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Hamilton, R. and Rae, A.J. orcid.org/0000-0003-0136-7659 (2020) Regions from the ground up: a network partitioning approach to regional delineation. *Environment and Planning B: Planning & Design*, 47 (5). pp. 775-789. ISSN 0265-8135

<https://doi.org/10.1177/2399808318804226>

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Regions from the ground up: a network partitioning approach to regional delineation

Environment and Planning B: Urban Analytics
and City Science
0(0) 1–15

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Abstract

In this paper, we consider the question of what is ‘in’ a region, from an economic perspective, based on commuting data. This follows a long line of studies on labour market delineation, including the widely used ‘travel-to-work area’ approach. Using Combo, a network partitioning algorithm, we analyse commuting data from the 2011 UK Census in order to define a discrete set of regions. Our aim is twofold: to contribute to methodological advances in regional delineation, and to produce results that have real-world utility. Following the introduction, we review previous work, before describing our data and methods. Our approach produces 17 new ‘regions’ for Scotland, in contrast to the existing set of 32. Our view is that algorithmic approaches to regional delineation have much to offer in a policy setting, but this must be tempered by the fact that regions, however defined, are inherently political constructs.

Keywords

Regional analysis, network structure, commuting, travel-to-work areas, geographical information science

Introduction

The question of the scale and size of regions has historically been approached from several perspectives, with seminal contributions from Ohlin (1933), Lösch (1954) and Meyer (1963) amongst the most well-known. This is testament to the enduring importance of the topic and to periodic advances in methodological thinking on the subject. Regional delineation also retains a high degree of policy relevance, with recent regional reorganisations in France, Denmark and Poland suggesting there is a place for methodologically robust approaches to

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understanding what is ‘in’ a region and where boundaries ought to be drawn. In other nations, such as Scotland, the question of regional reorganisation remains a live policy question, and our paper aims to make a contribution in this context.

We seek to build on previous approaches to regional delineation, from an economic perspective (e.g. Parr, 2014), through the use of an algorithmic approach. However, we are also mindful of the inherently political nature of the topic and the fact that however we define regions, issues of identity, culture, history and policy will inevitably remain important. Nonetheless, regions remain a critically important part of national policy infrastructures throughout the world, and robust and defensible approaches to their definition are essential, even if they are not ideal.

We aim to make a contribution on two fronts. First, we hope to make a *methodological* contribution in relation to how economic regions can be defined. Rather than starting with a series of nodes or using a set of parameters on geography or population, our approach is based on network partitioning (Sobolevsky et al., 2014), using commuting data. We think of this approach as being ‘from the ground up’, since it builds regions from small spatial units with no pre-set criteria (unlike the established travel-to-work area (TTWA) approach). Second, we hope to make an *empirical* contribution by informing contemporary debates about regional re-organisation in a real-world policy context. For this purpose, we have selected Scotland as a case study.

We have chosen Scotland in particular because the question of local government reorganisation has been raised there by a variety of stakeholders in recent years, and we wish to make a contribution to the evidence base on this important policy topic. Crucially, however, the Scottish Government have not yet taken any decisions on the form of a revised regional geography for local authorities. Our hope is that this approach can feed into policy conversations on the future of local government in Scotland, and elsewhere. The recent experience of France, which in 2016 moved from a geography of 22 ‘metropolitan’ regions to a new set of 13 (the so-called ‘le big bang des régions’), highlights the fact that regional geography is not simply an obscure academic enterprise; it can and does have very important economic and political implications.

In the next section, we briefly revisit previous approaches to regionalisation and discuss moves to reform local government in Scotland. We then introduce the data and method used in our research, which utilises the algorithmic network partitioning methods developed by Sobolevsky et al. (2014). This is followed by a section in which we report our results, with Scotland re-shaped into 17 new ‘regions’. We also compare this new regionalisation to the current set of 45 TTWAs for Scotland. The results could prove particularly useful in debates about the re-organisation of local government, but they also suggest that local nuance and ‘common sense’ are needed in their interpretation and application.

Approaches to regional delineation: A brief history

Background

There are many different approaches to defining the ‘region’ in regional studies and economics. This makes for a rich and diverse field of study, but it also means that we need to be clear about the scale of the building blocks we use and the underlying concepts they relate to. At the most basic level, the ‘region’ can be thought of as a sub-national geographical unit within a single nation. In a European context, the three-level European Union (EU) hierarchy of the nomenclature des unités territoriales statistiques (NUTS) has become an accepted spatial hierarchy and provides a standardised way of identifying ‘regions’.

The multi-level NUTS geography varies significantly in scale between countries, but it helps identify areas eligible for support from cohesion policy across the entire EU. Such regions closely resemble what Meyer (1963) called ‘programming regions’, or what we might term ‘policy regions’. Regions may also span areas that cover multiple countries, but our use of the term ‘region’ here relates specifically to sub-national geographic entities, described in different national settings as ‘municipalities’, ‘regions’ or ‘council areas’, amongst others. Such regions can be delineated in a number of ways, but our focus in this paper is on the identification of regions from a *functional* economic point of view.

