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Bayesian inference for the dissimilarity index in the presence of spatial autocorrelation

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ABSTRACT

The degree of segregation between two or more sub-populations has been studied since the 1950s, and examples include segregation along racial and religious lines. The Dissimilarity index is a commonly used measure to numerically quantify segregation, using population level data for a set of areal units that comprise a city or country. However, the construction of this index usually ignores the spatial autocorrelation present in the data, and it is also typically presented without a measure of uncertainty. Therefore we propose a Bayesian hierarchical modelling approach for estimating the Dissimilarity index and quantifying its uncertainty, which utilises a conditional autoregressive model to account for the spatial autocorrelation in the data. This modelling approach is motivated by a study of religious segregation in Northern Ireland, and allows us to quantify whether the dissimilarity index has exhibited a substantial change between 2001 and 2011.

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1. Introduction

In the absence of legally enforced segregation, there are social processes at work that cause an uneven distribution of households by income, race and religion. Some argue (e.g. Cheshire, 2009) that

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self-segregation is no bad thing, because it gives rise to specialised communities generating greater neighbourhood variety in our cities. In addition, public health researchers (such as Whitley et al., 2006) have identified evidence of ethnic density effects, suggesting that minority ethnic groups living close together may have better health than if they integrate more with the majority population. The counter argument is that segregation may reduce affinity and understanding between social groups, and thereby undermine social cohesion. Whether or not segregation is rising or falling is therefore an important empirical question. For example, the publicity surrounding concerns expressed by Trevor Phillips (the former leader of the Commission for Racial Equality) in 2005 that Britain was sleepwalking into segregation – becoming more divided by race and religion – reflected wider anxieties about social fragmentation. However, such claims have been challenged by Simpson (2007) and Simpson and Finney (2010) and others Jivraj (2012), Catney (2013) and Johnston et al. (2013), who provide evidence that segregation may actually be falling. Parallel debates and concerns have occurred in USA, Europe and elsewhere, giving rise to a truly voluminous literature on the meaning and measurement of segregation (Clark, 1986; Glaster, 1988; Ihlanfeldt and Scafidi, 2002; Musterd, 2005; Semyonov and Glikman, 2009).

Measuring segregation numerically is an inherently difficult task, which is typically undertaken using population level data from a set of n non-overlapping areal units comprising a city or country. Typically, segregation measures quantify the extent to which two or more sub-populations are integrated and live together or are isolated and do not interact. Numerous different indices of segregation have been proposed in the literature, and the widely cited review by Massey and Denton (1988) in 1988 categorised segregation indices into five different dimensions: (i) evenness—the level of variation in the relative size of the minority sub-population across the n areal units; (ii) exposure—the extent of the interaction between the minority and majority sub-populations; (iii) concentration—the relative physical amount of space occupied by each sub-population; (iv) centralisation—the relative degrees to which each sub-population are based in the centre of the city; and (v) clustering—the degree to which each sub-population clusters together in geographically close areal units. Numerous extensions have been proposed to these indices in the literature since this seminal critique in 1988, including having more than two sub-populations (Reardon and Firebaugh, 2002; Reardon and O'Sullivan, 2004), and addressing the modifiable areal unit problem (MAUP, Wong, 2003 and Simpson, 2007).

In this paper we consider the Dissimilarity index (Duncan and Duncan, 1955), which is one of the most widely computed indices of residential segregation. We use this index purely to motivate the issues and modelling approaches discussed in this paper, but are in no way attempting to justify its use over alternative measures such as the Gini index. Rather, our view is given a desire to compute a particular index, what are the statistical issues that should be addressed when doing so. Specifically we focus on two such issues, which have largely been ignored by the existing segregation literature. The first is that the index is a purely descriptive summary statistic, and is typically presented without a corresponding measure of uncertainty. However, as argued by Leckie et al. (2012) the quantification of its uncertainty would enable researchers to determine whether observed differences in the Dissimilarity index over space or time correspond to real changes in segregation, or simply the result of random sampling variation. A small number of papers have attempted to address this issue, using either a bootstrapping algorithm (Brülhart and Traeger, 2005) or asymptotic theory (Cortese et al., 1976; Winship, 1977; Inman and Bradley, 1991). However, Mulekar et al. (2008) compared a number of these asymptotic theory approaches, and concluded that the proposals cannot be replied upon to yield correct confidence intervals.

The second issue we consider in this paper is the impact of spatial autocorrelation on the construction of the Dissimilarity index, a problem that to our knowledge is yet to be addressed in this context. We note that existing research has altered the algebraic form of the dissimilarity index to account for spatial features such as boundary effects (see Morrill, 1991 and Wong, 1993), but that is not the attempt of this paper. Instead, we consider the standard formula for the Dissimilarity index, and argue that its estimation and uncertainty quantification should be adjusted to allow for the spatial autocorrelation in the data. This is because the sample proportions used to compute the index are subject to sampling variation and other errors, and the true unknown proportions can be better estimated by using the spatial autocorrelation in the data to facilitate a borrowing of strength in the estimation, which should yield more reliable inference.

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