2 Positivist Geography

Rob Kitchin

Introducing Positivism

Positivism is a set of philosophical approaches that seeks to apply scientific principles and methods, drawn from the natural and hard sciences, to social phenomena in order to explain them. Auguste Comte (1798–1857) is widely acknowledged as the father of positivism. He argued that social research prior to the nineteenth century was speculative, emotive and romantic and as a result it lacked rigour and analytical reasoning. Unwin (1992) details that Comte used the term ‘positive’ to prioritise the actual, the certain, the exact, the useful, the organic and the relative. In other words, he posited that it is more useful to concentrate on facts and truths – real, empirically observable phenomena and their interrelationships – rather than the imaginary, the speculative, the undecided, the imprecise. What Comte demanded was the objective collection of data through common methods of observation (that could be replicated) and the formulation of theories which could be tested (rather than as with empiricism, where observations are presented as fact). Such testing would be systematic and rigorous and would seek to develop laws that would explain and predict human behaviour. As such, Comte rejected metaphysical (concerned with meanings, beliefs and experiences) and normative (ethical and moral) questions as they could not be answered scientifically. Like with most other ‘isms’ and ‘ologies’ there are various different forms of positivism. The two most commonly discussed are *logical positivism* based on verification and *critical rationalism* based on falsification.

Logical positivism was developed by the Vienna Circle (a lose collection of social scientists and philosophers) in the 1920s and 30s. Like Comte, they posited that the scientific method used in the traditional sciences could be applied directly to social issues – that is, social behaviour could be measured, modelled and explained through the development of scientific laws in the same way that natural phenomena are examined. Such a view is called naturalism and is underpinned by a set of six assumptions as detailed by Johnston (1986: 27–8):

1. That events which occur within a society, or which involve human decision-making, have a determinate cause that is identifiable and verifiable.
2. That decision-making is the result of the operation of a set of laws, to which individuals conform.

3. That there is an objective world, compromising individual behaviour and that the results of that behaviour, which can be observed and recorded in an objective manner, on universally agreed criteria.
4. That scientists are disinterested observers, able to stand outside their subject matter and observe and record its features in a neutral way, without in any respect changing those features by their procedures, and can reach dispassionate conclusions about it, which can be verified by other observers.
5. That, as in the study of inanimate matter, there is a structure to human society (an organic whole) which changes in determinate ways, according to the observable laws.
6. That the application of laws and theories of positivist social science can be used to alter societies, again in determinate ways, either by changing the laws which operate in particular circumstances or by changing the circumstances in which the laws will operate.

The Vienna Circle significantly extended Comte's work, however, by formulating rigorous analytical procedures centred on verification. As such, they sought to define precise scientific principles and methods by which social behaviour could be measured and social laws verified (the extent to which scientific theories explained objective reality). The mode of measurement they advocated was one centred on the precise quantitative measurement of facts (e.g. heights, weights, time, distance, wage). These measurements allowed the statistical testing of relationships between variables as a means to test (verify) explanatory laws. Because the method focuses on known facts that are easily collected across large populations (e.g. using the census), it is possible to test and verify laws against very large sample sizes. Here, a deductive approach is employed, wherein a theory is formulated and hypotheses are set and then tested. In cases where the data does not support the hypotheses, the theory can be modified, new hypotheses set and the data re-analysed. A cumulative process is thus adopted, wherein theories are extended and built up in a structured and systematic manner through the incorporation of new findings and the rejection and resetting of hypotheses. Given that samples are often not perfect, complete verification is understood to be impossible, and logical positivism thus deals with weakly verified statements understood in terms of probabilities (the statistical likelihood of occurrence) that it aims to strengthen (Johnston 1986). By increasing the strength of probability that a relationship did not occur by chance and is potentially causal, hypotheses can be tested, and theories deductively constructed. In this way, logical positivism provides a method for gaining an objective knowledge about the world. Objectivity through the independence of the scientists is maintained through conformity to the following five premises (Mulkay 1975, cited in Johnston 1986: 17–18):

1. *Originality* – their aim is to advance knowledge by the discovery of new knowledge.
2. *Communality* – all knowledge is shared, with its provenance fully recognised.
3. *Disinterestedness* – scientists are interested in knowledge for its own sake, and their only reward is the satisfaction that they have advanced understanding.
4. *Universalism* – judgements are on academic grounds only, and incorporate no reflections on the individuals concerned.
5. *Organised scepticism* – knowledge is advanced by constructive criticism.

