, three core themes are explored in this paper: (1) the intricate small area geographies of ethnic group population distributions which cannot be captured with aspatial measures; (2) the multiple spatial scales of segregation and their variation between ethnic groups, using a flexible approach to delimitating zone boundaries rather than pre-prescribed (and often socially meaningless) administrative boundaries; and (3) the relationships between different forms ("dimensions") of segregation, and how these vary across spatial scales. These collectively offer a comprehensive and detailed evidence base on the ways in which members of ethnic groups are residentially integrated, and the different ways ethnic groups may interact across residential spaces.

The analyses are based on 2011 Census small area data, which are detailed next in addition to the methodology. The results sections begin with an overview of global aspatial and spatial segregation for all ethnic groups in England and Wales, before focusing on four ethnic group "case study" examples: White British, Indian, Bangladeshi and Chinese. For these groups, the impact of changing zonal size (spatial scale) on segregation values is interrogated, before geographical variation in unevenness and isolation is explored visually via maps of local index values, and finally the relationships between dimensions of segregation and group size are analysed.

# 3 | DATA AND METHODOLOGY

Data are derived from the 2011 Census of population of England and Wales, the most recent survey which offers full population coverage at small geographical levels and with an ethnic group breakdown (the 18 major ethnic groupings reported can be found in Figure 1). Segregation is explored for lower super output areas (LSOAs), which are aggregations of output
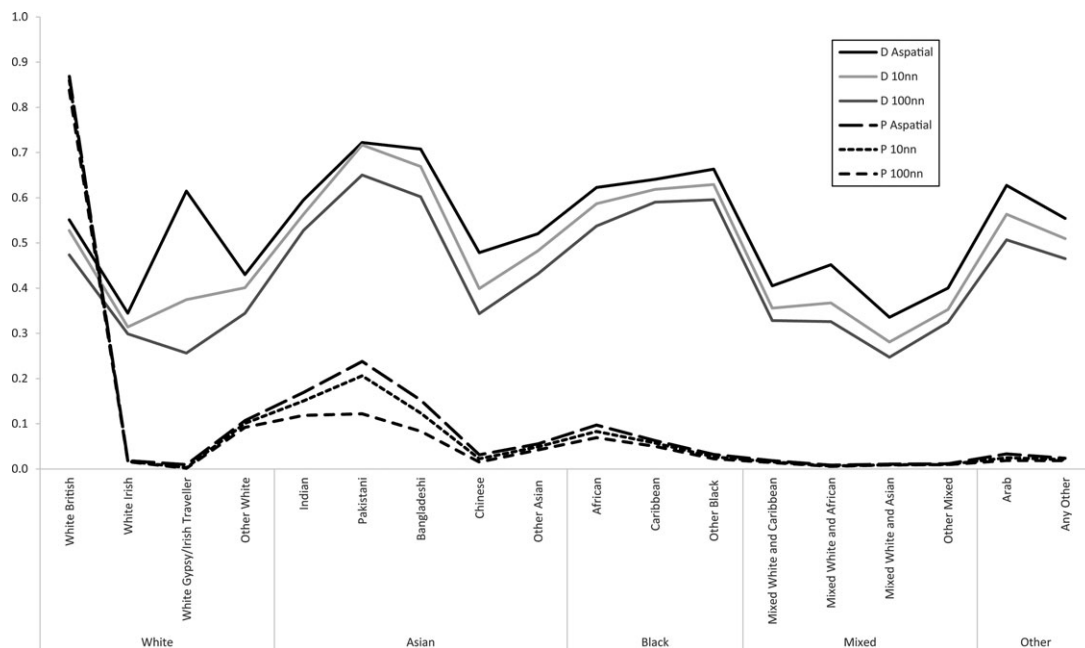


**FIGURE 1** Global aspatial and spatial unevenness (D) and isolation (P), all ethnic groups, England and Wales, 2011

*Notes*: England and Wales 2011 population = 56,075,912. Ethnic groups as percentage of population: White British = 80.5; White Irish = 0.9; White Gypsy/Irish Traveller = 0.1; Other White = 4.4; Indian = 2.5; Pakistani = 2.0; Bangladeshi = 0.8; Chinese = 0.7; Other Asian = 1.5; Black African = 1.8; Black Caribbean = 1.1; Other Black = 0.5; Mixed White and Caribbean = 0.8; Mixed White and African = 0.3; Mixed White and Asian = 0.6; Other Mixed = 0.5; Arab = 0.4; Any Other = 0.6

*Source*: 2011 Census, Table KS201EW (Crown Copyright). Author's own calculations

areas, the smallest Census geography. LSOAs are designed to be homogenous in terms of their population size ($n = 34,753$ LSOAs; mean population = approximately 1,600). These units offer a suitable compromise between very small areas which result in too much noise in the measurement of segregation locally, and larger spatial units which overly smooth spatial variation in ethnic group populations. The measurement of segregation for LSOAs[1] with flexibly defined neighbourhoods (using a locally adaptive kernel, as defined below) is an advantage over its measurement for small areas in larger zones (e.g. output areas within a city district), since the latter impose an a priori hierarchy of administrative boundaries. All mapped data make use of cartograms for clarity[2] (where the zones are made proportional to their population size; Dorling, 1996).

Rather than seeking to identify an "optimal" set of dimensions of segregation (e.g. Johnston et al., 2007; Reardon & O'Sullivan, 2004), the concern is instead with two dimensions – evenness and exposure, as measured by the Indices of Dissimilarity ($D$) and Isolation ($_mP^*_m$, hereafter $P$) (see S1) – which are argued to provide distinct information about the geographies of ethnic residential patterning (e.g. as evidenced by Lloyd & Shuttleworth, 2012). In this study, each ethnic group is compared to the rest of the population, for both segregation measures. Aspatial (S1.1), spatial (S1.2) and local (S1.3) (following Feitosa et al., 2007) versions of these measures are computed, and variation in these dimensions of segregation is accounted for by using multiple neighbourhood sizes, as represented by the bandwidth of the weighting functions defined in S1. For clarity, such weighting functions are often termed "kernels" and the size of the kernel (its spatial extent) is defined by its bandwidth. Two forms of kernels are used: the first uses a fixed distance around each zone (Gaussian function with *fixed bandwidth*; Fotheringham, Brunsdon, & Charlton, 2002) and the second uses a predefined number of zones (e.g. the 100 nearest LSOAs; bi-square function with *adaptive bandwidth*; Fotheringham et al., 2002); the latter is the main focus. In practice, the specific form of kernel selected is unlikely to have a major impact on the results; rather, it is the bandwidth which is most significant (Fotheringham et al., 2002).

