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Quantitative methods II: How we moved on – Decades of change in philosophy, focus and methods

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Abstract
The first of these three reports reprised human geography's theoretical and quantitative revolutions' origins, covering the philosophy, focus and methods that dominated their early years. Over the subsequent decades the nature of work categorised as quantitative human geography changed very considerably – in philosophy, focus and methods. This second report summarises those changes, highlighting the main features of the extensive volume of work published over the last five decades, as a prelude to the final report that will focus on the contemporary nature of quantitative human geography and its likely futures.

Keywords
change, focus, methods, philosophy, quantitative methods

I Introduction

> The future of geography is inextricably bound to the future of spatial analysis. (Golledge, 2009: 481)

The first of these three reports reprised human geography's theoretical and quantitative revolutions' origins. By the 1970s quantification had penetrated deeply into both UK undergraduate and North American postgraduate programmes (Lavalle et al., 1967; Robson, 1970; Whitehand, 1970, 1971). But the revolution was never completed; as that 'new geography' approached dominance it was challenged by several alternative perspectives (Johnston and Sidaway, 2016). Deployment of quantitative methods went on the defensive (illustrated by successive books on modelling: Chorley and Haggett, 1967; Macmillan, 1989; Peet and Thrift, 1989), but nevertheless sustained its disciplinary presence: attacking an increasingly wide range of research questions; occupying a central role in most teaching programmes; and increasingly (if less written about) being applied (Breheny, 1989) – though not always well (Senior, 1991).

Whilst engaged on that defence, however, human geography's quantifiers substantially changed their practices, which now differ very significantly from the original conceptions. This report reviews those changes under the three headings in the first report, giving most

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attention to philosophy; most of the methodological changes have been covered in detail in earlier reports by previous writers.

II Philosophy

The revolution's underpinning philosophy, made explicit by Harvey (1969), was positivism – to some, logical positivism aimed at identifying geographical laws. That was attacked: from outside the 'quantitative community' the revolution was important because it stressed analytical rigour and the necessity of theory, but critics claimed it was the wrong sort of theory (e.g. Cox, 2014; Peet, 1998; Barnes and Christopher, 2018); from insiders it reflected growing awareness of the original research agenda's limits – philosophical, methodological and substantive.

Two geographers long aware of those limitations had been disregarded. Crowe (1939: 11), *the* pioneer quantitative geographer (Johnston, 2019a), claimed geographers should seek 'scientific synthesis . . . [in] statements of tendencies similar to those of the social sciences'. Jones (1956: 370) contested Martin's (1951) claim that 'laws must be formulated which could be applied in human geography with the same exclusiveness and rigor as scientific laws are applied in the physical world', concluding that

> however broad the generalization, it might fail in strict application to any single phenomenon. Any pattern which emerges does so as the statistical mean of the behaviour of a mass of human individuals, and any generalization which the human geographer might find useful must be based on this behaviour. (Jones, 1956: 373)

Sayer (1992 [1984]) developed a similar argument using critical realist theory. That each effect has a direct cause does not imply laws of effects. Particular actions may have the same effect if the contingent circumstances are consistent; social science searches for those tendencies and the contingent circumstances within which they emerge. To Jones, therefore, social science produces 'generalizations covering a vast number of data':

> the search for ultimate causes is as meaningless as the limiting of geography to examine one cause among many. Each circumstance must be set against the historical frame of reference wherein its origin lies, and it is in that context that the geographer will most nearly approach the solution of causes. (Jones, 1956: 377; see also Jones, 2010)

Bennett (1981: 13; see also Bennett and Wrigley, 1981) saw critiques of positivism as based on a caricature. Criticisms focused on searches for universal laws were 'at best a misrepresentative irrelevance, and at worst a fatuous distraction' because that was no longer the goal (Bennett and Wrigley, 1981: 10). Some early quantitative geography 'was concerned, to too great an extent, with techniques per se, with creating an artificial sense of objectivity' (p. 10), but the approach was 'far more catholic than its critics would allow', although its exact nature was not fully specified. (Openshaw (1998a) later listed the 'good' and 'bad' aspects of quantitative human geography.) Others (e.g. Hay, 1979; Sheppard, 2001) sought accommodation with the alternatives advanced by positivism's critics. Most just got on with their research, with developing methods applied to a wider range of questions.

