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Using population surfaces and spatial metrics to track the development of deprivation landscapes in Glasgow, Liverpool, and Manchester between 1971 and 2011

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ABSTRACT

Measuring change in the spatial arrangement of deprivation over time, and making international, inter-city comparisons, is technically challenging. Meeting these challenges offers a means of furthering understanding and providing new insights into the geography of urban poverty and deprivation. In this paper, we introduce a novel approach to mapping and analysing spatio-temporal patterns of household deprivation, assessing the distribution at the landscape level. The approach we develop has advantages over existing techniques because it is applicable in situations where i) conventional approaches based on choropleth mapping are not feasible due to boundary change and/or ii) where spatial relationships at a landscape level are of interest. Through the application of surface mapping techniques to disaggregate census count data, and by applying spatial metrics commonly used in ecology, we were able to compare the development of the spatial arrangement of deprivation between 1971 and 2011 in three UK cities of particular interest: Glasgow, Manchester and Liverpool. Applying three spatial metrics – spatial extent, patch density, and mean patch size – revealed that over the 40 year period household deprivation has been more spatially dispersed in Glasgow. This novel approach has enabled an analysis of deprivation distributions over time which is less affected by boundary change and which accurately assesses and quantifies the spatial relationships between those living with differing levels of deprivation. It thereby offers a new approach for researchers working in this area.

1. Introduction

Measuring change in the spatial arrangement of deprivation over time, and making international inter-city comparisons (i.e. comparing cities from different countries), is technically challenging. To meet these challenges, this study created and tested a new approach by drawing together two existing techniques not applied to this field before. Combing these techniques facilitated a comparison of the spatial distribution of deprivation in three UK cities, Glasgow, Liverpool, and Manchester, over a 40 year period (1971–2011). The approach could, however, be applied to any situation in which there is a need to examine the spatial distribution of population or population characteristics at landscape level over time, where boundary changes have occurred which preclude using the same areal units over time, and/or where the nature of the areal units for which data are available differs between study areas. In the paper, we briefly explain our motivation for this methodological development, justify the need for a new approach, explain the approach itself, and then use comparisons of the distributions of deprived populations in Glasgow, Liverpool and Manchester over time to demonstrate its application. Finally, we consider the strengths and weaknesses of our approach.

2. Background

Maps have been used to enhance studies of poverty in urban Britain since the work of Charles Booth in London and Seebohm Rowntree in York during the late 19th and early 20th centuries (Dorling & Pritchard, 2010). Whilst conceptions and measures have evolved since then, producing and analysing maps of both poverty and deprivation remains highly relevant. The methods used to conduct spatial analysis of

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poverty and deprivation have also evolved; however, a key feature of such maps remains that they demonstrate that poverty and deprivation are not randomly distributed across urban areas – they are spatially arranged. Examining this spatial arrangement has furthered understanding of deprivation and poverty and, importantly, their impact on urban populations. The spatial configuration of the poorest people has implications for many aspects of society and has the potential to influence a number of social and health outcomes.

2.1. Study motivation

Our focus on methods resulted from an interest in examining the impact of the spatial distribution of deprivation on population health. Specifically, we were interested in comparing the spatial distribution of poverty in Glasgow, Scotland with two other cities in England: Manchester and Liverpool. These cities have been compared many times in the literature (Livingston & Lee, 2014; Mccartney, Collins, Walsh, & Batty, 2012; Walsh, Bendel, Jones, & Hanlon, 2010; Walsh, Mccartney, Collins, Taulbut, & Batty, 2017) because of two particular features. First, on many dimensions the three cities are incredibly alike, having a similar population size, socio-economic history, and current levels of socio-economic deprivation. Second however, Glasgow differs markedly in one particular respect; it has very much worse population health (Walsh et al., 2010). Between 2003 and 2007 for example, Glasgow's all-cause premature mortality was 30% higher than Liverpool and Manchester. Yet, Glasgow's high level of mortality relative to the other two English cities has not always been present; it emerged in the 1970s (Walsh et al., 2010), suggesting that 'something changed' to cause its adverse position. Understanding what 'changed' between the 1970s and subsequent time periods was the driving force behind our methodological innovation.