# 4 | GLOBAL AND LOCAL SEGREGATION

This first analytical section provides an overview of the measures of the two dimensions of segregation explored in the paper, evenness ($D$) and exposure ($P$), for all 18 of the major ethnic groups of England and Wales (Figure 1).

Global (aspatial) segregation values are presented for context; these are discussed in depth elsewhere (Catney, 2016b, 2017). As a brief summary: low levels of unevenness in the White Irish and Mixed groups are matched by low levels of isolation from other groups. High unevenness and isolation are shown for the South Asian groups (although with moderate levels of unevenness for the Indian group). Unevenness and isolation are moderate-high for the Black ethnic groups, and relatively low for the Chinese group. Isolation from other ethnic groups is highest for the White British group, whereas unevenness is moderate. In contrast, the Other White ethnic group exhibits relatively low levels of unevenness, but high isolation. As we shall see later in the paper, $P$ provides insight into a conceptually distinct aspect of ethnic group separation to $D$, and so unevenness for one group may be relatively high while isolation is low for that group. In other words, a group could be spatially uneven in some regions, but exposed to members of other ethnic groups.

After exploring segregation at multiple adaptive bandwidths, two spatial scales have been selected for segregation measurement: 10 and 100 nearest neighbours. The prescriptive terms "micro" and "macro" segregation (as with, for example, Johnston et al., 2016; Reardon et al., 2008) provide a useful means of categorising scale differences. However, these terms have been avoided in this study in recognition of the multiscalar nature of segregation (Fowler, 2016), which will vary between groups and geographical areas. As a guide for the discussion of results, areas are referred to as (1) "neighbourhoods", "small areas", or "local", or (2) "regional" or "large areas". The former relate to small numbers of nearest neighbours (10) and/or small distance bandwidths (up to 10 km). These areas are intra-city, including smaller walkable distances up to the extent of an urban area. The latter might be thought of as inter-city or between urban–rural areas.

Without exception, global aspatial $D$ and $P$ values are higher than their spatial equivalents at 10 nearest neighbours, which are higher than (or identical to, in the case of three Mixed ethnic groups for $P$) the group's value for spatial segregation at 100 nearest neighbours. The impact of scale on spatial segregation is explored in more depth later in the paper.

# 5 | ETHNIC GROUP DISTRIBUTIONS

This section provides context for the spatial distributions of selected ethnic groups using percentage maps. They illustrate the unequal geographical distributions of ethnic groups across England and Wales and provide a platform for comparison

later in the paper, so that a judgement can be made as to what local measures of segregation contribute above this simple representation of ethnic group residential geographies. The ensuing statistical analyses are complex and information-dense; for the sake of clarity and space, four case study ethnic groups will form the basis of the rest of the analyses: White British, Indian, Chinese and Bangladeshi.

Figure 2 shows the four ethnic groups (a–d) as a percentage of the total population in each LSOA. The contrasting geographical distributions and characteristics of these groups – in terms of histories of settlement and migration, group size, and economic and educational well-being (Jivraj & Simpson, 2015) – mean that the groups represent useful examples for the spatial components of this analysis. The majority ethnic group, White British, is populous across all of the study area, in both urban and rural areas. Along with the largest minority group (Indian), the White British group has moderate unevenness and high isolation. The Bangladeshi population was found to have among the highest levels of minority group
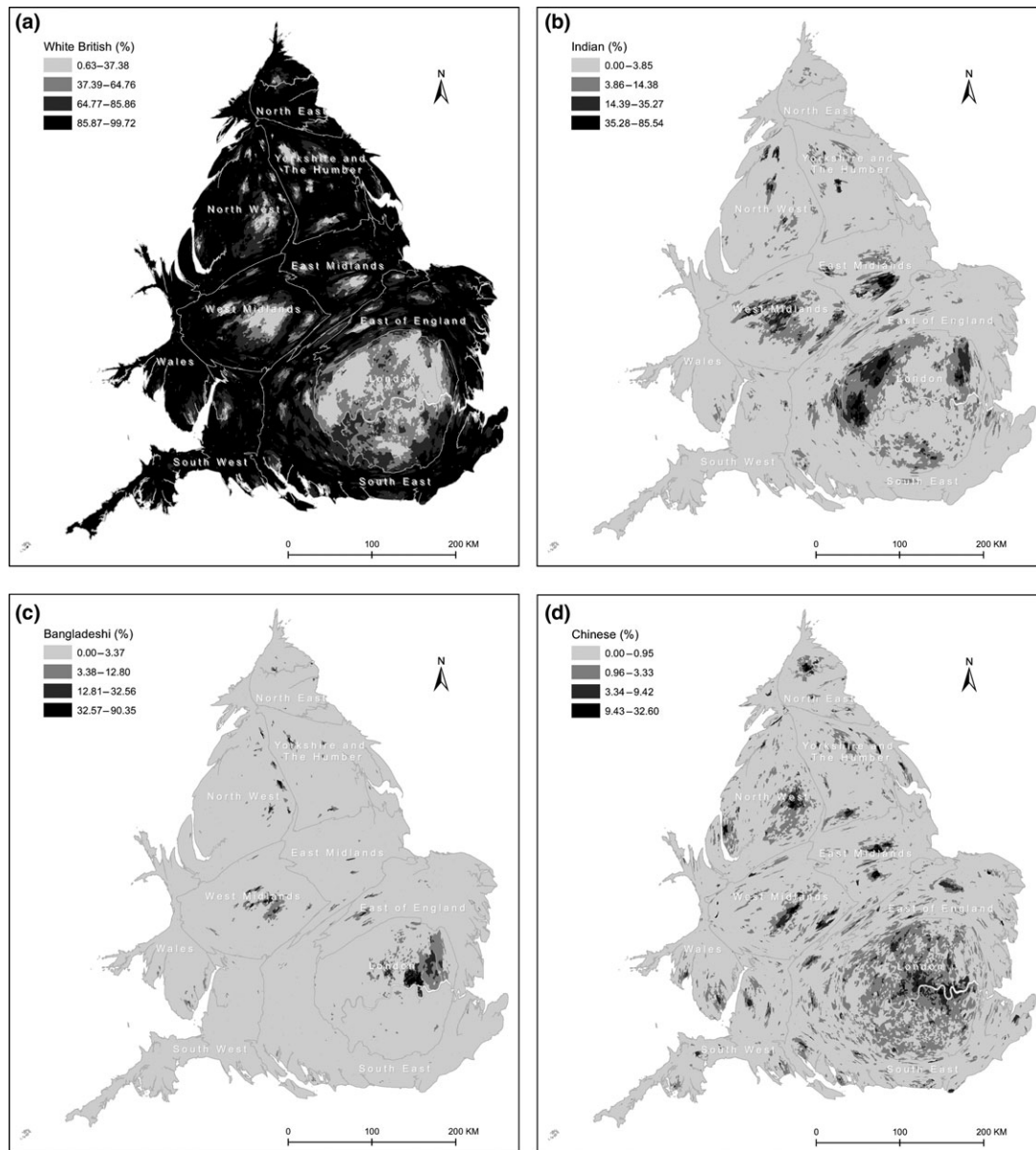