This shift of philosophical foundation involved no longer emphasising spatial form but stressing process. The early focus was on spatial patterns – points and hierarchies, lines and flows, surfaces and diffusions – resulting from human actions rather than the actions themselves. Increasingly attention focused on spatial order in decision-making – behavioural geography (Cox and Golledge, 1969, 1981; Golledge and Stimson, 1987, 1997), for which 'Few, if any, of the classic positivist tenets now seem to be necessary' (Couclelis and Golledge, 1983: 332). Positivism set 'standards of clarity, consistency, and rigor in the development of argument and in the conduct of inquiry', shifting it away from ‘fuzzy-mindedness, verbosity, muddled thinking and obscurantist discourse’ (p. 334) – hence they chose the term ‘analytic geography’, which studied ‘human existence . . . anchored in a shared external world’ (p. 337) and that did not need ‘the survival of the old-fashioned physicalism that sees the model of all knowledge in science and in particular that science of three centuries ago’.

There was also a growing acceptance that much human geography was insufficiently developed theoretically and, unlike the hard sciences, lacked the foundations for predicting outcomes. Gould (1981: 174), for example, preferred to ‘start with the data and try to make the data speak for themselves’, within a ‘frame of meaning’ that ‘must be derived by phenomenological and descriptive methods before they can be used in the empirical and explanatory part of a science . . . [deploying] descriptive analyses [that] should help us identify the geometries and mathematical structures that will not crush the phenomena’. (Gould’s (1980) chosen method/approach for this, Q-analysis, gained virtually no followers, however.) Some promoted what others interpreted as little more than naïve empiricism (e.g. Openshaw, 1991, 1992; Taylor and Overton, 1991); Openshaw’s ‘data-led’ discipline (1991: 622) explored the ‘increasingly spatial-information-rich world’ (Openshaw, 1992: 465) – exemplified by his Geographical Analysis Machine (Openshaw et al., 1988) and Geographical Explanation Machine (Openshaw, 1998b), which used computers’ ‘brute force’ to identify spatially significant clusters of, for example, particular diseases. This involved exploring patterns and their possible causes within broad theoretical structures rather than, as some argue (e.g. Taagepera, 2008, 2015), developing theories with precise, testable hypotheses. Not all accepted that argument, however (e.g. Plummer et al., 2012).

Such approaches paralleled arguments in sociology. Goldthorpe, quoting Neyman (1975: 417), argued that:

> The common feature of . . . populations was that, while their individual elements were subject to considerable variability and might appear, at least in some respects, indeterminate in their states and behaviour, they could nonetheless *exhibit aggregate-level regularities of a probabilistic kind*. (2016: 7; emphasis in original)

Sociology studies ‘events that can be shown to occur within a given population or subpopulation *with some degrees of regularity*’ (Goldthorpe, 2016: 44; emphasis in original). Similarly, Smith (2019: 108) summarised such work as ‘what happens in one case study may (probably will) be unique; but that does not mean that it will not allow general principles about particular social phenomena to be drawn out’. A comparable definition could have been devised for the path many quantitative human geographers took – though it wasn’t (but see Rushton, 1969). Like Goldthorpe (2016: 8; emphasis in original), they sought for the ‘probabilistic regularities that characterise a particular population, or its appropriately defined subpopulations’, for which statistical methods are essential, and to determine the ‘processes or mechanisms which *in their operation at the individual level* actually produced these regularities’. Explanation remained a common term in their lexicon; prediction did not (Johnston, 1986; Jackson et al., 2006).

Few quantitative human geographers expressed this changed philosophical foundation in presentations aimed at wide audiences. *Quantitative Geography: Perspectives on Spatial Data Analysis* (Fotheringham et al., 2000: xi; see also Fotheringham, 2006: 5) was written to ‘redress the rather antiquated view of quantitative geography held by many outside the research area’ but may not have reached many critics. The goal is ‘to accrue sufficient evidence which makes the adoption of a particular line of thought compelling’ regarding ‘variation in relationships over space’ but rarely searching for ‘hard evidence that global “laws” of human behaviour exist'. Kitchin (2006: 24) recognised that difference, but claimed that a consequence of arguing that 'the scientific method [is] the most sensible and robust (rather than the only) approach to geographical enquiry' (as in the pioneering text on statistical analysis in geography – Gregory, 1963; Johnston, 2018) is that much quantitative geography has 'relatively weak and unstable philosophical underpinnings (much of it backsliding into empiricism) and [is] vulnerable to theoretic critique and challenge for which it has little response' (p. 27).[1]

III Focus

Many among quantification's early promoters were stimulated by location theories assuming economically rational spatial behaviour (Taylor, 1981; Haggett's (1965) pioneering text is a paradigm exemplar); geometry was their mathematical language (Bunge, 1966).