In contrast to Comte, the Vienna Circle accepted that some statements could be verified without recourse to experience, making a distinction between analytical statements and synthetic statements. Analytical statements are *a priori* propositions whose truth is guaranteed by their internal definitions (Gregory 1986a). Such analytical statements are common in the formal sciences and mathematics, where questions are often solved in a purely theoretic form long before they can be empirically tested. Indeed, theoretical physics almost exclusively seeks to provide solutions (based on known laws and properties) to problems that remain impossible to empirically test (see for example Hawking's *A Brief History of Time*). Synthetic statements are propositions whose truth needs to be established through empirical testing because they lack internal definition and are complex. In addition, the Vienna Circle forwarded scientism (that is the claim that the positivist method is the only valid and reliable way of obtaining knowledge, and all other methods are meaningless because they do not produce knowledge that can be verified) and a narrowly defined scientific politics that argued that positivism provides the only means of providing rational solutions to all problems (Johnston 1986).

Critical rationalism was developed in response to logical positivism and challenges its focus on verification. Forwarded by Karl Popper, it contends that the truth of a law does not depend on the number of times it is experimentally observed or verified, but rather whether it can be falsified (Chalmers 1982). Here it is argued that rather than trying to provide a weight of confirmatory evidence, scientific validation should proceed by identifying exceptions that undermine a theory. If no exceptions can be found then a theory can be said to have been corroborated. The critique of such an approach is that a theory can never be fully validated as a yet unidentified exception might still be awaiting discovery. As a consequence, the approach is difficult to implement except in cases of full sample populations and has not been adopted by many geographers (Gregory 1986b). A variety of other versions of positivism have been proposed and contemporary positivist philosophy significantly extends the work of the Vienna Circle. That said, debates in geography draw on these older forms of positivism mainly because positivist geography itself rarely engages in any deep or meaningful engagement with philosophy and, as such, its underpinnings have not been advanced with regard to new forms of positivism.

Development and Use of Positivism in Human Geography

> Positivism is one of the unrecognised, 'hidden' philosophical perspectives which guides the work of many geographers. … [It remains hidden] in the sense that those who adhere to many of its central tenets rarely describe themselves as positivists. … While many boldly carry the banner of their chosen philosophy, the name of positivism is rarely seen or heard in the works of geographers who give assent to its basic principles. (Hill 1981: 43)

Until the 1950s, geography as a discipline was essentially descriptive in nature, examining patterns and processes, often on a regional basis, in order to try and understand particular places. From the early 1950s, a number of geographers started to argue that geographical research needed to become more scientific in its method, seeking the underlying laws that explained spatial patterns and processes. For example, Frederick

Schaefer (1953: 227), in a paper often cited as the key catalyst for the adoption of scientific method in human geography, argued that 'geography has to be conceived as the science concerned with the formulation of the laws governing the spatial distribution of certain features on the surface of the earth'. In effect Schaefer drew on the arguments of logical positivism to contend that geography should seek to identify laws, challenging the exceptionalist claims of geographers such as Hartshorne (1939) that geography and its method was unique to that of other social sciences. In other words, geography should shift from an ideographic discipline (fact gathering) focusing on regions and places to a nomothetic (law producing) science focused on spatial arrangement.

The principal concern of the early advocates of geography as a *spatial science* was that geographical enquiry up to that point was largely unsystematic and analytically naïve. Geographers were developing empiricist accounts of the world by simply accumulating facts as evidence for generalist theories. The problem with such empiricist endeavours was that they did not distinguish between casual correlations and accidental or spurious (non-causal) associations. For example, environmental determinist accounts suggested that environmental conditions explicitly influenced society in a casual fashion (e.g. high ambient temperatures caused underdevelopment in tropical countries by inducing idleness among local residents) (Hubbard et al 2002). Moreover, such accounts committed ecological fallacies – that is, ascribing aggregate observations to all cases within an area. However, just because two things are observed in the same place at the same time does not mean that one caused the other or that they apply universally. They need to be tested scientifically. Indeed, most people now accept that ambient temperature may influence human behaviour but it does not determine it, and it has little or no effect on levels of development. For geographers such as Schaefer, geography as a discipline would only gain real utility, and by association respectability within the academy, if it became more scientific. Scientific method would provide validity and credibility to geographic study and it would provide a shared 'language' for uniting human and physical geography.