**FIGURE 2** Percentages of population identifying with (a) White British, (b) Indian, (c) Bangladeshi and (d) Chinese ethnic groups, LSOAs, England and Wales, 2011

*Notes*: For reference, the nine regions of England plus Wales are labelled. Given the great disparities in the ranges of ethnic group proportions, the category ranges vary for each group; the extent of these ranges are in themselves informative of the differences in group spread. The classes are determined using the natural breaks scheme of Jenks (Jenks & Caspall, 1971)

*Source*: 2011 Census, Table KS201EW (Crown Copyright). Author's own calculations

unevenness and isolation (Figure 1), given its geographical concentration in east London. The Chinese ethnic group is selected because it has very low national levels of segregation (Catney, 2016b); while similar in size to the Bangladeshi ethnic group, the Chinese population has a much more geographically spread residential distribution, which includes urban and rural locales. Hence although these two groups are relatively small minority groups, their specific spatial configurations represent useful examples to demonstrate the power of local segregation modelling.

## 6 | SCALES OF ETHNIC GROUP SEGREGATION

The scales at which segregation can be observed for each group are next considered. Figure 3 is a graph of spatial unevenness and isolation for bandwidths of 0 (aspatial measure), 1 and at 5 km intervals, up to and including 100 km (fixed bandwidth). Distance bandwidths provide insight into segregation across multiple scales, from the neighbourhood to the regional, and for the whole of England and Wales, rather than just urban locales. These spatial measures are informative of the size of ethnic group concentrations, and thus the spatial organisation of groups between neighbourhoods and larger areas.

It is immediately clear that the scale of segregation varies both *between* and *within* ethnic groups: different values for each ethnic group are observed according to the scale at which segregation is measured, and also for the same ethnic group at different geographical scales. For both dimensions of segregation explored here – evenness and exposure – each ethnic group has higher levels of segregation at small "neighbourhood" scales, and less at large "regional" scales. It is no surprise that segregation levels are higher in small areas; neighbourhoods are more likely to share similar population characteristics than are regions (although for insight into the complexity of this relationship, see Johnston et al., 2016). However, the impact of scale is not uniform for each ethnic group.

Taking spatial unevenness (D) first, of the four groups shown, the Bangladeshi group has the highest levels of segregation at the local level, but unevenness falls sharply as the neighbourhood size increases. Indeed, this group has the most notable difference in segregation levels between small and larger areas; that is, Bangladeshi segregation levels are high relative to other groups, but these high levels are only very localised. For a 35 km bandwidth, for example, Bangladeshi segregation is lower than for the White British and Indian ethnic groups. Indian and White British segregation decreases steeply at the smallest neighbourhood size (between 0 and 10 km).
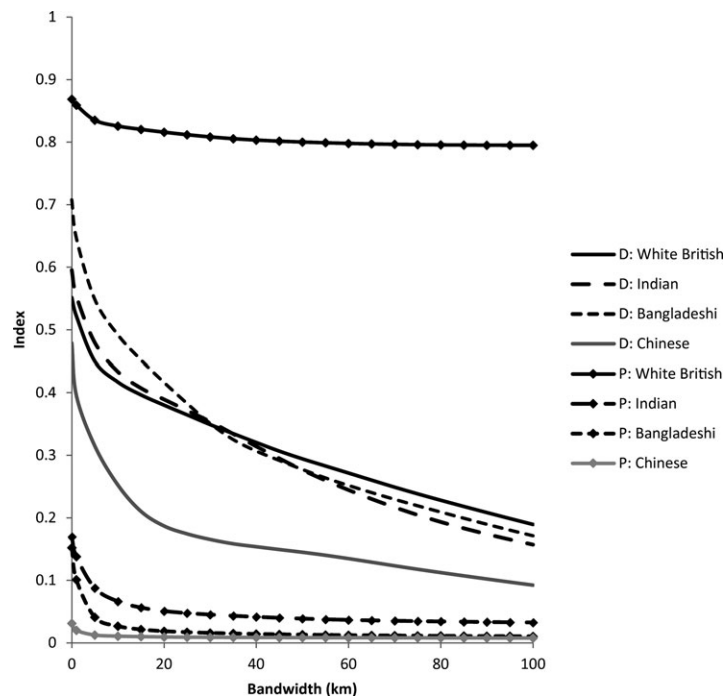


**FIGURE 3** Scales of segregation: Spatial unevenness *(D)* and isolation *(P)* by distance bandwidth for White British, Indian, Bangladeshi and Chinese groups, England and Wales, 2011
*Source*: 2011 Census, Table KS201EW (Crown Copyright). Author's own calculations

The relative levels of segregation between ethnic groups vary across spatial scales, so that a given group might be relatively more unevenly spread than another at one spatial scale, with the order reversed at larger scales. For each of the White British, Indian and Bangladeshi groups, the relative size of $D$ (that is, the order between groups from highest to lowest) changes at a bandwidth of between 30 and 40 km. For those bandwidths, segregation levels for the Bangladeshi group decrease, and White British levels of unevenness are the highest of the four groups – an observation found for all subsequent scales, up to and including the largest spatial scale (100 km). An exception is the Chinese group, whereby unevenness levels are consistently lower than for the three other groups at *all* spatial scales, reflecting this group's comparatively even spread across England and Wales (Figures 1 and 2).