In Brown and Holmes’ (1971) paper on the delimitation of functional regions, they stated that ‘fundamental to the formulation and implementation of contemporary national economic planning policy is a more detailed understanding of geographic space and the concept of a region’ (57).

This perennial truth has greater significance when the policy pendulum shifts back to the question of sub-national governance, as it has of late in Scotland. From a practical point of view, the ‘function’ considered in the identification of regions has most often related to commuting or migration and the associated concepts of the labour market area and housing market area, respectively (e.g. Jones, 2002). Typically, in such cases, census data are used as the basis for partitioning regions. There is considerable spatial overlap between housing and labour market geographies, as Hincks (2012) has shown, but this paper relates to the labour market and its functional geography as a test case for the Combo method described below.

Census-based regional delineation also has a long history. For example, in the United States, it extends back until at least 1905 (Adams et al., 1999), and it is a part of the national policy milieu in many nations. In the United Kingdom, there is a particularly strong tradition of housing and labour market-related functional delineation and analysis, with the work of Coombes and Openshaw (1982), Champion (2001) and Hincks (2012) being of particular importance. This has led to the situation where the concept of the TTWA has become a fixture in the regional policy lexicon, even as the regional policy pendulum has swung back and forth between ‘on’ and ‘off’ over the years (e.g. Garretsen et al., 2013).

Approaches to regional delineation, as the literature reminds us, are not merely arcane academic methods; they have important real-world applications. Within the United Kingdom, for example, the TTWA remains an important part of the national spatial data infrastructure and has, for example, been used in practice to identify areas eligible for regional aid (the ‘Assisted Areas’), housing market assessment and in implementing local economic development policies. The TTWA approach has also been used in other nations, including Canada and South Korea. It differs from our approach in one critical respect: it is based on the criteria of ‘self-containment’, where at least 75% of the area’s resident workforce also work in the area and at least 75% of the people who work in the area also live in the area (ONS, 2016). One might justifiably argue that despite its widespread acceptance, it is based on a somewhat arbitrary 75% cut-off, even if it does produce robust results (Jones and Watkins, 2009: 64).

Our approach, described below, builds regions from ‘the ground up’ based on network partitioning of commute flows and therefore provides an alternative method which can (i) identify regions based on the strength of their ties and (ii) be applied to any kind of origin-destination data. The second point is particularly important since we hope to make a methodological contribution where national governments seek to redraw regional maps, and economic linkages are of course only part of the story.

Recent regional reorganisations

As we noted above, France's regional geography was reduced from 22 'metropolitan' regions to 13 in 2016. Seven of the original regions, including Île-de-France (the Parisian Region) remained unchanged but all others were significantly modified. For example, the new region of Hauts-de-France ('Upper France') includes the former regions of Nord-Pas-de-Calais and Picardy. This is the most obvious recent example but others include Albania, which in 2004 went from 384 to 61 municipalities (Reforma Administrative Territoriale, 2017), Denmark, which went from 271 to 98 municipalities and from 13 to 5 large regions in 2007 during its *Strukturreformen* process (LGDK, 2009), and Poland, which went from 49 to 16 in 1999 (OECD, 2008). The scale of these 'regions' varies by nation yet they are all important administrative units in their own right and closely align with Meyer's 'programming region' (Meyer, 1963).

Within the UK, England's formal regional structure was dismantled in 2010 with the arrival of a new government. In Scotland, the desire to reform the administrative geography of sub-national council areas has been raised several times in recent years, though it has perhaps been delayed owing to a series of national votes, including the Independence Referendum of 2014 and the General Elections of 2015 and 2017. Nonetheless, it seems plausible that at some point in the short to medium term, Scotland's 32 local government areas will be reconfigured. This is a major part of the justification for choosing Scotland. Another reason is that it provides a good test case for a country with a significant urban-rural split, since 3.5 million people live in the densely populated Central Belt with the remaining 1.7 million distributed much more widely across the rest of the country.

In the wider area of local government reform, the Christie Report of 2011 looked at the topic and called for a 'thorough transformation of our public services' (Scottish Government, 2011). It did not highlight a need for spatial reorganisation and, in fact, it noted that compared to Finland, Denmark and Norway, Scotland already had a low number of municipalities. In 2013, the Scottish Government then appeared to reject any idea of reducing the number of local authorities (The Herald, 23 May 2013) yet by 2017 the issue of redrawing 'Scotland's Council map' was back in the media spotlight (The Herald, 28 February 2017).

This subject should also be seen in the context of the Police and Fire Reform (Scotland) Act 2012, which merged Scotland's nine police forces to create a single law enforcement agency, Police Scotland, in 2013. This has been followed by a number of exercises to test what a new sub-national structure might look like, most notably Reform Scotland's 'Renewing Local Government' report in 2012 (Reform Scotland, 2012), which recommended a reduction from 32 to 19 council areas (Table 1). This serves as a useful point of reference for the results presented later in the paper.