The Quantitative Revolution

What followed was the so-called 'quantitative revolution', wherein the underlying principles and practices of geography transformed (Burton 1963), with description replaced with explanation, individual understandings with general laws, and interpretation with prediction (Unwin 1992). In order to employ a scientific method, to transform human geography into a scientific discipline concerned with the identification of geographical laws, a number of geographers started to use statistical techniques (particularly inferential statistics concerned with measuring probability of a relationship occurring by chance) to analyse *quantitative* data. Quantitative data was seen as factual, objectively and systematically measured. It was therefore universal in nature, free of the subjective bias of the measurer and analyst. By statistically analysing and modelling these data, geographers hoped to be able to identify universal laws that would explain spatial patterns and processes, and also provide a basis for predicting future patterns and identifying ways to constructively intervene in the world (e.g. altering policy to engender change). So, just as physics and chemistry tried to determine the general laws of the physical world, geographers adopted a naturalist position (a belief in the equivalence of method between social and natural sciences) to try to determine the spatial laws of human activity.

Box 2.1 Spatial models and laws

Throughout the late 1950s and 1960s a whole plethora of geographical models and laws, based on scientific analysis of quantitative data and taking the form of mathematical formulae, were developed using a hypo-deductive approach. For example, early quantitative geographers tried to find a formula that adequately modelled the interaction of people between places. One of these was Isard et al's (1960, detailed in Haggett 1965: 40) inverse-distance gravity model:

$$M_{ij} = (P_j / d_{ij}) \,.f(Z_i)$$

where M_{ij} is the interaction between centres *i* and *j*, P_j is a measure of the mass of centre *j*, d_{ij} is a measure of the distance separating them and $f(Z_i)$ is a function of Z_i, where Z_i measures the attractive force of destination *i*. This advanced earlier models that did not take into account how 'attractive' each location might be in relation to each other (for example, in climate or amenities).

This transformation in theory and praxis led to a whole variety of different types of laws, most of which did not pretend to be the universal law as portrayed by many critics. For example, Golledge and Amedeo (1968, summarised in Johnston 1991: 76) detailed four types of law being developed in human geography: '*Cross-sectional laws* describe functional relationships (as between two maps) but show no causal connection, although they may suggest one. *Equilibrium laws* state what will be observed if certain criteria are met. … *Dynamic laws* incorporate notions of change, with the alteration of one variable being followed by (and perhaps causing) an alteration in another. … Finally *statistical laws* … are probability statements of B happening, given that A exists' (the first three laws might be deterministic or statistical).

The aim, in short, was to create a scientific geography, with the standards of precision, rigour and accuracy equivalent to other sciences (Wilson 1972). However, as Hill (1981) notes, given that spatial science borrowed the idea of scientific method largely without conscious reflection on its philosophical underpinnings, it is perhaps better to term it positivistic rather than positivist. Certainly, many positivistic geographers (most who would prefer to adopt the label of quantitative or statistical geographers) would balk at the scientism and scientific politics of logical positivism, though they would see the scientific method as the most sensible and robust (rather than the only) approach to geographical enquiry. Indeed, the label positivist geography is one that has largely been assigned by its critics in recognition of the allegiance of its underpinnings, rather than one claimed by its practitioners.

As with all 'revolutions', certain key sites and people were instrumental in pushing and developing the emerging quantitative geography. In the US, geographers such as William Garrison at Washington State, Harold McCarty at Iowa State and A.H. Robinson at Wisconsin trained a generation of graduate students who became faculty elsewhere, where in turn they propagated their ideas (Johnston 1991). In the UK, Peter Haggett at Bristol and later Cambridge was a key influence (along with physical geographer Richard Chorley). Indeed, Haggett's book *Locational Analysis in Human Geography* (1965) was an important text that helped to strengthen the case for quantitative geography. Such was the pace of adoption that by 1963 Burton had already declared that the revolution was over and quantitative geography was now part of the mainstream. That said, it is important to note that not all geographers were enthusiastic converts to what was increasingly called spatial science, and many continued to practise and teach other forms of geographical enquiry (Johnston 1991; Hubbard et al 2002). Nonetheless, the quantitative turn, and its conception of space as a geometrical surface on which human relationships are organised and played out, did change how many of these geographers conceived the notions of space and place.