To Bennett and Wrigley (1981: 6):

> the paradigm of spatial geometry has been weakened . . . many of the questions deriving from the methodology of spatial geometry have been left behind . . . [being replaced] by an emphasis on spatial process.

The core concept was now place rather than space; places differ in myriad ways, creating mosaics with each part a context for individual decision-making. Identifying their varying characteristics involved 'areal analysis', but an early book, *Statistical Geography* (Duncan et al., 1961) – exploring spatial variations and their co-variance quantitatively – was largely ignored. Geographers turned to those issues later, but without appreciating *Statistical Geography*'s important arguments and so had to 're-invent' them – in one case not for 50 years (Johnston and Jones, 2019).

There was a considerable broadening of substantive interests. Within urban geography, for example, sociologists' development of social area analysis and factorial ecology (Johnston, 1971; Timms, 1971 – later the basis for geodemographics: Harris et al., 2005) stimulated mapping residential patterns, deploying factor/principal components and classification analysis (Taylor, 1981), and the resulting segregation (on which there is a very extensive literature: e.g. Lloyd et al., 2015; Piekut et al., 2019; Yao et al., 2018). Exploration of neighbourhood effects built on these studies, investigating how local contexts influence behaviour, and how they might be inferred from aggregate data without committing ecological fallacies (a non-geographical survey of that large literature is Galster, 2019). Those aggregate studies were accompanied by investigations using survey data to analyse individual behaviour patterns in, for example, voting (Johnston and Pattie, 2006), with the greater availability of relevant data facilitating explorations at a range of spatial scales (e.g. Harris, 2017).

IV Methods

In the quantitative revolution's early decades statistical procedures were mainly used to test (usually verify) hypotheses using methods within the general linear model, notably regression and correlation. Mathematical approaches were adopted by only a few and were rarely covered by introductory texts (Taylor, 1977, is an exception).[2] Substantial work was, however, led by Alan Wilson at Leeds (Johnston, 2019b), embracing mathematical modelling (Wilson, 1970, 1981, with introductory texts; Wilson and Kirkby, 1975) in a variety of contexts (Rees and Wilson, 1977), stressing particular views on location theory (Wilson, 1974, 2016a, 2016b) and deployed in applied locational exercises (Birkin et al., 1996).[3]

Geographers became increasingly aware of the limitations of standard statistical procedures when applied to spatial data. Addressing them stimulated growing sophistication of spatial analysis – engaging the interest of statisticians and computer scientists plus other social scientists (Fotheringham and Rogerson, 2009), illustrated by work in several areas.

1 Spatial autocorrelation

King (1969: 157–62) noted that whereas economists paid considerable attention to autocorrelation issues, geographers had not ‘progressed far in handling the problem of spatial autocorrelation’; Gould (1970) questioned the validity of using standard statistical inference procedures, but although methods were available to address the issue (brought to geographers’ attention by Cliff and Ord, 1973, 1981; Cliff et al., 2009), 40 years later Brunsdon (2001: 1) noted that ‘there are still plenty of studies published which rely on non-spatial data analysis techniques’.

Cliff and Ord’s pioneering work informs much contemporary spatial science (Getis, 2008, Ord, 2010), including development of *local statistics* – measures of spatial clustering (such as Anselin, 1995; Getis and Ord, 1996; Sokal et al., 1998; Boots, 2003) plus analyses of local variability (Ord and Getis, 2012), the dynamics of spatial distributions (Rey, 2016), and multivariate geographical relationships (Anselin, 2019). This resonates with *spatial econometrics* (Paelinck et al., 1979; Hepple, 1996), models incorporating explicit ‘spillover’ terms in spatial relationships (causal or coincidental) which can increase the uncertainty around parameter estimates, reducing the prevalence of false positive results (Anselin, 1988; Anselin and Griffith, 1988; LeSage and Pace, 2009; Kelejian and Piras, 2018).

These developments addressed a contention that models assuming that relationships exist independently of context deny geography (Foster, 1991). Approaches exploring whether relationships are spatially invariant included Geographical Weighted Regression (GWR: Fotheringham et al., 2006) and its extensions (Brunsdon et al., 2007; Fotheringham et al., 2015; Murakami et al., 2019) – inductive pattern-seeking procedures focusing on data near sites of interest rather than the full data set (Wolf et al., 2018).