Given the theoretical lineage of the subject, and its practical applications, we chose Scotland as a test case for the network partitioning methodology described below. Additional reasons, as we have noted above, are that Scotland has not yet begun any formal consultation on such a process, and that it provides an appropriate test case in terms of its spatial structure, with a mix of concentrated urban areas and more diffuse, smaller settlements in the rest of the country. Our approach is based on economic linkages, since we are seeking to understand more about functional economic spaces. We believe this could also make a contribution to the debate about regional reorganisation more broadly, since economic linkages give shape to local economies, which in turn require appropriately scaled units of government.

Table I. Reform Scotland's 19 new council areas, 2012.

#	Reform Scotland proposed council area	Existing council areas	Pop est 2010	km2
1	Argyll and Bute	Argyll and Bute	89,200	6909
2	Ayrshire	East Ayrshire North Ayrshire South Ayrshire	366,860	3369
3	Dumfries and Galloway	Dumfries and Galloway	148,190	6426
4	Dunbartonshire	East Dunbartonshire West Dunbartonshire	195,150	334
5	East and Mid Lothian	East Lothian Midlothian	178,640	1033
6	City of Edinburgh	City of Edinburgh	486,120	264
7	Eilean Siar	Eilean Siar	26,190	3071
8	Fife	Fife	365,020	1325
9	Forth Valley	Clackmannanshire Falkirk West Lothian Stirling	465,840	3070
10	Glasgow City	Glasgow City	592,820	175
11	Grampian	Aberdeen City Aberdeenshire Moray	550,620	8737
12	Highland	Highland	221,630	25,659
13	Lanarkshire	North Lanarkshire South Lanarkshire	638,240	2242
14	Orkney Islands	Orkney Islands	20,110	990
15	Perth and Kinross	Perth and Kinross	147,780	5286
16	Renfrewshire	East Renfrewshire Inverclyde Renfrewshire	339,560	595
17	Scottish Borders	Scottish Borders	112,870	4732
18	Shetland Islands	Shetland Islands	22,400	1466
19	Tayside	Angus Dundee City	254,860	2242

In taking this approach, we recognise that such a task should only ever be partially quantitative, such is the historic, cultural and political nature of the 'region'. An important historical point is that we have, in a way, been here before with the nine former regions of Scotland created by the Local Government Act of 1973 and abolished in 1996 by the Local Government etc. Act 1994. These regions *did* have some functional basis yet were eventually scrapped and replaced by smaller administrative units. Thus, prior to any new regional reorganisation, it seems like an opportune time to revisit the subject matter for Scotland. Before doing so, in the next section of the paper, we explain our approach to regional delineation in relation to the Combo method, and the Scottish commute dataset.

An alternative approach to regional delineation: Combo methods and data

Over the past 15 years, the question of community detection has received much attention in the field of network analysis (Fortunato, 2010; Newman, 2004), and a number of different

algorithms have been proposed to answer it (e.g. Liu et al., 2014). Whilst there is no clear consensus on the method or terminology, the key features of a network are clear: it contains a set of *nodes*, connected by *edges*. In the context of this study, nodes are origins and destinations and edges are the commuter links between them. A community (or cluster) is then defined as a group of origins and destinations with a high density of connections between them and relatively few connections to origins and destinations outside the community. This is directly analogous to the concept of ‘self-containment’ in the derivation of TTWAs, and is explained in more detail below.

Community detection algorithms have been applied to a wide range of datasets, including social networks, public health and bank transactions (e.g. Schoen et al., 2014). Here, we apply the ‘Combo’ partitioning method (Sobolevsky et al., 2014) to commuting data, following similar work on the United States (Nelson and Rae, 2016). We use data from the 2011 Census, which recorded the residential and workplace locations for all respondents over the age of 16. The data, aggregated to Output Areas (mean population 309), is published for the whole United Kingdom. Using this commute data and the Combo approach, described below, we are able to define a set of regions.

Some earlier work on community detection has been cited within regional studies or regional science (e.g. Ratti et al., 2010) yet, perhaps owing to a lack of interdisciplinary cross-fertilisation, other relevant approaches have largely been overlooked (e.g. Coscia and Hausmann, 2015; Thiemann et al., 2010). Thus, with this paper, we are also attempting to bridge a gap. In a paper in *Physical Review E* in 2014, Stanislav Sobolevsky et al. from MIT set out an approach to community detection in complex networks that has real value for understanding commuting patterns. Community detection in general is one of the pivotal tools for understanding network structures so with this approach we seek to apply an established method to the problem of human mobility. In their paper, the authors describe the Combo algorithm, which builds on a combination of existing approaches to network partitioning.