Harvey's Explanation in Geography

Despite the rapid growth of quantitative geography throughout the 1960s, as noted, it largely operated in a philosophical vacuum – it focused on methodological form, not the deeper epistemological structure of knowledge production (Gregory 1978). David Harvey's book *Explanation in Geography* was a milestone text for the discipline. Harvey's key observation was that until that point geographers had rarely examined questions of how and why geographical knowledge was produced. And no-one had tried to forward a robust and theoretically rigorous methodological (rather than philosophical) base for the discipline. Harvey's text thus sought to provide such a base by explicitly acknowledging the importance of philosophy to geographical enquiry. In particular, he drew on the philosophy of science (which can effectively be translated as positivism despite the fact that Harvey never uses the term) to construct a theoretically sound ontology and epistemology – presented as a coherent scientific methodology. As Harvey (1973) himself later acknowledged, however, wider philosophical issues were skirted, as his aim was to concentrate on formalising methodology using philosophy rather than philosophy *per se*.

Spatial Science as Implicit Positivism

While Harvey's text was enormously influential, providing an initial, theoretically robust ontological and epistemological base for spatial science, it is fair to say that most geographers employing the scientific method have subsequently paid little attention to its philosophical underpinnings. As such, as Fotheringham (Chapter 25) notes, positivism *implicitly* underpins much spatial science work, in that while research seeks to determine casual relationships and spatial laws through statistical analysis and geographical modelling, there is little explicit appreciation or engagement with positivism or other philosophies. As such, while there is the adoption of a scientific method and the use of terms such as law, model, theory and hypothesis, these are often used without an appreciation of what they actually mean or constitute (Hill 1981; Johnston 1986). Such research forms a major part of the discipline today, despite criticisms levelled at its positivistic underpinnings. For example, nearly all GIS and geocomputational research is practised as spatial science (although it is fair to say that much of it has actually continued the tradition of empiricism, wherein facts are allowed to 'speak for themselves' and are not subject to the rigours of spatial analysis through statistical testing – for example, in most mapping work the maps are allowed to speak for themselves; it is also increasingly rare to see hypotheses stated and then tested). This is not to say that all *quantitative* geography is implicitly positivist (or empiricist). In fact, much is not. Indeed, quantitative geography refers to the geographical inquiry that uses quantitative data, and such data can be interrogated from a number of ontological and epistemological positions (it is important never to conflate data type with a philosophical approach).

Criticism and Challenges to Positivist Geography

The period of transformation in geography's method opened the way for a sustained period of reflection on ontology, epistemology and ideology of geographical inquiry from the late 1960s onwards. This coincided with a period of large social unrest in many western countries during which many geographers were questioning the relevance and usefulness of the discipline for engaging with and providing practical and political solutions. Consequently, numerous geographers started to question the use and appropriateness of the scientific method and its new, philosophical base of positivism from a number of perspectives. It is important to note here that many of these critiques were not of using and analysing quantitative data per se, but rather of the positivist approach to analysing such data – it was a critique of ontology, epistemology, method and ideology, not data type.

The critiques of positivistic geography came from many quarters. For some, such as Robert Sack (1980), positivistic geography was a form of spatial fetishism, focusing on the spatial at the expense of everything else. Spatial science represented a spatial separatist position, decoupling space from time and matter, which he argued meant that it had little analytical value – determining spatial patterns would not tell us why such patterns exist or why they might change over time because it fails to take account of social and political process.