There are less notable differences in the levels of isolation ($P$) at different scales for each ethnic group, but nonetheless, for this measure – as with unevenness – segregation values are higher at smaller than larger spatial scales. The largest declines are observable for very small bandwidths (around 5–10 km for the ethnic groups shown). Changes in $P$ with increasing bandwidths reflect the different sizes (or scales) of concentrations of each group. The small dip in $P$ values for the White British group (at 5 km) is largely attributable to members of the White British group being more exposed to members of other ethnic groups in London and Birmingham than elsewhere where the group is geographically isolated and $P$ values are consistent (and high relative to the other groups).

# 7 | THE GEOGRAPHIES OF LOCAL SEGREGATION

The indices presented in Figure 3 are spatial measures, computed as a sum of local components, where neighbourhoods are defined as a fixed distance around each LSOA. While bandwidths of fixed distance provide insight into the scale of segregation, this is not an appropriate approach for measuring *local* segregation, since the kernel will smooth variation in urban areas (with many small LSOAs) and will be too small in sparsely populated rural areas. In contrast, the following analysis utilises a nearest neighbour approach (adaptive bandwidth), using a set number of zones rather than the size of an area (as defined earlier), and local segregation values are explored for each *individual* LSOA. Experimentation with different bandwidths showed that 10 and 100 nearest neighbours captured much of the geographic variability in segregation levels.[3] The former represents a more "local" set of zones while the other represents a broader geographical area, or region.

One of the major advantages of the local measurement of segregation is that the outputs are mappable and local values are not bounded by larger areas such as cities (as with global measures; for example segregation might be computed for all output areas within the local authority district of Manchester, as with Catney, 2016b). Unlike with global (whether standard aspatial or spatial) measures of segregation, the comparison of segregation between areas is valid (for a discussion of the problems of comparing global segregation values between geographical areas, see Simpson, 2007). Spatial $D$, here computed using a fixed number of neighbours, decomposes into local components (see S1), which are shown in Figure 4 for (a) White British, (b) Indian, (c) Bangladeshi and (d) Chinese ethnic groups. Given space constraints, segregation values for a bandwidth of 10 nearest neighbours only are shown. These mapped local values allow an assessment of which small areas contribute to spatial (global) unevenness values.

The most obvious message from Figure 4 is that spatial unevenness has very distinctive geographies. While some ethnic groups share similar values of global aspatial $D$ (White British and Indian: Figure 1), these measures conceal a huge amount of geographical variation between and within groups. These disparities are particularly notable in London and Birmingham (located in the West Midlands region), but not exclusively so. Indeed, the figures demonstrate how the differing spatial distributions of ethnic groups cannot be sufficiently captured by focusing on metropolitan areas alone. While the White British group, for example, has low unevenness throughout England and Wales, areas of relatively high unevenness are not restricted to the most densely populated urban locales. The patchwork of Chinese distributions would clearly be missed by exploring segregation solely in urban areas.

For each of the ethnic groups shown in Figure 4 there are relatively large values of unevenness in the north of England, including in and near the North West cities of Liverpool and Manchester, as well as Leeds and Bradford (Yorkshire and the Humber) – areas with histories of the minority groups' settlement and growth. Figure 4a shows that for the White British group by far the largest contributions to $D$ are in London and Birmingham. The Indian and Bangladeshi ethnic groups (Figure 4b, c) have more obvious large values of unevenness outside London compared to the Chinese and White British groups, including in Birmingham, Leeds and Bradford, and Leicester and Nottingham (East Midlands). The Indian ethnic group appears to have the largest areas of localised $D$ (although this is of course relative to the range of values for this group), while the Bangladeshi group, which has among the largest global aspatial $D$ values (Figure 1), has a much more localised "concentration" of unevenness, as also suggested by Figure 3. Segregation values for the Chinese group are lower
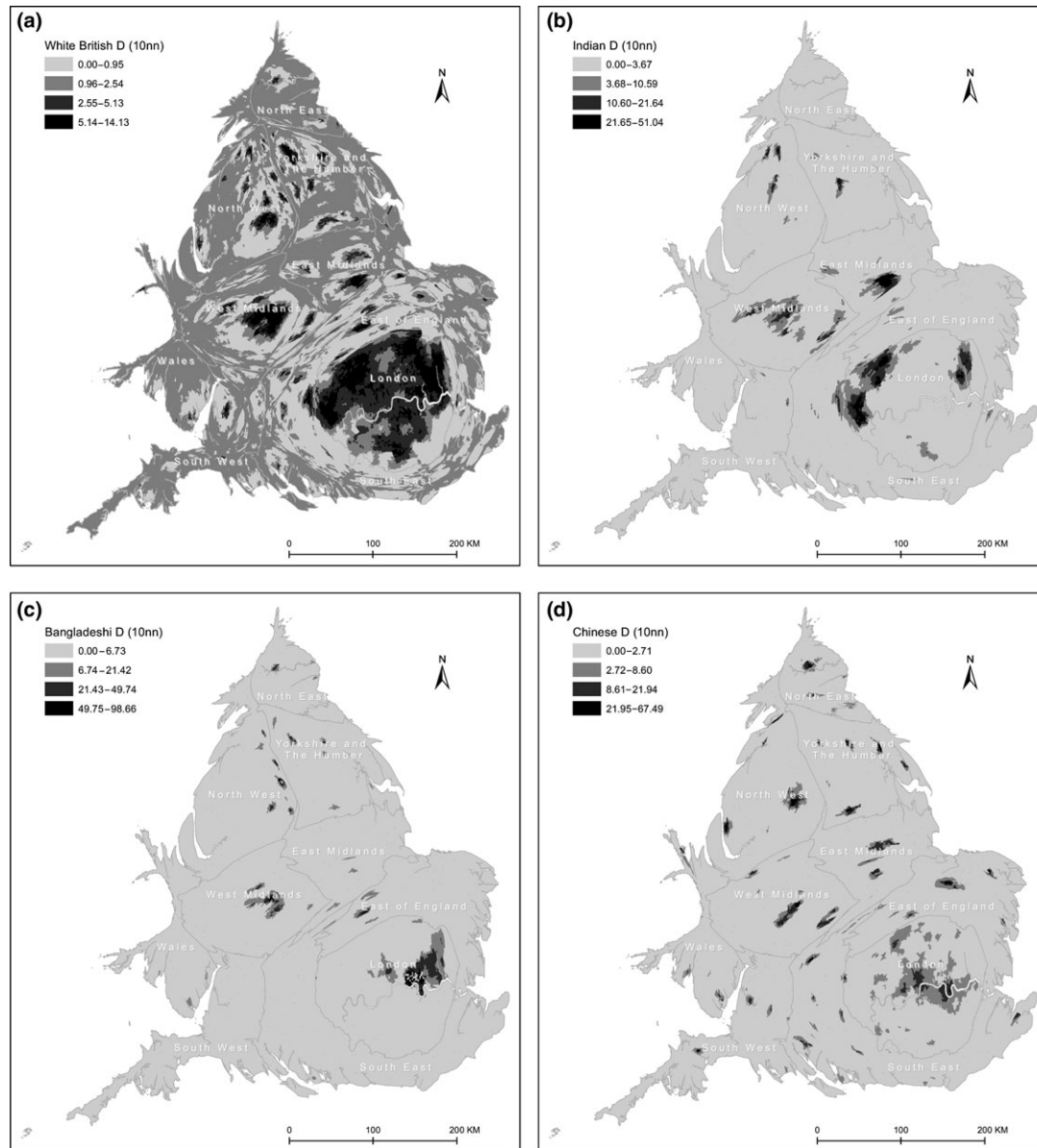
**FIGURE 4** Local unevenness (*D*) for 10 nearest neighbours for (a) White British, (b) Indian, (c) Bangladeshi and (d) Chinese ethnic groups, LSOAs, England and Wales, 2011