We therefore believe an algorithmic approach to network partitioning has much to offer the field of regional studies, since the patterns we seek to understand are neither uniform nor easily understood and they require a method that can handle complexity. In this case, Combo provides an optimised approach since it was tested against six existing algorithms and shown to outperform them all, with respect to maximising what is known as ‘modularity’ (Sobolevsky et al., 2014). That is, the Combo algorithm searches for a network partitioning solution that maximises *intra*-community connections and minimises *inter*-community connections. The better it does this, the more the modularity score tends towards its maximum value of 1.0. To put this more simply, Combo identifies individual origin and destination pairs which are most strongly connected and then groups sets of these into ‘communities’, using an iterative process. The TTWA method also begins by linking origin and destination pairs, though it follows a different process thereafter (see Coombes et al., 1986).

As Bond and Coombes (2007: 1) note, ‘there is no single theoretically correct algorithm for grouping zones’ so we offer the Combo approach here as a potentially useful alternative to the TTWA method that can be implemented for any kind of origin-destination or network data, and which builds regions from the ‘ground up’; that is, without the set of parameters on self-containment, population, and number of workers that are an integral part of the TTWA algorithm. The full technicalities of the Combo approach are more than that can be described in detail here, so we set out below the steps involved and refer readers to Sobolevsky et al. (2014) for a precise exposition of the method. For the present study, Combo was compiled from source in C++ and run in a desktop computing environment.

Stepwise summary of the Combo algorithm (Sobolevsky et al., 2014)

- **INPUT:** a network of nodes is required. In our case, these were origin and destination area centroids from the 2011 census. By default with Combo, at the outset all nodes are assigned to a single community.
- *Step 1:* for each origin-destination pair, Combo searches for the optimal community partitioning based on the best modularity gain from moving a node from an origin to destination community (i.e. Combo iteratively tests a variety of network partitions for each node pair).
- *Step 2:* assign nodes from origin to destination community according to partition optimisation (and repeat).
- *Step 3:* select optimal partitions based on best gains achieved by moving nodes to different partitions.
- *Step 4:* test optimality of final partitioning solution and if it is maximised, end. This final step ensures that the modularity score for the final partitioning is as high as possible.
- **OUTPUT:** the final output of Combo is the partition of a network of nodes into a set of ‘communities’, which in this case is a set of labour market regions for Scotland.

As the authors note, ‘the fulcrum of the algorithm is the choice of the best recombination of vertices between two communities’ (Sobolevsky et al., 2014: 5). It is a computationally intensive process but can easily handle 30,000 nodes (i.e. 900 million potential origin-destination pairs) within a few hours of processing time in a desktop computing environment.

In the next section of the paper, we report the results of our analysis of origin-destination data for Scotland. These data were released on 25 July 2014 and are derived from Question 11 of Scotland’s most recent Census, conducted on 27 March 2011. This question also asks about travel to school or college. In an attempt to focus most closely on travel to work data only, our analysis of commuters here is limited to those aged 16 and over who were in employment in the week before the Census. It is possible that a small number of commuters in our dataset are travelling to an education destination rather than a workplace but for the purposes of the present study, this is also a relevant category of commuter, though not the focus.

Because community detection algorithms are computationally intensive, and because Output Areas are not typically large enough for such analyses in terms of the numbers of jobs present, we aggregated our original set of 46,351 Output Area data to 1235 Intermediate Zones (IZs) for Scotland in order to run Combo. This provides a sufficiently granular geography to construct regions from, with IZs having a mean population of nearly 4300. This geography is comparable to those used in previous studies, such as US Census Tracts (Nelson and Rae, 2016). Out of a potential origin-destination matrix of more than 1.6 million connections in our dataset, there were 213,265 IZ-to-IZ connections. We excluded the small number of flows that began or ended outside Scotland since our focus here is on constructing regions within a single country.

A new labour market geography: The 17 ‘regions’ of Scotland

This paper is about the identification of sub-national geographical units based on a form of economic network data. However, terminology relating to the ‘region’ can be confusing or misleading. For example, until the Local Government etc. Act 1994 what is now the ‘Highland Council’ area was known as ‘Highland *Regional* Council’ and between 1973

and 1996 Scotland consisted of nine two-tier 'regions' and three island areas. Our results fall somewhere in between the current 32 council areas and the previous nine regions and are close in number to Reform Scotland's 19 proposed new local council areas. Our final set of 17 regions is also significantly less than the existing set of 45 TTWAs, though it should be noted that one objective of TTA regionalisation is to maximise the number of TTWAs; a key difference from the Combo approach, which seeks instead to maximise modularity.

We applied Combo to the 2011 IZ commute dataset for Scotland. The process assigned each IZ to a cluster in order to maximise the network modularity score; a measure of how 'good' the clusters are with respect to their internal coherence (Newman, 2004). A higher modularity score means that a higher proportion of areas within each region are linked to areas *within* the same region. Conversely, a lower modularity score means there is more interaction between regions. For each new region, we also computed a 'cluster density' value and a 'bleed ratio'. The bleed ratio is a measure of the proportion of all commutes that start or end outside a given region (the inverse of 'self-containment' in TTWAs), whereas cluster density is the ratio of actual links within a cluster to all possible links (i.e. if everywhere is connected to everywhere else then the cluster density will be 1.0).