Marxist and radical critiques developed the latter point. By rejecting issues such as politics and religion and trying to explain the world through observable facts, radical critics noted that spatial science was limited to certain kinds of questions and was further limited in its ability to answer them. It treated people as if they were all rational beings devoid of irrationality, ideology and history, who make sensible and logical decisions. It therefore modelled the world on the basis that people live, or locate their factories and so on, in places that minimise or maximise certain economic or social benefits. Critics argued that individuals and society are much more complex, with this complexity impossible to capture in simple models and laws. As a consequence, Harvey (1973: 128), in a notable turnaround, condemned positivistic geography just a few years after writing its 'blueprint': there is 'a clear disparity between the sophisticated theoretical and methodological framework we are using and our ability to say anything meaningful about events as they unfold around us.' For Harvey, spatial science could say little about issues such as class divisions, Third World debt, geopolitical tensions and ecological problems, because it was incapable of asking and answering the questions needed to interrogate them. Moreover, it was noted that positivistic geography lacked a normative function in that it could seek to detail what is and forecast what will be, but gave no insight into what should be (Chrisholm 1971). For Harvey and others, the only way to address such issues was to turn to radical theories such as Marxism which sought to uncover the capitalist structures that underpinned social and economic inequalities and regulated everyday life, and to transform such structures into a more emancipatory system.

Accompanying radical critiques, from the early 1970s humanist geographers similarly attacked positivism with regard to its propensity to reduce people to abstract, rational subjects and its rejection of metaphysical questions (Buttimer 1976; Guelke 1974; Tuan 1976). In effect it was argued that spatial science was peopleless, in the sense that it did not acknowledge peoples' beliefs, values, opinions, feelings and so on, and their role in shaping everyday geographies. Clearly, individuals are complex beings who do not necessarily behave in ways that are easy to model. Humanistic geographers thus proposed the adoption of geographical enquiry that was sensitive to capturing the complex lives of people through in-depth, qualitative studies.

In addition, both radical and humanist critics questioned the extent to which spatial scientists are objective and neutral observers of the world, contending that it is impossible (and in the case of radicals undesirable) to occupy such a position. Geographers, it was argued, are participants in the world, with their own personal views and politics, not privileged observers who could shed these values while undertaking their research (Gregory 1978). At the very least, researchers make decisions over what they study and the questions they wish to ask, and these are not value-free choices.

This argument was supplemented by feminist geographers such as Domosh (1991), Rose (1993) and McDowell (1992), who argued that spatial science was underpinned by a masculinist rationality. That is, positivism was defined by man's quest for a god's-eye view of the world, one which was universal, 'orderly, rational, quantifiable, predictable, abstract, and theoretical' (Stanley and Wise 1993: 66), and in which the knower 'can separate himself from his body, emotions, values, past and so on, so that he and his thought are autonomous, context-free and objective' (Rose 1993: 7). They argued that geographical enquiry had to reject such rationality and become much more sensitive to power relations within the research process, and the geographer more self-reflexive of their positionality, supposed expertise, and influence on the production of knowledge. In other words, geographers had to give up the pretence that they could necessarily create a master, universal knowledge of the world and accept that knowledge will always be partial and situated (from a certain perspective). What this meant in practice was that feminist geographers largely dismissed quantitative geography as a viable means of feminist praxis.

In turn, this feminist critique opened the door to a wider debate on the relationship between feminism epistemology and spatial science in a special forum of *Professional Geographer* (1994: Should women count?), which in turn helped (alongside texts such as Pickles 1995) to fuel the development of critical approaches to GIS in the late 1990s and early 2000s. Critical GIScience draws off feminist, postmodern and poststructuralist theories to rethink the *modus operandi* of spatial science (see Curry 1998, Kwan 2002, Harvey 2003). In many senses it is an attempt to reposition quantitative geography by providing it with a radically different philosophical framework to positivism, one that is more contemporary and robust to traditional criticisms of spatial science and which enables it to address questions that previously it avoided or was unable to tackle.