*Notes*: The maps for each ethnic group have different categories of unevenness to best reflect their own ranges; it should thus be remembered when comparing geographical patterns between ethnic groups that the values are relative

*Source*: 2011 Census, Table KS201EW (Crown Copyright). Author's own calculations

in most areas and less spatially distinct than for the other groups shown. Commensurate with their more dispersed presence across the country, the Chinese group (Figure 4d) has moderate values of *D* in less urban areas of England and Wales, which are not distinguishable for the other ethnic groups.

One of the most distinctive patterns between the ethnic minority groups shown is found in London, where the places which have low or high segregation are not uniform for all groups. For example, for the Indian ethnic group, unevenness values are relatively high in north and western areas, but low in the rest of the capital. Bangladeshi unevenness is larger in the mid-northern areas of London but low elsewhere, and the Chinese group has a more dispersed pattern of *D* values, with some pockets of unevenness across London, but which are not as "regionalised" as for the other groups.

If we consider ratios (not shown given space constraints) of macro (zone size of 100 nearest neighbours) to micro segregation (10 nearest neighbours) (as applied for the US by Reardon et al., 2008), the White British group has very localised high ratio values in London and Birmingham compared to fairly homogenous low values throughout the rest of England

and Wales; these ratio values reflect the localised high unevenness and regionalised evenness of this group. There are no clear trends for the Indian, Bangladeshi and Chinese groups, with the exception of some patches of high ratios in London, Birmingham and some areas of the mid-north of England, reflecting localised high unevenness, with low unevenness in most other locales with respect to the rest of the population.

Figure 5 illustrates the local components of spatial isolation ($P$). The maps for each ethnic group demonstrate how isolation is highly localised, and considerably more so than for unevenness. Given that values of this index are a function of group size, relative values are of greater use than absolute values. Figure 4 illustrated how zones with high values of $D$ tended to be surrounded by zones with similarly high values; with $P$ this is not the case. Very tightly-bounded concentrations of high isolation are observable for the Bangladeshi ethnic group, whereas concentrations of high $P$ values are less obvious for the Indian ethnic groups and even less so for the Chinese group. Low values of White British isolation from the rest of the population are notable in London and other large urban centres.
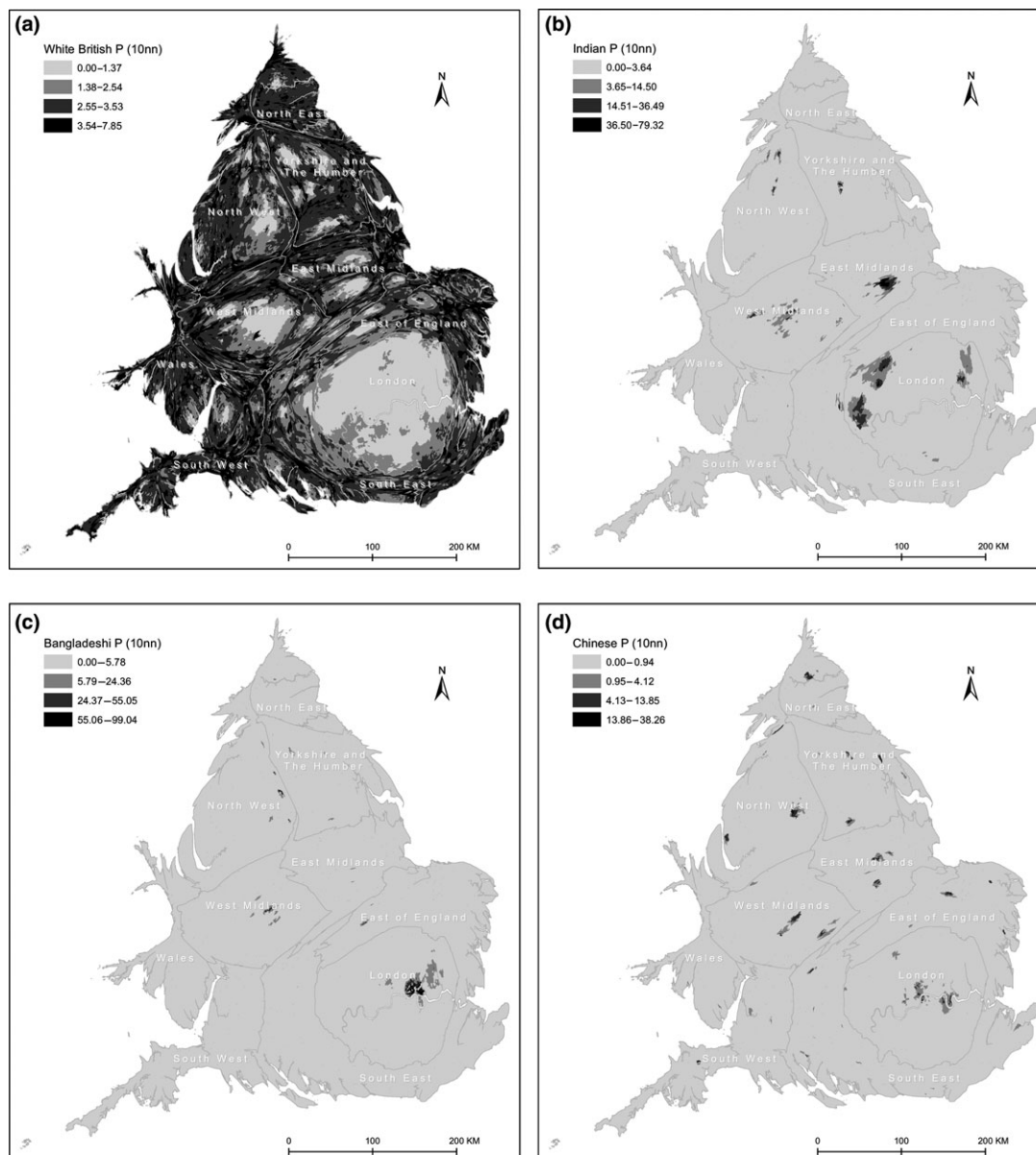