From commutes to 'regions'

Implementing Combo produced 17 clusters for Scotland and an overall modularity score of 0.74. This value compares favourably to scores reported in a similar Combo-based study by Sobolevsky et al. (2013) which reported modularity scores for France (0.78), the UK (0.62), Italy (0.72) and Belgium (0.74). In each case, a set of geographically coherent regions was produced. As demonstrated in Figure 1, the Combo clusters derived from IZ-IZ commutes are also geographically coherent, in that they are comprised of a set of contiguous spatial units with no exclaves. Some of our new regions are identical or very similar to previous council areas, such as Dumfries and Galloway in the south of Scotland, or Highland in the north. The major changes are in the highly populated Central Belt of Scotland where Combo has produced fewer regions. These include areas we have named 'Greater Glasgow', 'Edinburgh and the Lothians', and 'Lanarkshire'. The new set of 17 regions vary widely in size and population, as one might expect given the economic and topographic diversity present within Scotland.

Greater Glasgow is the largest Combo region, with a total of 1.17 million people as of 2011. This is followed by Edinburgh and the Lothians (835,000), Lanarkshire (575,000), Grampian (476,000) and Dundee, Perth and Angus (406,000). The present council areas of Scotland have far fewer people. The City of Glasgow is currently the most populous, at 615,000, followed by the City of Edinburgh (507,000), Fife (370,000), North Lanarkshire (339,000) and South Lanarkshire (317,000). At the other end of the scale, the current council areas of Orkney, Shetland and the Western Isles have the same population as the equivalent Combo regions. Particularly interesting is the extent to which the algorithmic approach identifies Argyll and Bute, and Inverclyde, as being functionally separate regions, both of which have smaller populations than their current council area equivalents. In the case of Inverclyde in particular, this is surprising given its proximity to Glasgow, Scotland's largest labour market area. Despite being very close to Glasgow in terms of distance, it appears to be functionally disconnected.

To understand the 17 clusters in more depth, we have included a series of metrics in Figure 1. As stated above, the bleed ratio tells us about the proportion of commutes that begin outside or end outside a given Combo region. The cluster density is a measure of how internally connected each set of IZs is; the higher the value, the more connected it is.