Positivist geography today

Despite the criticism levelled at geographical work underpinned by positivist reasoning, implicit positivism remains strong within human geography. A very large number of geographers argue that they are scientists, employ scientific principles and reasoning, and seek laws or mathematical models that purport to explain the geographical world. Many, as Stewart Fotheringham notes in his chapter, give little thought to the philosophical underpinnings of their scientific method and are not interested in philosophical debate and critique, shaking their heads in frustration and disbelief at ongoing philosophical discussions and 'wondering what is happening to the rest of their discipline'. Of course, much of the rest of the discipline are shaking their collective heads at the philosophical naivety of spatial scientists. Questions around what geographers should study, how they should study it, and for whom are important because they define the discipline and its praxis – philosophy is a core, inescapable feature of geographic research (see Hill 1981, Hubbard et al 2002). To ignore such questions, or to take them as self-evident, means that implicitly positivistic geography has weak and unstable underpinnings (much of it backsliding into empiricism) and leaves it vulnerable to critique for which it has little response. To simply argue that those who criticise positivistic geography do not understand its bases, or lack the required skill to practise and therefore understand it, or are damaging the discipline by engaging with wider philosophical debate is a weak and deflective response that fails to tackle any of the criticism levelled at it.

This is not to say that all spatial science lacks theory; rather, much of it lacks a fundamental and robust ontological, epistemological and ideological base. It also does not mean that their work is not useful or valuable; it most patently is or it would not be practised, commissioned or used by policy makers and business. However, by ignoring wider philosophical debate spatial scientists often fail to make a robust case for their approach to new generations of geographers, who are often seduced by the criticisms levelled at positivism and quantification more broadly (and this will continue to be the case unless addressed). Instead they rely on the commercial and policy cache of GIS to make implicitly positivistic geography sustainable. As the debates in GIScience illustrate, however, the implicit positivism underpinning GIS use is open to challenge, with an acknowledgement that the employment of the scientific method can be practised from more critical perspectives.

That said, despite critique and its seeming shrinkage in importance in the discipline, the future of positivistic science seems relatively assured. Just as GIS gave fresh impetus to spatial science in the 1990s, new technological developments seem set to provide a significant boost to its fortunes in the present decade. Over the past few years a data revolution has been taking place that has now reached a tipping point: we have entered the age of 'big data'. Big data involves enormous, dynamic, interconnected digital datasets relating to people, objects, interactions, transactions and territories. Big data is commonly characterised as being large in volume, high in velocity (in real-time) and wide in variety (with the majority of the data unstructured in form – text, images, audio, rather than simply numbers) (Laney 2001; Zikopoulos et al 2012). It is also relational (linked to other data) and has a fine granularity (related to individual people, objects, transactions as opposed to being aggregated). Ever more data are being produced by software-enabled technologies such as computers, digital cameras and smartphones, as well as sensors and processors embedded in buildings, vehicles, and environments; non-digital objects are being made machine-readable through devices that can scan various kinds of barcodes and radio frequency identifiers; social media users are generating massive volumes of volunteered information through exchanges such as Facebook or Twitter posts, as well as through online searches, browsing sites or purchasing goods and services (Kitchin and Dodge 2011). Every interaction and transaction that utilises software and ICT generates data. Importantly for geographical analysis, much of this data is georeferenced, referring to particular places or located in space through the GPS traces of mobile devices (Goodchild 2007). Moreover, the data are generated in real time. The result is data that can provide very detailed views of large systems in flux and can potentially enable sophisticated spatio-temporal modelling.

The scale, timeliness and variety of the data now being produced is startling and is growing rapidly. For example, Gantz and Reinsel (2011) estimated that the 'amount of information created and replicated on the Internet will surpass 1.8 zettabytes (1.8 trillion gigabytes)' in 2011 stored in '500 quadrillion files ... growing by a factor of 9 in just five years' and 'more than doubling every two years'. They predict that in the next decade, 'the number of servers (virtual and physical) worldwide will grow by a factor of 10, the amount of information managed by enterprise datacenters will grow by a factor of 50, and the number of files the datacenter will have to deal with will grow by a factor of 75, at least'.

The challenge is to analyse and extract value from these massive, dynamic and varied datasets. For some, the approach required is quite empiricist. For example, Chris Anderson (2008), Editor in Chief at *Wired* magazine, has declared that big data signals 'the end of theory', arguing that 'the data deluge makes the scientific method obsolete'. Anderson's argument is that big data inherently speak for themselves, producing meaningful and insightful knowledge about social, political and economic processes and complex phenomena; that all that is required to provide such insights is sophisticated data management, mining and correlation analytics that can reveal patterns and make sense of the data deluge. He concludes:

> Petabytes allow us to say: 'Correlation is enough.' We can stop looking for models. We can analyze the data without hypotheses about what it might show. We can throw the numbers into the biggest computing clusters the world has ever seen and let statistical algorithms find patterns where science cannot. ... Correlation supersedes causation, and science can advance even without coherent models, unified theories, or really any mechanistic explanation at all. There's no reason to cling to our old ways.

