Tackling the Curse of Cartograms: addressing misrepresentation due to invisibility and to distortion

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Summary
Cartograms are popular for presenting geographical information. However, their increased ease of production has led to an uncritical adoption in a number of papers, reports and media presentations with little consideration to whether how they are produced is the best for presenting the data available. The 'curse of cartograms' is that they are susceptible to geographical distortion caused by distributionally skewed data that renders much of the cartogram as illegible as the choropleth it seeks to replace. We argue for a more judicious selection of the scaling variable better to balance the problems of misrepresentation due to both invisibility and distortion.

KEYWORDS: cartogram, misrepresentation, visualisation, mapping

1. Introduction

Cartograms are a popular way of presenting geographical information, with a range of free software able to produce them in a few simple steps. What was once an unusual method of cartographic visualization has become *de rigueur* to the extent that it is not unusual to see cartograms appearing in academic papers, student theses, in the media or on a blog site, highlighting geographical disparities in who voted against Brexit, the ethnic geography of the UK or global HIV prevalence, for example. Whilst cartograms have earned their place in the geographical toolbox being a thought provoking method of visualisation, our concern is that their ease of production has made them a 'go to' graphic without commensurate reflection on whether they are the right graphic to go to.

Cartograms can be seen as an attempt to address the problem of misrepresentation in mapping statistical information; notably, the problem of invisibility when some areas are too small to see at the map scale. However, there are two dominant problems of misrepresentation:

- misrepresentation through **invisibility**
- and misrepresentation through **distortion**.

Whilst cartograms address the former of these, they often amplify the latter. If the primary purpose of a map is to present geographic information as clearly as possible then cartograms often fail because the level of geographical distortion renders much of the map illegible, especially for the strongly skewed (and spatially clustered) distributions common amongst social and demographic variables. As Coltekin (2015) notes, "cartograms are interesting and can be powerful, but because they distort the geometry, displaying the actual geometry alongside with the cartogram as a reference is helpful,

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perhaps even necessary. Keeping in mind the relative size of many countries at the same time and mentally comparing them to their distorted geometry seems like a recipe to cognitive overload [...] Furthermore, the distortion tends to "eat" some regions" (p.1164).

Here our interest is in exploring cartographic compromises, resizing parts of a map in proportion to a chosen attribute but striking balance between invisibility and distortion.

2. **From choropleth to cartogram: typical approaches**

Figure 1 is a standard choropleth map showing the mean average selling price per local authority of houses sold in England during 2016. The map suffers from the problem that the (urban) areas of highest population density are smallest on the map and their values are hard to discern, especially in London.

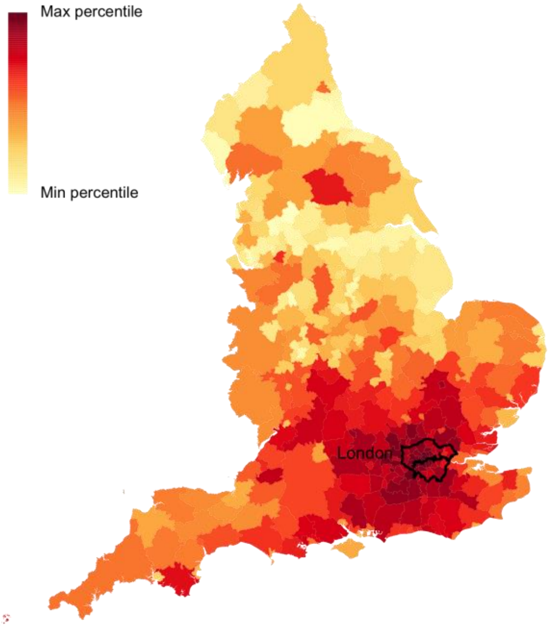

Figure 1 Choropleth map of the average house price sale per local authority in 2016.

To respond to this, the left display in Figure 2 uses a cartogram. It was created with the Dougenik et al. (1985) algorithm, implemented in R's cartogram library but the detail is less important than the process: the areas are resized in accordance to their population count; that makes the urban areas proportionately larger; however, the expansion is at a price – it distorts the map.

The distortion worsens if the areas are resized by the attribute of interest, the average house prices (right of Figure 2). Warping the map draws attention to where the attribute is most abundant but it is unclear whether this offers any advantage over more conventional shading approaches combined with a simple map insert for example.