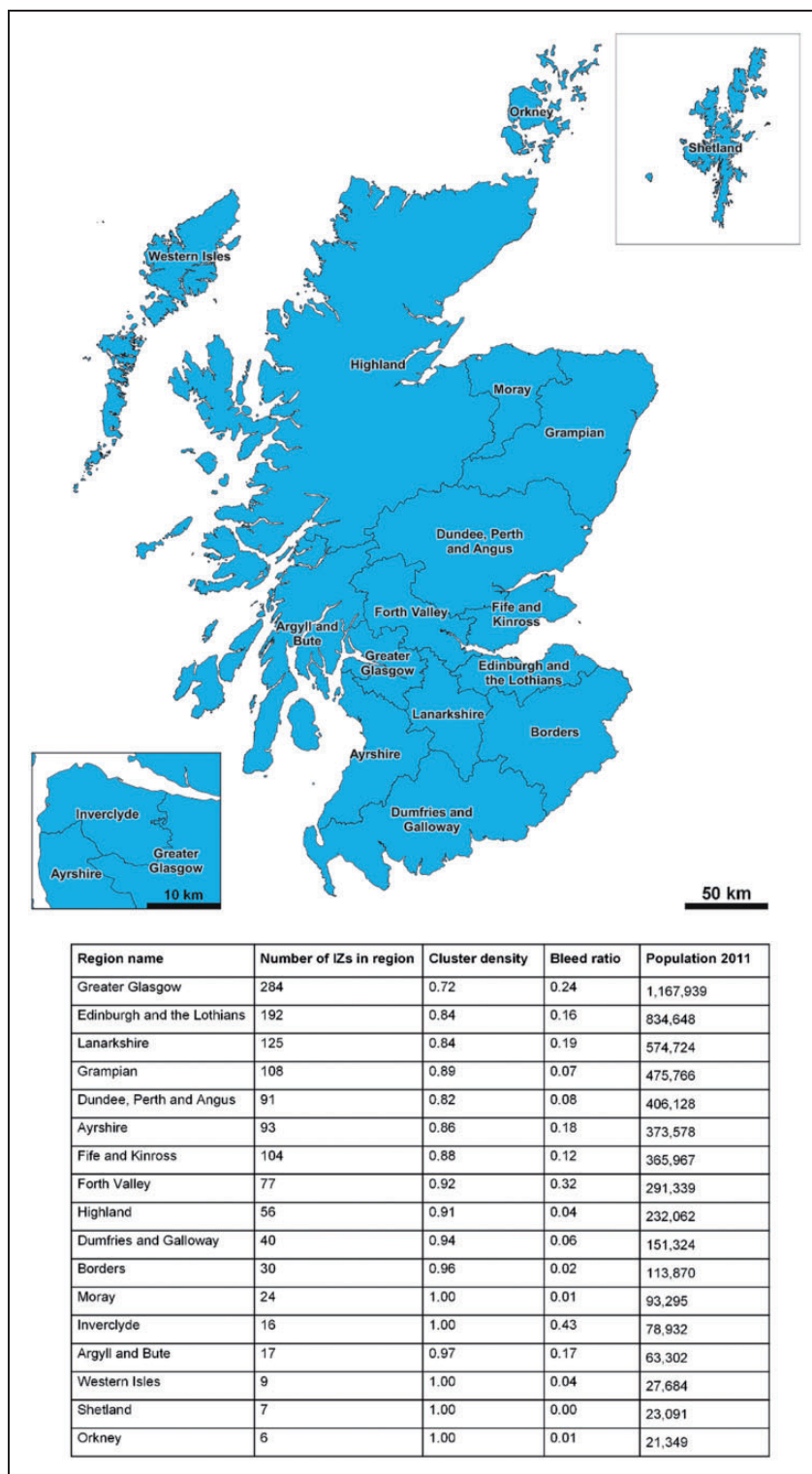


Figure 1. The 17 Combo regions of Scotland, with summary data.

The cluster density scores calculated for Scotland's Combo regions are shown in Figure 1 and range from 0.72 (the 'Greater Glasgow' cluster) to 1.0 (e.g. Moray). Cluster density, like any geographic measure, is naturally scale-dependent and will yield higher scores if a smaller geography is used.

We can also calculate the ratio of links that are fully within a cluster to those that only begin or end within a cluster. We refer to this as the 'bleed ratio' and it gives an indication of the extent to which commute flows 'bleed' into or out of each region. It also gives an indication of a region's wider 'pull' in relation to areas beyond its boundary. Here, a low value indicates a *higher* degree of self-containment whilst a higher value indicates a higher degree of 'bleed' to other clusters, and thus lower self-containment. These values are also shown in Figure 1, in addition to population numbers for each Combo region.

As one would expect, the island clusters (Orkney, Shetland and the Western Isles) exhibit high cluster densities and low bleed ratios, indicating both high internal connectedness and high self-containment. In contrast, Inverclyde – to the west of Glasgow – has a high cluster density (1.0) but it also has a bleed ratio far higher than any other area (0.43). Greater Glasgow has the lowest cluster density, which may be indicative of the fact that jobs are focused on several large sites within the region, including Glasgow city centre and Glasgow International Airport. Its relatively high bleed ratio is also indicative of an employment region that attracts, and sends, commuters from further afield.

At first glance, the new Combo regions of Scotland appear to exhibit a spatial coherence and internal consistency, but they also differ from existing geographies. As a kind of sense check, then, we compared the results of our Combo analysis to existing geographical divisions of Scotland in order to assess the similarities and differences.

Comparing Combo results with existing geographies

It is useful to compare the Combo regions to existing regional delineations of Scotland, in order to get a sense of how logical they appear. For this purpose, we selected council areas and the existing set of TTWAs, also derived from 2011 Census data. These represent administrative and labour market geographies respectively and are presented in Figure 2. If the

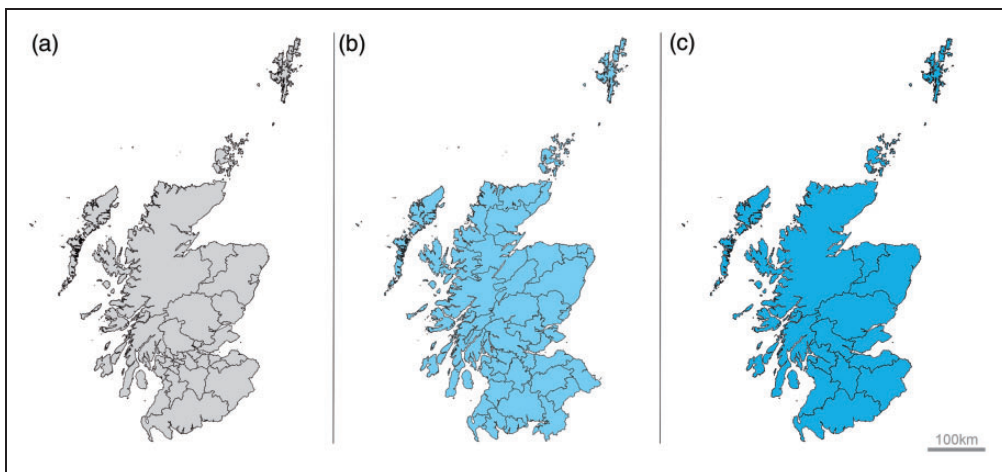


Figure 2. Comparison of Scottish regional geographies. (a) 32 Council areas; (b) 45 TTWAs; (c) 17 Combo regions. TTWA: travel-to-work area.