Similarly, Prensky (2009, original emphasis) argues: 'scientists no longer have to make educated guesses, construct hypotheses and models, and test them with data-based experiments and examples. Instead, they can mine the complete set of data for patterns that reveal effects, producing scientific conclusions *without* further experimentation.' In essence, Anderson and Prensky are contending that the analysis of big data can float free of theory, with the weight of evidence, revealed through data analytics, providing deep insight into the world. Under this scenario, what might transpire in the long term is the continuation of spatial science as implicitly positivist at best, and implicitly empiricist at worst.

What such reasoning fails to appreciate is that the algorithms underpinning data analytics are based on scientific reasoning and are refined through scientific testing – and that science is laden with ontological and epistemological assumptions, as with any other science, including empiricism. In other words, data analytics do not arise from nowhere or within a scientific vacuum; rather, they arise from science method, and this method is predominately positivist in its formulation.

In contrast to those promoting data analytics shorn of scientific method are those who argue that big data will usher in a new phase of computational social science that analyses data which has enormous breadth, depth, scale and timeliness and is inherently longitudinal, rather than the much smaller, one-time, snap-shot datasets that characterise existing quantitative data sets and qualitative research (Lazer et al., 2009). Here, big data presents untold possibilities for a new wave of positivistic models that address some of the critiques levelled at it previously: the data are finely granulated and much more exhaustive, algorithms and models are much more refined and sensitive to context and contingency, and computation is so powerful that it is possible to produce highly sophisticated spatio-temporal models of social and environmental processes and, given the size and range of the data sets, it is possible to more quickly hone hypotheses and be confident in their veracity. Such data-intensive science will enable geographers to analyse bigger and more complex systems more efficiently and effectively and to advance an understanding of society rooted in analysis underpinned by the scientific method. Such an approach is implicitly positivist in its underpinnings. The emergence of big data and computational social science thus has the potential to breathe new life into quantitative geography and positivistic forms of geographical analysis.

References

Anderson, C. (2008) The end of theory: the data deluge makes the scientific method obsolete. *Wired*, 23 June 2008, http://www.wired.com/science/discoveries/magazine/16-07/pb_theory (last accessed 12 October 2012).

Burton, I. (1963) The quantitative revolution and theoretical geography. *The Canadian Geographer* 7: 151–162.

Buttimer, A. (1976) Grasping the dynamism of lifeworld. *Annals of the Association of American Geographers* 66: 277–292.

Chalmers, A.F. (1982) *What is this Thing Called Science?* University of Queensland Press, St. Lucia.

Chisholm, M. (1971) In search of a basis of location theory: micro-economics or welfare economics. *Progress in Geography* 3: 111–133.

Curry, M. (1998) *Digital Places: Living with Geographic Information Technologies*. Routledge, New York.

Domosh, M. (1991) Towards a feminist historiography of geography. *Transactions, Institute of British Geographers* 16: 95–115.

Gantz, J. and Reinsel, D. (2011) *Extracting value from chaos*. IDC, Framingham, MA http://idcdocserv.com/1142 (last accessed 1 October 2012).

Golledge, R. and Amedeo, D. (1968) On laws in geography. *Annals of the Association of American Geographers* 58: 760–774.

Goodchild, M. F. (2007) Citizens as sensors: the world of volunteered geography. *GeoJournal* 69: 211–21.

Gregory, D. (1978) *Ideology, Science and Human Geography.* Hutchinson, London.

Gregory, D. (1986a). Positivism. In Johnston, R.J., Gregory, D. and Smith, D.M. (Eds). *The Dictionary of Human Geography*, 2nd Ed. Blackwell, Oxford.