**FIGURE 5** Local isolation ($P$) for 10 nearest neighbours for (a) White British, (b) Indian, (c) Bangladeshi and (d) Chinese ethnic groups, LSOAs, England and Wales, 2011

*Notes*: As for local $D$, the range of values for each ethnic group varies

*Source*: 2011 Census, Table KS201EW (Crown Copyright). Author's own calculations

**TABLE 1**  Correlations between $D$ and $P$ (10 and 100 nearest neighbours) and percentages, by ethnic group, at LSOA level

| Ethnic group | D vs P (10nn) | D vs P (100nn) | D (10nn) vs % group | D (100nn) vs % group | P (10nn) vs % group | P (100nn) vs % group |
|---|---|---|---|---|---|---|
| White British | −0.573 | −0.559 | 0.102 | 0.094 | −0.118 | −0.123 |
| Indian | 0.890 | 0.817 | −0.014 | 0.001 | −0.020 | −0.018 |
| Bangladeshi | 0.754 | 0.785 | 0.042 | 0.043 | 0.035 | 0.034 |
| Chinese | 0.805 | 0.677 | −0.017 | −0.035 | −0.016 | −0.022 |

*Notes.* All correlations are significant at the 0.01 level with the exception of that for $D$ (100nn) vs % Indian. nn is nearest neighbours.
*Source*: 2011 Census, Table KS201EW (Crown Copyright). Author's own calculations.

# 8 | EXPLORING THE RELATIONSHIPS BETWEEN LOCAL UNEVENNESS AND ISOLATION

This final analytical section considers how unevenness and isolation might be related between ethnic groups and across spatial scales. The preceding analyses and allied research suggests that $D$ and $P$ provide distinct information, however little is known about the relationship between segregation dimensions for multiple ethnic groups at the local level. Here the relationships between local evenness and local isolation are explored, considering if the associations between these two dimensions of residential segregation are stronger at one spatial scale than another. Local segregation measurement allows for these relationships to be analysed, since a value is assigned to each local area (in this case, each LSOA). The correlation coefficients between local $D$ and $P$ are reported for each selected ethnic group for 10 and 100 nearest neighbours in Table 1.

Perhaps the most obvious difference in the nature of the relationships between ethnic group segregation is that unevenness and isolation are negatively correlated for the White British group, but positively correlated for the ethnic groups Indian, Bangladeshi and Chinese. Referring back to Figures 4 and 5, we can observe that while White British $D$ levels are high in London and other urban areas, $P$ is relatively low for these locales. On the other hand, $D$ and $P$ are generally high in the same urban areas for the three ethnic minority groups reported. A second observation is that the White British group demonstrates the weakest relationship between these dimensions of segregation, at both spatial scales. The range of values of unevenness and isolation are smaller for this ethnic group than for the other groups shown (as denoted by the maximum values in Figures 4a and 5a). This likely reflects the large size of this group and its larger share of the population in most small areas throughout England and Wales. Thirdly, while the correlation coefficients for 10 and 100 nearest neighbours for the White British, Indian and Bangladeshi groups are similar, the relationship between unevenness and isolation is rather different at these two spatial scales for the Chinese ethnic group (0.805 for 10 nearest neighbours, and 0.677 for 100 nearest neighbours). This relates to the fact that distinct spatial concentrations of the Chinese population are numerically few and tend to be small in size, with no obvious regional (large-scale) pattern to this group's spatial distribution (Figures 4d and 5d). Finally, it is notable that, contrary to the results for the three other ethnic groups presented, Bangladeshi evenness and isolation are more strongly related at larger rather than smaller spatial scales. This reflects the very fine-scale spatial concentration of much of the Bangladeshi ethnic group in one area of London (Tower Hamlets) and Oldham in Greater Manchester; here, there is a very high value of local $P$ at the neighbourhood scale (10 nearest neighbours). This isolation value is notably larger here than in other areas, while the corresponding unevenness value is less distinct. Once the neighbourhood size is increased, this atypically large value of isolation decreases and the relationship between isolation and evenness thus becomes stronger.