goal of any future regional reorganisation is to reduce the number of areas, then the Combo approach could provide a way to do this that closely matches existing administrative units. However, what is notable is the extent to which the Combo regions of Scotland differ from the 45 TTWAs. The most obvious difference is in the north of Scotland, and the Highland area in particular, where the TTWA geography is much more fragmented than that produced by Combo. This is partly a factor of the geographical building blocks and statistical parameters used in TTWA composition (TTWAs are based on Lower Layer Super Output Areas (LSOA) in England and Wales, Data Zones (DZ) in Scotland, and Super Output Areas (SOA) in Northern Ireland). It is also indicative of a high level of internal connectivity, as the Highland cluster density of 0.91 indicates. The question of which approach is 'right' does of course depend upon the ultimate purpose of any regional delineation. For rural areas like the north of Scotland, the more fragmented TTWA approach may make most sense from a functional economic perspective, and the Combo approach may make most sense from an administrative perspective.

In order to provide further detail, Figure 3 shows a zoomed-in view of the Greater Glasgow Combo region in relation to the current Glasgow City Council area and the 2011 Glasgow TTWA. In the case of the current Glasgow City area, there is an eight-fold increase in the geographic area between the council area and the new Combo region (1457 km^2 vs. 175 km^2) and, as mentioned above, close to a doubling of population, from 615,000 for Glasgow City to 1.17 million for Greater Glasgow.

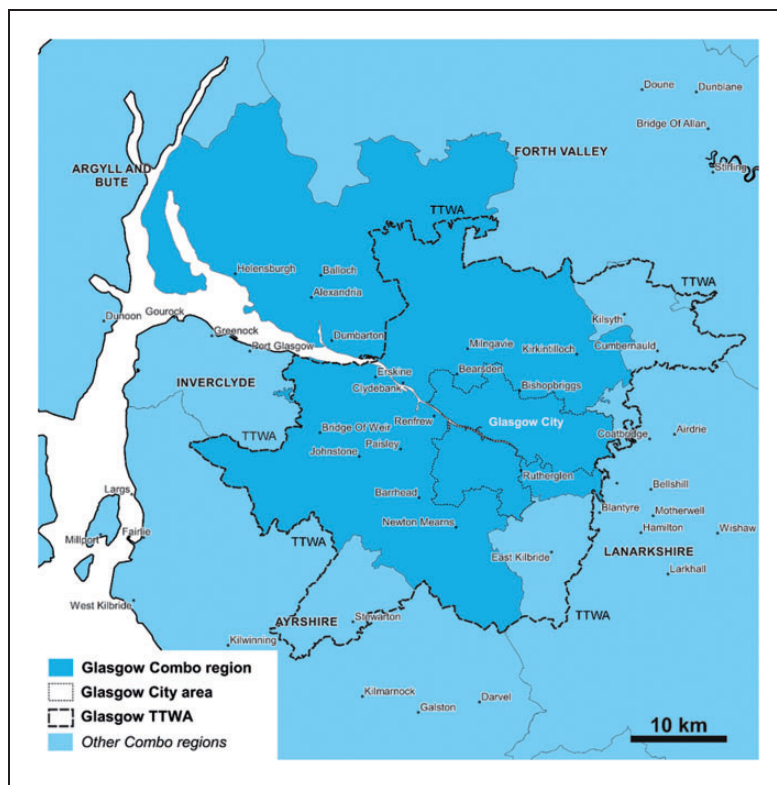


Figure 3. 'Greater Glasgow' (Combo) vs. Glasgow City and Glasgow TTWA. TTWA: travel-to-work area.

The Glasgow TTWA, on the other hand, is a much closer match in terms of size and population, as we would expect given its functional basis. The Glasgow TTWA is Scotland's largest in terms of population, at 1.26 million, and has an area of 1269 km². What is particularly interesting is the extent to which there is considerable overlap, yet the Combo approach excludes portions of the TTWA area to the south and north east, but goes much beyond it in the west. In particular, the settlements of Cumbernauld and Kilsyth to the north east of Glasgow are included within its TTWA, but not in our Combo region for Greater Glasgow. Following Webster (1997: 5) and his comment that Glasgow's TTWA's self-containment was 'deceptive' (owing to the majority of commuting from Cumbernauld and Kilsyth being to places outside Glasgow's TTWA), this is a useful illustration of the impact of taking different empirical approaches to the same problem in the field of regional delineation.

The difference between these two geographies is indicative of both the approach used and the underlying parameters of the analysis. In the case of the TTWA approach, it may relate to the impact of using a 75% self-containment threshold, and in the case of Combo it may relate to the way the algorithm assigns individual nodes to clusters based purely on strength of connection. Neither approach is perfect, but when it comes to helping us understand the functional geography of places, both are useful. However, the Combo approach *may* be more useful when it comes to questions of regional reorganisation, since it is able to produce larger geographic units using any kind of network data and builds them entirely from the ground up. This then raises the question of whether we *should* let algorithms alone define our regions. From our perspective, the answer is a qualified 'no', as we explain in the next section.