2 The modifiable areal unit problem (MAUP)

Much quantitative social science uses data reported for areas (Johnston et al., 2019, discuss the constraints they impose on analyses). The chosen lattice could influence any relationship found across districts; different divisions of an area into 50 districts may produce different results, as might one into 25 rather than 50 districts. Openshaw and Taylor’s (1979, 1981) experiments decomposed the problem into scale (the number of areas) and aggregation (a particular set of areas at a given scale) effects, and Gudgin and Taylor (1979) reported seminal work on the geography of representation; their sophisticated spatial theory and empirical examples showed how the translation of a party’s vote shares into seat shares reflects not only its vote total but also how clustered they are into small areas, such as neighbourhoods, how spatially concentrated those clusters are, and the detailed location of the boundaries of constituencies superimposed on those maps. Recognition of the MAUP also underpinned development of automatic zoning algorithms to define bespoke areas for reporting census data (Martin et al., 2001). Geographers were also among the pioneers developing bespoke neighbourhoods for analysing spatial variations in census data (Buck, 2001; McAllister et al., 2001).

3 Scale and multi-level analysis

Scale is a key geographical-cartographical concept; the realisation that relationships are not necessarily consistent across spatial scales stimulated methods of spatial decomposition (Haggett, 1964; Moellering and Tobler, 1972; Jones and Casetti, 1992). A major extension came with adoption of multilevel modelling (Jones et al., 1992; Jones and Moon, 1993), developed in educational research for examining the nature and strength of relationships between variables at several scales (Jones, 1991; Jones and Duncan, 1996), with geographers involved in the software developments at the Centre for Multilevel Modelling[4] and their application in studies of, for example, scalar variations in residential segregation (Jones et al., 2015, 2018) and political polarisation (Johnston et al., 2016) – modified to uncover interactions among variables in multivariate models (Jones et al., 2016), or intersectionality (Green et al., 2017; Evans et al., 2018).

Alongside these developments accommodating spatial data's particular nature, human geographers extended their quantitative repertoire in other ways. Increasingly survey data became available on individuals. Methods for analysing interval and ratio data were not suited to such non-continuous measures, so geographers were introduced to categorical data analysis for addressing nominal and (less frequently) ordinal data (Wrigley, 1985) plus methods for analysing longitudinal/panel data (Wrigley, 1986). In the wider context of pattern-seeking rather than hypothesis-testing and law-seeking, they also adopted and adapted to their spatial concerns methods of exploratory data analysis (Tukey, 1977; Cox and Jones, 1981).

These innovations in methods and data were facilitated – in some made feasible – by improvements in computing environments, including software specific to geographic/spatial applications, such as GeoDa[5] (Anselin et al., 2006; see also Rey and Anselin, 2007; Bivand et al., 2008); geographers have also made considerable use of the R software package to integrate modelling and visualisation (Brunsdon and Comber, 2018; Lovelace et al., 2019). These led to the formulation of several new appellations for quantitative work: *geocomputation*, in which Stan Openshaw was a prime mover, establishing the Centre for Computational Geography at the University of Leeds (Batty, 2017; Harris et al., 2017); *geographical information systems/science*, which lies outwith the scope of these progress reports; and *geographic data science* (Singleton and Arribas-Bel, 2019). Electronic devices with geopositioning facilities are used for data collection, providing information (some in real-time) on where people have been, and when (e.g. Kwan, 2009, 2012); participatory GIS has been similarly deployed (e.g. Huck et al., 2019). The visualisation capability of GIS and other software has facilitated extensions to exploratory spatial data analysis (MacEachren and Kraak, 1997; Andrienko et al., 2003), although geospatial data raise particular issues of uncertainty, illustrated in papers introduced by Chun et al. (e.g. 2019). Developments in cartography and the presentation of spatial data (Robinson et al., 2017; Cheshire and Uberti, 2017), much of it pioneered by Tobler (see Unwin, 2019), include increasing use of cartograms (Tobler, 2004; Dorling and Thomas, 2016; Nusrat and Kobourov, 2016; Harris et al., 2018).

As is common when innovations become part of 'normal science', these developments have not only been incorporated into standard quantitative methods texts but are also the subject of specialist volumes (e.g. Upton and Fingleton, 1985, 1989; Haining, 1993; Bailey and Gatrell, 1995; Fotheringham et al., 2000; Tate and Atkinson, 2001; Fotheringham and Rogerson, 2009; Lloyd, 2010, 2014). Inclusion of these formerly-specialist geographical concerns into 'mainstream' statistical texts on, for example, multilevel (Gelman and Hill, 2007) or local smoothing (Wood, 2017) models suggests that innovations from geographers' revolution are gaining wide adoption as this 'specialist' knowledge becomes easier to explain and distribute to wider audiences (as in Darmofal, 2015).