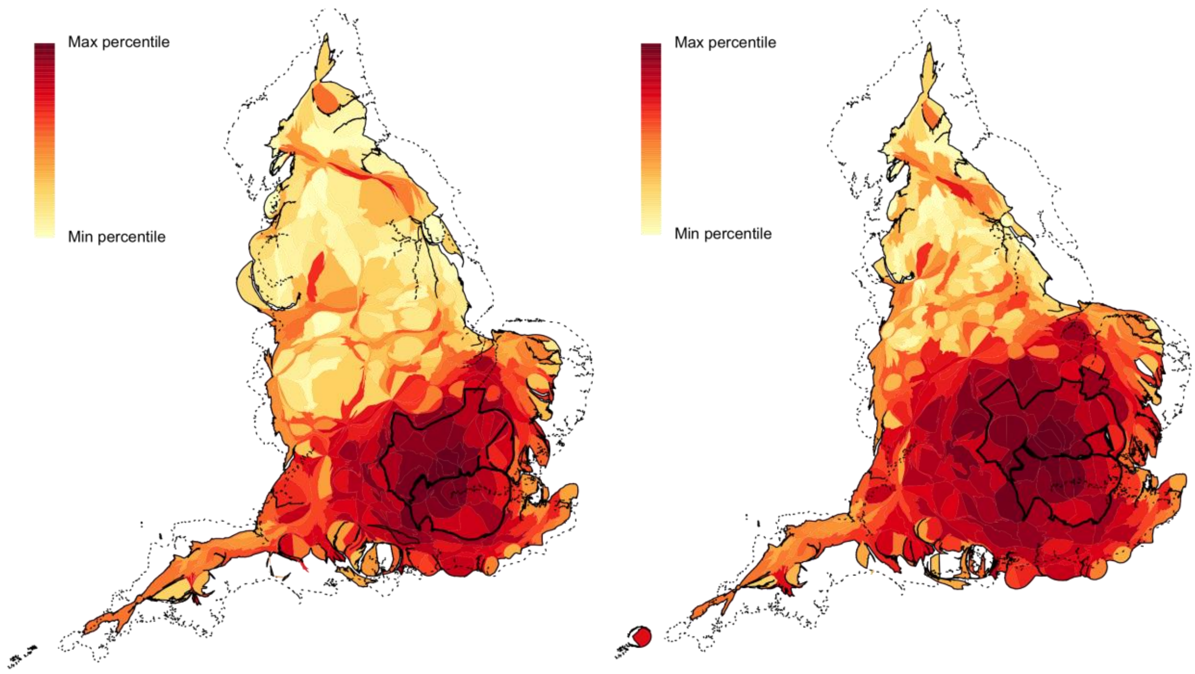

Figure 2 Cartogram versions of Figure 1: (left) scaled by population size; (right) scaled by the attribute value

3. Some simple alternatives

It is not obvious why rescaling the map either by population size or by the attribute value is the best way of conveying the geographical information. There is an argument for expanding parts of the map so they are clearly visible but it would be better to do so without the high level of locational distortion that classic cartograms entail. Methods to produce cartograms are agnostic about the rescaling variable, it is up to the user to decide. That affords flexibility to experiment with alternative specifications.

Figure 3 shows three possibilities. The first rescales on a constant, aiming to give each area equal space on the map. It is similar to a tile map in this regard but retains a sense of the areas' original shapes without rendering them all as equally sized squares or hexagons. The second rescales by the square root of the area of each local authority. This has the effect of making small authorities relatively larger but the level of geographical distortion is minimal. The third adopts a similar idea but the power term applied for the transformation was found using a Box-Cox method (and is equal to 0.034).

However, the generally accepted nostrum remains that a density-equalised map, or a close approximation to it, is the most appropriate form of cartographic display. This ignores the distributional characteristics of the variable used to drive the process. If there are notable distributional outliers – and there often will be – then the cartogram gives prominence to them. Hawkins (1980, p1) defines an outlier as "an observation which deviates so much from other observations as to arouse suspicions that it was generated by a different mechanism". Thus a cartogram which purports to show the spatial distribution of values generated by one process becomes dominated by the spatial distribution of outliers that might have been generated by a different process. A cartogram it is a map that highlights the exception, obscures the norm, and risks providing the reader with only a partial picture of what is happening and where.