Are algorithmic regions the way forward?

There is always a balance to be struck between the power of computation and the politics of geographical space. Relying too heavily on the former will result in regionalisations that, whilst empirically consistent, may have little purchase in the real world. On the other hand, regionalisations which rely too heavily on perceptions and local allegiances may prove a poor match for the way we live and govern. Regional organisations, and local government reform in particular, are often placed in the 'too difficult' box of policy reform, since they evoke such strong emotions. Even so, there remains a need, particularly in austere times, to revisit this question. How we approach the topic is important, and a network partitioning approach to regional delineation can certainly help, as we have attempted to demonstrate. Yet we believe that despite the power of the approach, we should not let algorithms alone define regions, for two main reasons.

The first relates to Hume's law, or the 'is-ought' problem. An algorithmic approach to regional delineation will typically do a very good job of depicting what 'is' in terms of connectivity, but it cannot tell us much about what regions 'ought' to look like. A good example of this is the case of Inverclyde, a less affluent, more disconnected part of west central Scotland which has struggled in recent decades to overcome the legacy of deindustrialisation. The Combo approach shows us that this 'is' a separate functional economic region, but the real question here might be whether it 'ought' actually to be part of the Greater Glasgow policy region if it is to benefit from the wider range of employment and housing opportunities available there. This may require enhanced infrastructure and improved transportation but it would appear logical from a policy point of view. Thus, an algorithmic approach can provide good descriptive results but has less to say on normative questions of regionalisation.

The second reason why algorithms alone are insufficient relates to what we call here the ‘Kingdom of Fife conundrum’. This is essentially the regional history question revisited and has such power that it cannot be overlooked. Fife is a peninsula to the north of Edinburgh and south of Dundee (Figure 1) and is still often referred to as the ‘Kingdom of Fife’, owing to its origins as the Kingdom of ‘Fib’ during the late Iron Age and early Medieval period (c.297 to c.900 CE). Any regionalisation that seeks to alter the locally accepted borders of Fife is likely to run into problems. This was noted after the publication of the Reform Scotland proposals in 2012 when BBC Scotland Political Editor Brian Taylor commented on the response in Fife:

Needless to say, they were less than pleased. And, when Fifers are displeased, they are inclined to let the rest of us know about it. Which is a very long way round to saying that it is a courageous politician indeed who tampers with council boundaries. (BBC, 2012)

Thus, the depiction in Figure 1 of Fife as encompassing the area of Kinross may be an unlikely and unwelcome solution in any potential regional reorganisation, even if it does reflect the underlying reality of economic geography. This also represents a kind of reversal of the Inverclyde case, where something ‘is’ in a region but history and politics tell us it ‘ought’ not to be. Thus, in summary, our view is that we should let algorithms help us when it comes to regional delineation, but they should not have the final say. This may seem like an obvious point but in the age of the algorithm it is worth repeating.

Conclusion

A body of knowledge in regional studies, built up over several decades, demonstrates the primacy of the political in relation to geographic space. For logistics companies delivering parcels, this may not be a problem, but for any geographical unit adopted by government, the politics of space cannot be ignored. This is why we believe, despite the power of the algorithmic approach and its hidden power in contemporary society, the context of regions – social, cultural, political – will always be an over-riding factor in their composition and what they contain. This is a major reason why the topic remains undisturbed in most nations and why politicians typically steer well clear of it.

Yet despite these tensions we have seen in recent years some nations reconfigure their regional geographies, most often aimed at the reduction in the number of administrative units. The topic remains dormant in most nations, but in Scotland it remains something of an open question. If there is to be a ‘big bang des régions’ in Scotland, as in France, then it is important that we take into consideration a number of factors, some of which can be accurately assessed using algorithms, but many that cannot. Understanding the functional geography of the nation, we would argue, should be a large part of any future administrative realignment, since it can provide a dispassionate account of how space is organised and operates from a functional economic perspective; and this, we would argue, should be a major consideration in how sub-national government operates.

As Parr (2008) in particular has shown, however, we need to be aware of the different kinds of spaces with respect to their purpose. For the purpose of governing a country in an efficient manner with respect to resources, the delivery of local services, planning, and housing there may be no single best answer as to what *ought* to be in a region, but the Combo approach can help reveal what *is* in, and what is not. It also provides a potentially more flexible alternative to the traditional TTWA approach. If functional economic

geography is to be taken into consideration in any future regional reorganisation of Scotland, then we hope that this study can provide useful evidence in that regard.

Acknowledgements

We would like to thank the Editor and the anonymous reviewers for helpful suggestions on this paper. We also thank Aleksander Stysiak, Garrett Nelson, Adrian Bailey and Vlad Mykhnenko for sharing their knowledge on recent regional reorganisations in Europe.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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