The increasing availability of big data – information collected and collated, perhaps in real time, by commercial and other bodies from non-random samples (Kitchin, 2014) – has further broadened geographers' interests, as at the Consumer Data Research Centre (Longley et al., 2018).[6] These promise much but raise problems, set out in a book on urban analytics (Singleton et al., 2018; Batty, 2019; see also Kitchin and Perng, 2016; Kitchin et al., 2018), a new term coined for their analysis. Extremely large datasets make traditional notions of statistical 'significance' unhelpful: at worst, every relationship is significant, but with varying degrees of importance, requiring revised theoretical frameworks and statistical methods for coherent analyses (for a dialogue about these issues see Graham and Shelton, 2013). Further, many methods now commonly deployed were developed only as computation intensified and data proliferated, mimicking a broader trend in statistical work (e.g. Efron and Hastie, 2016: 448). How the discipline evolves to meet the challenges of a data-driven world, in which so many activities involve digital techniques, logics and devices, extends well beyond such technical issues and is being explored under the theme of digital geographies (Ash et al., 2018).

These methodological developments illustrate the growing sophistication of geographers' particular spatial focus. The discussion has been far from comprehensive in coverage of methods on which future developments are being built (the use of artificial intelligence, for example (Openshaw and Openshaw, 1997); of agent-based modelling and other simulation procedures; and of experimental methods), They characterise the emerging future of quantitative human geography and are the focus of the final report in this series.

V Conclusions

The 1960s to 1980s saw considerable intra-disciplinary conflict as proponents of different approaches struggled for dominance in human geography's research and teaching agenda. Such conflict is now muted as accommodations were implicitly reached whereby the separate approaches co-exist with relatively little interaction. There are occasional outbursts and attempts at re-defining, either by promoting a particular approach or side-lining another (excluding it from introductory textbooks, for example: Johnston, 2006), but adherents to separate positions now operate in relative ignorance of others' activities. Some attempts at overviews of the entire discipline either exclude or misrepresent some of its component parts, however; quantitative human geography has been presented by some as if its current practices differ little from those deployed 50 years ago (for example, Cresswell, 2013; Couper, 2015; see Johnston et al., 2014). Hence the formulation of these three progress reports, providing a broad overview of a rapidly changing, vibrant subdiscipline that many human geography texts largely ignore.

Not only is quantitative human geography technically more sophisticated now (see, for example, Kwan, 2010; Legates et al., 2003), but its philosophy, substantive foci and methodologies are very different. For many decades human geography's key metaphor, using Buttimer's (1993) terminology, was the mosaic. The quantitative revolution sought to change that to machine (with all the potential dangers of instrumentalism, of 'is becoming ought') but the remaking of the quantitative approach outlined here has returned it to mosaic – a focus on places more than on spaces. Some features of the revolution's early years, such as the primacy of central place theory, have almost entirely faded: others remain – gravity models are still fitted to flow data and the spread of diseases explored with diffusion models (Cliff et al., 2009) and spatial forms are investigated (D'Acci, 2019), as in the pioneering application of fractal theory (Batty and Longley, 1994; more generally on systems approaches, see Batty, 2005, 2013). But these extensions of traditional concerns have occurred alongside an explosion of changes in philosophy, focus and methods whose nature has been briefly reviewed here, as the foundation for the final report in the series that will set out the contemporary agenda.

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Notes

1. In the same book Fotheringham (2006: 237) began a chapter on ‘Quantification, Evidence and Positivism’ with the claim that ‘Quantitative geographers do not often concern themselves with philosophy . . . although externally we are often labelled (incorrectly in many cases) as positivists, such a label has little or no impact on the way in which we prosecute research’.
2. The approach was given an entire section in Wrigley and Bennett (1981), however.
3. Wilson’s entropy-maximising methodology was, however, adapted for uncovering spatial variations in aspects of voting patterns (see Johnston, 2019b).
4. See http://www.bristol.ac.uk/cmm/.
5. See https://spatial.uchicago.edu/geoda.
6. See https://esrc.ukri.org/research/our-research/consumer-data-research-centre-cdrc/

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