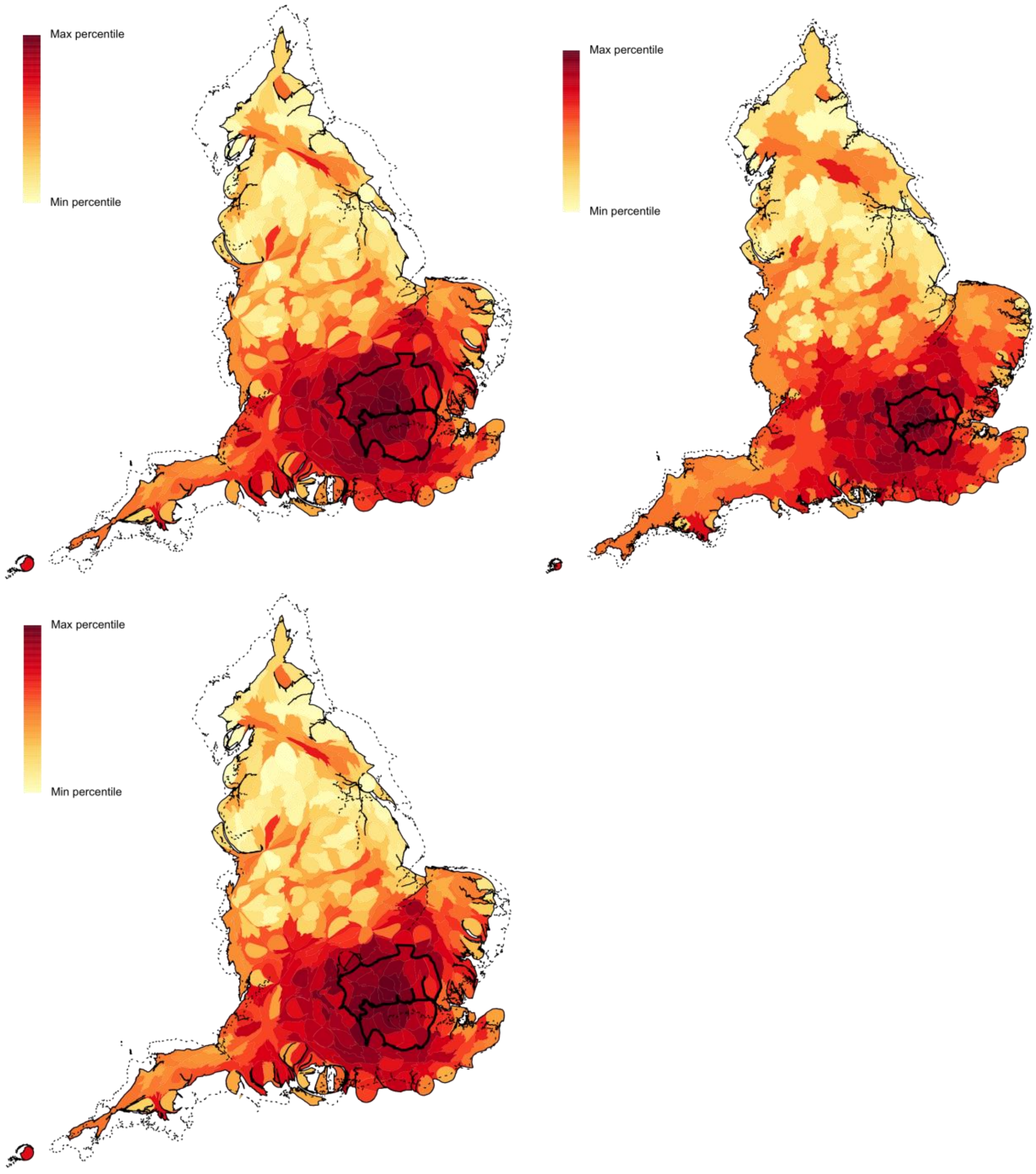

Figure 3 Alternative ways of drawing the cartogram that reduce the geographical distortion (see text for details)

As a case-in-point, the leftmost boxplot in Figure 4 suggests that about 8 per cent of the counties in the well-known Georgia educational attainment dataset have populations with unusually high values. Figure 5 present four maps: (a) represents the boundaries plotted in UTM planar coordinates; (b) represents the boundaries scaled using the Gastner and Newman algorithm with 1990 population as the mass variable; (c) uses the square root of the population, and (d) the log of the population. The untransformed population counts in (b) give undue prominence to the 13 counties with unusually high populations – they are outliers in the distribution of county populations and they are outliers in a cartographic sense too. The square root boxplot in Figure 4 still shows 9 outliers, whereas the log transform reduces this to four, also giving some symmetry to the distribution.

Mindless application of the Gastner-Newman algorithm to a mass variable for a handy set of spatial units is not the way forward. Instead, some data exploration is required before the appropriate transformation is applied to the data prior to the creation of the cartogram.