Gregory, D. (1986b). Critical rationalism. In Johnston, R.J., Gregory, D. and Smith, D.M. (Eds). *The Dictionary of Human Geography*, 2nd Ed. Blackwell, Oxford.

Guelke, L. (1974) An idealist alternative to human geography. *Annals of the Association of American Geographers* 64: 193–202.

Haggett , P.(1965) *Locational Analysis in Human Geography.* London, Arnold.

Harvey, D. (1969) *Explanation in Geography.* Oxford, Blackwell.

Harvey, D. (1973) *Social Justice and the City.* London, Edward Arnold.

Harvey, F. (2003) Knowledge and Geography's technology – politics, ontologies, representations in the changing ways we know. In Anderson, K., Domosh, M., Pile, S. and Thrift, N. (Eds). *Handbook of Cultural Geography*. Sage, London. pp. 532–543.

Hartshorne, R. (1939). *The Nature of Geography*. Association of American Geographers, Lancaster, PN.

Hill, M.R. (1981) Positivism: A 'hidden' philosophy in Geography. In Harvey, M.E. and Holly, B.P. (Eds). *Themes in Geographic Thought*. Croom Helm, London. pp. 38–60.

Hubbard, P., Kitchin, R., Bartley, B. and Fuller, D. (2002) Thinking Geographically: *Space, Theory and Contemporary Human Geography*. Continuum, London.

Isard, E., Bramhall, R.D., Carrothers, G.A.P, Cumberland, J.H., Moses, L.N., Prices, D.O. and Schooler, E.W. (1960) *Methods of Regional Analysis: An Introduction to Regional Science*. MIT Press, MA.

Johnston, R.J. (1986) *Philosophy and Human Geography: An Introduction to Contemporary Approaches* (2nd ed.) London, Arnold.

Johnston, R.J. (1991*) Geography and geographers: Anglo-American geography since 1945* (4th ed.) Edward Arnold, London .

Kwan, M-P. (2002) Feminist visualization: Re-envisioning GIS as a Method in Feminist Geographic Research. *Annals of the Association of American Geographers*, 92(4): 645–661.

Laney, D. (2001) 3D Data Management: Controlling Data Volume, Velocity and Variety. Meta Group. http://blogs.gartner.com/doug-laney/files/2012/01/ad949-3D-Data-Management-Controlling-Data-Volume-Velocity-and-Variety.pdf (last accessed 22 Oct 2012).

Lazer, D., Pentland, A., Adamic, L., Aral, S., Barabási, A-L., Brewer, D., Christakis, N., Contractor, N., Fowler, J., Gutmann, M., Jebara, T., King, G., Macy, M., Roy, D. and Van Alstyne, M. (2009) Computational Social Science. *Science* 323: 721–733.

McDowell, L. (1992) Doing gender: Feminism, feminists and research methods in human geography. *Transactions of the Institute of British Geographers* 17: 399–416.

Mulkay, M.J. (1975) Three models of scientific development. *Sociological Review* 23: 509–526.

Pickles, J. (ed) (1995) *Ground Truth: The Social Implications of Geographic Information Systems*. Guilford Press, New York.

Prensky, M. (2009) H. sapiens digital: From digital immigrants and digital natives to digital wisdom. *Innovate* 5(3). http://www.innovateonline.info/index.php?view=article&id=705 (last accessed 12 October 2012)

Rose, G. (1993) *Feminism and Geography.* Cambridge, Cambridge University Press.

Sack, R. (1980) *Conceptions of Space in Social Thought*. Macmillan, London.

Schaefer, F.K. (1953) Exceptionalism in geography: a methodological examination. *Annals of the Association of American Geographers* 43: 226–249.

Stanley, L. and Wise, S. (1993) *Breaking Out Again: Feminist Ontology and Epistemology*. Routledge, London.

Tuan, Y-F. (1976) Humanistic geography. *Annals of the Association of American Geographers* 66: 266–276.

Unwin, T. (1992) *The Place of Geography*. Longman, Harlow.

Wilson, A.G. (1972) Theoretical geography. *Transactions, Institute of British Geographers* 57" 31–44.

Zikopoulos, P.C., Eaton, C., deRoos, D., Deutsch, T. and Lapis, G. (2012) *Understanding Big Data*. McGraw-Hill, New York.