Table 1 also presents correlations for unevenness and isolation with percentages at LSOA level, for the four ethnic groups. Neither dimension of segregation is strongly correlated with own-ethnic group percentage, for any group. This confirms the added value of local measurement beyond ethnic group concentration as measured through percentages.

# 9 | DISCUSSION

The findings provide clear evidence that there is a pronounced geography of ethnic residential segregation, with very localised spatial variability in ethnic group distributions. While national and city-level aspatial "global" segregation measures have utility – in particular for comparing experiences between groups, for monitoring change over time and for informing

policy (Catney, 2016b, 2017) – the findings suggest that more spatially-sensitive studies of segregation should become the primary method to properly characterise residential integration. The spatial variation in segregation observed, and the differing impacts of scale for each ethnic group, force us to be mindful of the intricate and diverse experiences of segregation within ethnic groups, and not just between them.

A powerful example is provided through analysis of the Bangladeshi ethnic group, which is understood as among the most segregated of all groups in the UK (Catney, 2016b; Figure 1). The results suggest that aspatial index values have a role, but cannot provide the full picture. The Bangladeshi group has high levels of segregation for only very small spatial scales and in very concentrated locales (primarily in inner London), and lower segregation levels than for other ethnic groups across larger areas (Figure 3). This not only challenges our understandings of segregation patterns, but hints at the reasons behind them. For the Bangladeshi group, pockets of segregation are small-scale and geographically rare (and, as shown by Johnston et al.'s (2016) analysis of London, declining at the micro-scale), despite the comparatively high levels of segregation found for this group at the national level. These localised concentrations in areas with a long history of Bangladeshi settlement – such as Tower Hamlets in east London – might be the outcome of housing pressure and overcrowding (Finney & Lymperopoulou, 2014), or, more positively, reflections of strong neighbourhood attachment and belonging.

This paper began by arguing that the diversification of traditionally less ethnically diverse spaces has been largely ignored in residential segregation studies. While change over time was not explored, the analysis has shown very clearly that by focusing on national rather than city-wide patterns of segregation, we can gain a better understanding of the complexities of residential geographies within and between groups. As examples, the Chinese group's residential settlement distribution is not urban-focused, unlike several other minority groups (Catney, 2016b), and variation in segregation for this group is missed by not moving beyond metropolitan spaces. The White British group is dominant in large areas of rural England and Wales, but (relatively) higher levels of segregation are not restricted to urban areas for this group.

The analysis of the relationship between segregation dimensions and percentages is illuminating in several respects. The results demonstrate the added benefit above and beyond own-group percentages of using local segregation indices, and a composite measure of the spread of an ethnic group and their spatial isolation in neighbourhoods, to explore ethnic group geographies. While numerous empirical studies employ measures of "co-ethnic concentration" (percentages) to consider the association between social and economic outcomes and segregation (particularly in health research, for example), this suggests the need for a greater sophistication in the approaches used to measure segregation at the local level.

While rationalising segregation dimensions into "superdimensions" of segregation provides a powerful means of summarising segregation (Johnston et al., 2007; Reardon & O'Sullivan, 2004), the findings presented here suggest that more research is required which considers the ways in which these dimensions inter-relate across space and at multiple scales. In this paper, it was found that the correlations between unevenness, isolation and group percentages were generally weak (particularly between both segregation dimensions and group percentages), as well as variable between ethnic groups and across spatial scales, as measured here for neighbourhoods and regions. Large values of unevenness ($D$) did not consistently correspond to large values of isolation ($P$) for the same locale, and isolation appeared to be more sensitive to local features, for example with more pronounced transitions in values of local $P$ than of $D$ at the edges of areas with a large share of a given ethnic group. Residuals from the regression of local $D$ (as the independent variable) against local $P$ (as the dependent variable: not shown given space constraints) indicate that these measures are strongly related in some areas, but not in others. It is the relationship between these two dimensions – the fact that they are not linearly related across all neighbourhoods and thus provide distinct information on local segregation – which makes their use in conjunction valuable. These results are interpreted in the context of the very different characteristics of ethnic groups, including population size, geographical spread and spatial configuration (e.g. an area of high own-group concentration neighbouring an area of low own-group concentration), and how these group-specific characteristics affect the spatial dynamics of other groups.

In short, segregation measures are scale-dependent and thus the relationships between them are too. Since the results demonstrated that there is not a linear relationship between index values and the size of neighbourhood analysed, this geographical and ethnic group specificity renders a priori selection of segregation dimensions problematic. Yet the existing literature has not to date fully explored the concept that segregation dimensions do not have the same meaning at each scale. A key message from these results is that studies which incorporate scale, locality *and* dimensions would provide the most comprehensive understanding of the dynamics of ethnic group distributions.

The scales of segregation are significant as they hint at the possible mechanisms behind and consequences of segregation, and the group-specific experiences of these. The flexible boundaries permitted using spatial measures of segregation are not only more sensitive to "on the ground" spatial barriers than administrative areal units, but they also allow the definition of neighbourhood to vary between each ethnic group. Spatial and local models of segregation provide an opportunity to consider these scales.

For all ethnic groups, segregation (unevenness and isolation) levels decrease sharply beyond very small spatial scales. This observation – that segregation is higher in smaller than larger areas – is well-known, however the specific scales at which these decreases occur, or ethnic group variation in these scale effects, are not. The pronounced dip in segregation (for both measures) at around 5–10 km is suggestive of the nature of ethnic residential segregation, and may be indicative of the processes behind it. Segregation is clearly high only in tightly-bounded local areas: at the street-level or within housing developments. Beyond these very small spatial scales, segregation between ethnic groups falls dramatically, suggestive of greater interactions across larger areas. Members of different ethnic groups are mixing residentially within their wider urban area – across *several* streets, *between* housing developments. Observed at these larger – and yet (importantly) still relatively small – spatial scales, the population is more residentially integrated.

Yet the thresholds of segregation identified are not uniform across ethnic groups (as also demonstrated in allied research on London's changing ethnic segregation patterns by Johnston et al., 2016), and through this approach one is able to identify bespoke "cut-offs" for which segregation might be observed (for example, for unevenness, around 1 km for the Bangladeshi group and 5 km for the Chinese group). This has important implications for how we understand the scale of ethnic interactions, reflecting what we might term "operational spaces". An area of 5 km will be bigger than, say, a city's China town, but smaller than the city's district boundaries, and, perhaps importantly, is easily manoeuvred (for many it is walkable, for example).