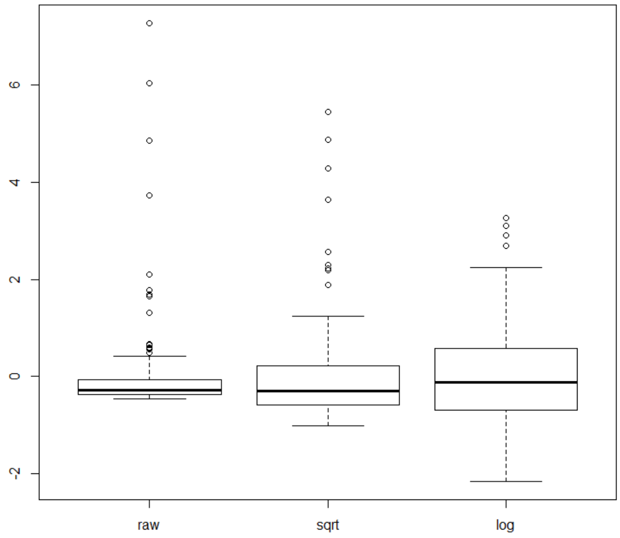

Figure 4 Boxplots for raw and transformed population counts

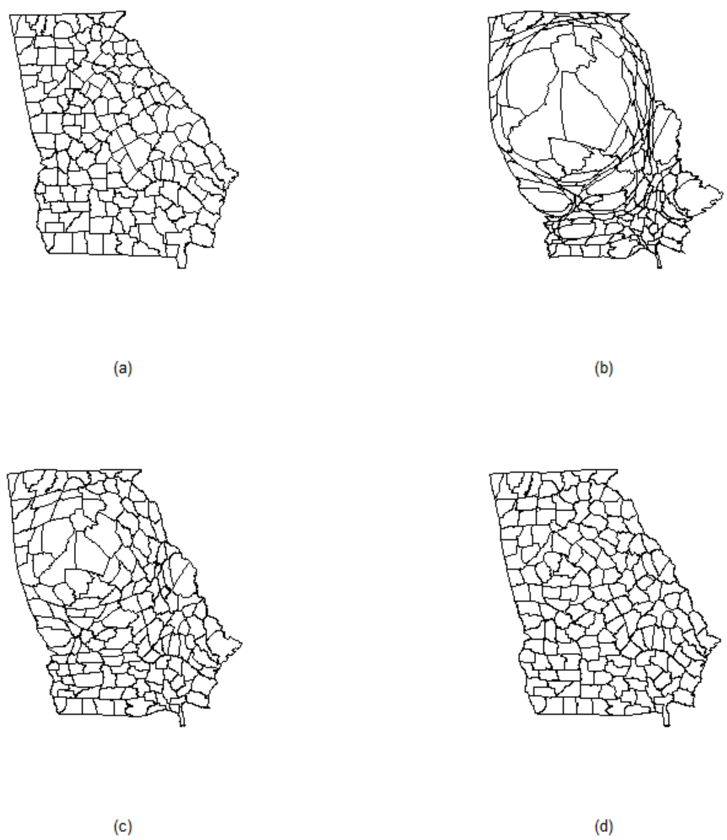

Figure 5 (a) Georgia county boundaries, (b) scaled by population, (c) scaled by the square root of the population, and (d) scaled by the log of the population

4. Discussion

Harley (1989) argues that cartography is not context-free: our maps, and indeed maps generally, are neither objective nor are they reality. We create maps for a purpose, they are an act of communication. Perhaps one issue is associated with the relatively recent appearance of widely available cartogram software. Ninety years ago Gillihan (1927) was using lumps of 'plasticise', the weight of each lump proportional to the population, then rolled flat to a constant thickness. Tobler (2004) created bespoke software, but little was widely available in GIS software until the last decade. Whilst there has been interest in using tile maps instead of cartograms, one of us (Brunsdon) has developed a method of Density Equalised Map Projection that expands only the 'invisible' areas and leaves the others alone, and the Financial Times wrote an interesting article on their search for a better US election map, described as 'a third way between election maps and cartograms' – see http://on.ft.com/2eIgs6N - in general we don't seem to have come very far: the last sentence in Tobler (2004) observes that the Gaster-Newman algorithm 'can be considered a mathematical version' of Gillihan's procedure. In our haste to create value-by-area cartograms have we overlooked some of the fundamental questions of why we are creating these displays, what we are trying to show, who is the intended audience, how we are trying to show it, and what message we are wishing to convey?

5. Acknowledgements

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6. Biographies

Rich Harris is Professor of Quantitative Social Geography at the School of Geographical Sciences, University of Bristol. He runs a lot except when his back is hurting, which it is right now. Apparently, beer is an anti-inflammatory but he's 6 days into Dry January.

Martin Charlton is Senior Research Associate at the National Centre for Geocomputation, National University of Ireland Maynooth. He needs to do more exercise and drink less beer.

Chris Brunsdon is Professor of Geocomputation and Director of the National Centre for Geocomputation, National University of Ireland Maynooth. His exercise levels are OK, but there's still a case for reducing his intake of chips and beer. He once lost his shoes in Japan.

David Manley is Reader of Quantitative Geography at the School of Geographical Sciences, University of Bristol. He likes beer too but also whiskey. He's been known to run but none of his colleagues have witnessed it.

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