One theory is that the cities developed differing spatial patterns of deprivation in the 1970s or subsequently, and that this explains the disparities in their population health (Livingston & Lee, 2014; McCartney et al., 2012; Walsh et al., 2017). It is important to emphasise the focus is not *levels* of deprivation – the cities have almost identical levels of, and temporal trends in these. Instead, the theory is that the cities differed in the development of *where* more and less deprived people live within each city. This theory is underpinned by previous research which showed that the health of urban residents can be influenced not only by their individual and neighbourhood levels of deprivation, but also by those in both proximal areas, and the wider urban area as a whole. The entire city's spatial pattern of deprivation is thus a possible contributor to population health there (Allender, Scarborough, Keegan, & Rayner, 2012; Cox, Boyle, Davey, Feng, & Morris, 2007; Livingston & Lee, 2014; Maheswaran, Craigs, Read, Bath, & Willett, 2009; Richardson, Moon, Pearce, Shortt, & Mitchell, 2017; Sridharan, Turnstall, Lawder, & Mitchell, 2007; Zhang, Cook, Jarman, & Lisboa, 2011). Testing this theory was the motivation for our methodological development. Choosing to work on Glasgow, Liverpool and Manchester which have been so extensively studied, meant we were could be sure the levels of deprivation in the city were almost identical over time, and our approach could focus on the distribution of that deprivation. We began by exploring the existing literature to see whether and how others had approached tracking spatial arrangements of deprivation over long time periods, and what the issues would be.

2.2. Existing literature and techniques

Others have already examined spatial arrangements of deprivation within Glasgow. The most notable study was by Livingston and Lee (2014) who explored the influence of deprivation levels in neighbouring areal units on the health of residents, making a comparison between Glasgow, Manchester and Liverpool. They found an impact of surrounding deprivation at two different scales on neighbourhood health outcomes in Glasgow and Liverpool but not in Manchester which suggested that they had not discovered the explanation for Glasgow's higher mortality. Their approach used small area measures of deprivation and although it was comparable between the cities, it was a contemporary measure constraining them to a cross-sectional study. Livingston and Lee (2014) also noted the difficulty posed by the fact that the cities from different countries (Scotland and England) used different definitions of the areal units themselves and that unit selection was not straight-forward.

Areal unit definition, consistency over time, and selection are the key challenges in this field. The definition of the areal unit introduces the well-known modifiable areal unit problem (MAUP) (Openshaw, 1984). The MAUP refers to the fact that relationships identified in data aggregated to a set of areal boundaries (such as postcode sectors or output areas) are at least partly dependent on the boundaries used (Flowerdew, Manley, & Sabel, 2008; Norman, 2010; Rae, 2009). Consequently, the data values for each area might be a reflection of the area boundary rather than of the underlying distribution of the data. Thus, if areal units differ between cities in their basis and size, there is a risk that any conclusions about between-city differences in spatial relationships are driven more by the areal units than by true differences on the ground.

When we add the reality of change in areal unit definitions over time, the uncertainties introduced by the MAUP are multiplied massively. A variety of different approaches to minimising the problem of boundary changes have been tested, and we explored each to assess whether they would meet our needs. Menis and Hultgren (2006), for example, advocate the use of dasymetric mapping in conjunction with areal interpolation to adjust census data to a common set of boundaries. Typically, however, the ancillary data used in dasymetric mapping is land use data, usually from remotely sensed satellite images (Holt, Lo, & Hodler, 2004; Menis & Hultgren, 2006; Slocum, McMaster, Kessler, & Howard, 2009). To apply their technique to our problem would have required land use data back to the 1970s; such data were not available. Norman (2010, 2016) and Exeter, Boyle, Feng, Flowerdew, and Scheirloh (2005) offer alternative approaches to issues of boundary changes over time which could have been adopted in this study. Norman (2010, 2016) converts older census data to recent boundaries by using the population overlap between different boundary systems to apportion data, using weights calculated by postcodes falling in the same source and target area. Disadvantages of this technique include uneven levels of error between any pair of boundary systems (due to some localities experiencing widespread adjustments whilst others experience little or no change), and increasing error over time. Whereas Norman (2010, 2016) focussed on (re)creating data for contemporary geographies, Exeter et al. (2005) determined coincidences of boundaries to define a set of fixed areal units ('Consistent Areas Through Time' (CATTs)) which could be used to compare data from the 1981, 1991, and 2001 census in Scotland. Such an approach, however, is only feasible in Scotland because of the ways in which census zones were built there. A further disadvantage of this approach is that it results in zones with very uneven physical and population sizes. For the purposes of this study, further limitations of Norman (2010, 2016) and Exeter et al.'s (2005) approaches are that they still result in non-uniform areal-unit based zones, suited to choropleth mapping, and do little to minimise the MAUP.

One other approach we identified discarded the use of areal units altogether. Pacione (2004) created maps from successive decennial censuses showing that temporal change in the spatial arrangement of deprivation in Glasgow. However, his approach was limited because he only mapped the centroids of the smallest available areal units at each time point in order to deal with boundary change. This was problematic as it did not provide an indication of the spatial extent of these areas and therefore the spatial relationships between the residents, nor was it able to assess formally whether more or less deprived areas bordered one another. There was no attempt to consider or quantify the distribution of deprivation at a city level.