Fowler (2016, p. 25) urges us to move away from erroneously seeking to identify a "correct" scale of analysis, while Reardon et al. remind us that "there is no single geographic scale of segregation" (2008, p. 490). A continuum of segregation across spatial scales has also been demonstrated for the ethnic groups in this study, however identifying a "characteristic" scale at which segregation is most prominent (or on the contrary least evident) might help us to identify the extent of ethnic spaces, and in turn may be informative of spatial horizons, spatial knowledge, local networks, and physical and social barriers and their interactions and implications for ethnic mixing. For example, if small- but not large-scale segregation is observed for a given ethnic group, we might deduce that there are few opportunities for mixing with other ethnic groups in the immediate residential neighbourhood, but greater opportunities in the larger-scale spaces – wider areas where individuals may also work, go to school, or shop and socialise. If segregation is observed for micro- *and* macro-scales, then there is little evidence of mixing at any scale, suggestive of few opportunities for contact with other groups.

## 10 | CONCLUSIONS

A sophisticated picture of small area ethnic spatial mixing in England and Wales has been presented in this paper, by paying attention to the local variation in segregation as yet largely overlooked for the British case. The results have revealed that this spatial complexity is inter- and intra-ethnic, inter- and intra-neighbourhood, and, as studies for elsewhere have shown, highly dependent on the scale and measure of segregation selected, neither of which operate independently of each other. It is obvious that one size does not fit all in studies of ethnic relations across space. By determining *which* geography matters – just how small-scale analyses need to be in order to understand ethnic group dynamics – we can better understand ethnic patterns and the processes behind them. This has potential currency beyond the British case, beyond research on segregation, and both within and between the discipline of Geography and allied Social Sciences. The lessons learned could be applied to research which is quantitative or qualitative (or mixed methods), national or locality-based, focused on one group or many, and concerned with one or more time periods. The specific scales and geographies identified through research such as that presented here could be used to inform the methodological approaches to, conceptual understandings of, and interpretations of empirical evidence in studies of: ethnic inequalities, discrimination and inclusion (and the lived experiences thereof); inter-ethnic relations in local place and space; minority (im)mobilities; neighbourhood identity, representation and belonging; the evolution of (super-)diversity and its consequences; and migrant place-making.

Methodologically, the results presented encourage us to reconsider existing analytical approaches to studying segregation, in particular the conclusions on the impact of scales of measurement and the relationships between segregation dimensions. The findings demonstrate how the same data analysed differently (for example, with aspatial measures) can produce rather different conclusions about the comparative levels of segregation between ethnic groups, and how segregation can be understood in specific locales. This is an important issue in the UK context given highly politicised debates about the extent of ethnic mixing in an increasingly diverse society.[4]

While the suggestion that segregation varies across spatial scales is not new (although the empirical evidence for the British case developed here is novel), nor is the integration of flexible scales in measuring segregation (e.g. Reardon et al.,

2008), here it is argued that the insight this spatial and scale variation in ethnic residential segregation offers has to date been undervalued in developing conceptual frameworks about ethnic interactions across neighbourhood space. This is especially important in considering emerging spaces of ethnic diversity beyond the city boundary (Catney, 2016a; Lee & Sharp, 2017; Lichter, 2012), which have hitherto been overlooked.

The use of measures of unevenness and isolation in combination offer additional insights into the nature of segregation for each ethnic group and across space, with opportunities for understanding better their evolution over time. In addition to the multiple opportunities for how local perspectives may infiltrate other studies of ethnic processes, there are numerous ways in which this work could be extended, within and beyond this case study area: analyses of change through time would be particularly insightful since we can suppose that for each group the dimensions may change together in different ways; this would provide a comprehensive picture of changing ethnic group geographies across space *and* time. This may also help to shed light on the pace of change for newly diversifying locales, which has policy as well as academic value. The local measures of segregation developed here could be used to inform research in the outcomes of inequalities, for example such as for health or crime (McLennan, Noble, & Wright, 2016). There are also potentially fruitful avenues in research on the multiplicity of mixing, which is undermined by studies that focus on just one arena of segregation – for example residential, workplace *or* schools. How scales of segregation operate, and vary within and between ethnic groups, could be better understood through a more comprehensive examination of the numerous ways people of different ethnicities come together and interact.

The results presented in this paper demonstrate the rich and complex tapestry that characterises the ethnic geographies of England and Wales. The links between the scale, locality and dimensions of segregation have been explored, but much more research is needed into these relationships. The scale dependency of the dimensions of segregation is also context dependent: Are the implications of residing in a neighbourhood with high unevenness different to those for a neighbourhood where isolation is high? Is it appropriate to measure exposure across a large area, or is this dimension more suited to exploring micro-scale segregation? Such questions provide impetus to capture the dimensions of segregation locally, in order to more fully understand the intricacies of (non-)interaction across ethnic spaces.

## ENDNOTES

[1] The analyses were undertaken using purpose-written R and Fortran routines.

[2] Cartograms were created using the ArcGIS Cartogram Geoprocessing Tool version 2 written by T. Gross and which uses the approach developed by M. Newman and M. Gastner of the University of Michigan (http://www.arcgis.com/home/item.html?id=d348614c97264ae19b0311019a5f2276).

[3] However, in some senses smaller or larger bandwidths would still offer the same insight for certain types of neighbourhoods; if a group is very locally clustered then this may be observed regardless of the number of nearest neighbours selected.

[4] For examples of these debates in the media and policy, see: https://theconversation.com/britain-is-becoming-more-diverse-not-more-segregated-68610 and https://www.theguardian.com/society/2016/nov/01/call-for-action-to-tackle-growing-ethnic-segregation-across-uk (accessed 10 February 2017), and Casey (2016).

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## SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.
**S1**. Segregation measures.

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**How to cite this article:** Catney G. The complex geographies of ethnic residential segregation: Using spatial and local measures to explore scale-dependency and spatial relationships. *Trans Inst Br Geogr*. 2018;43:137–152. https://doi.org/10.1111/tran.12209