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Section ARTICLES

Investigaciones Regionales

Some Challenges for Regional Science Research

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ABSTRACT: Regional scientists have long faced challenges in developing the interdisciplinary field where their focus is on the spatial context of social, economic and environmental phenomena, and dealing with spatial data presents considerable methodological challenges. This article discusses the evolution of Regional Science, the critiques it has received and the challenges it has confronted. It addresses specifically some contemporary challenges that relate to methodological issues, such as: how to measure and model endogenous regional growth performance; the limitations of using *de jure* regions rather than *functional* regions as the spatial framework in regional analysis; the need to making greater use of unit record data and integrating those data into generalised spatial frameworks; and making use of the opportunities offered by «big data» in urban and regional analysis.

JEL Classification: R1; R3; O1; B2.

Keywords: Regional Science; Regional Analysis; Regional Differentials; Endogenous regional development; *de jure* regions; Functional regions; Unit record/micro data, Micro-simulation, Big data.

RESUMEN: Los científicos regionalistas se han enfrentado a numerosos desafíos en el desarrollo del ámbito interdisciplinario en el que analizan el contexto espacial de los fenómenos sociales, económicos y medioambientales, y asimismo tratar con amplias bases de datos plantea desafíos metodológicos considerables. Este artículo estudia la evolución de la Ciencia Regional, las críticas que ha recibido y los retos con los que se ha enfrentado. Analiza específicamente algunos retos contemporáneos relacionados con problemas metodológicos como: de qué forma medir y los logros del modelo de crecimiento endógeno regional; los límites de la utilización de regiones *de iure* más que regiones *funcionales* como base espacia en el análisis regional; la necesidad de realizar un mayor uso de microdatos o datos por unidad y de integrarlos en estructuras espaciales más generales; y las oportunidades que ofrece la utilización de «big data» en el análisis urbano y regional.

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Clasificación JEL: R1; R3; O1; B2.

Palabras clave: ciencia regional; análisis regional, diferencias regionales; desarrollo regional endógeno; regiones *de iure;* regiones *funcionales*; registros por unidades/microdatos; micro-simulación; *big data.*

1. Introduction

Periodically regional scientists have questioned the direction and relevance of regional science, highlighting the challenges it has faced as an interdisciplinary field of research. From its origins in the US in the 1950s, it is now in its seventh decade having grown from strength-to-strength, with the Regional Science Association International now having a membership approaching 5,000 and with almost 40 Sections in countries spread across the world. (For reviews of the origins and evolution of regional science see Isard, 2003; Boyce, 2004; Florax and Plane, 2004; Batey, 2010; Mulligan, 2014; Nijkamp, Rose and Kourtit, 2015; Stimson, 2015).

In this chapter I first provide a brief overview of the origins and development of regional science and the challenges it has faced. I then specifically focus on some of the contemporary methodological issues regional science needs to address. That includes: discussing issues of measurement for modelling regional endogenous development; the limitations of using *de jure* regions and the need to use functional regions as the spatial framework in regional analysis; the need to make greater use of unit record (micro) data and employing micro-simulation to integrate survey-based and aggregate data in regional analysis; and the potential of «big data» in urban and regional analysis.

2. An overview of challenges in regional science

2.1. Origins and evolution

The evolution of regional science as a discipline in its own right was based on:

> «... a merger of concepts from economics (e.g., general equilibrium theory, input-output analysis, programming theory, production theory), geography (e.g., central place theory, diffusion theory), mathematics and econometrics (e.g., spatial autocorrelation analysis, systems dynamics), and related disciplines such as political science, sociology, and decision theory» (Boyce, Nijkamp and Shafer, 1991, p. 1).

Thus, regional science had *interdisciplinary* roots, arising initially out of the perceived need in the early 1950s for:

— economists to upgrade the low level of regional analysis and to more explicitly incorporate *time* and especially *space* into a comprehensive theory of society and economy (Isard, 1956, p. vii); and

— other disciplines, like geography and planning, to become more rigorous in their approaches (Garretsen and Martin, 2011).

From its beginning, regional science was firmly embedded in neo-classical theory, adopting a mathematical and statistical analytical approach to the empirical investigation of regional phenomena. That was clearly evident in the early seminal books by its founder, Walter Isard (1956; 1960).

Reflecting on the origins, evolution and development of regional science, Isard and Reiner (1968) told how the founders of regional science saw it as focusing on:

> «... the locational dimension of human activities in the context of their institutional structure and function and on the significance of this dimension in the understanding of social behaviour and forms».

The regional scientist was said to be concerned not only with the location decision of the individual decision-maker within an environment, but also with the location itself and the locational framework (Isard and Reiner 1968). Regional science research had a focus on three major classes of decision-maker:

— *individuals* (or households);
— *entrepreneurs* (businessmen or firms); and
— *public bodies* (such as city governments and regional planning organizations).

Certainly from the outset a central purpose in regional science research was to identify and analyze the problems of regions and to suggest solutions (Isard and Reiner, 1968). Thus, it had an applied orientation as well as being concerned with theory and methods. Regional scientists have had an affinity with numerous applied fields to investigate a wide range of issues confronting cities and regions, including: city and regional planning; transportation; public administration; agronomy; and industrial engineering. But, as Isard and Reiner (1968) have emphasised, regional science has differed from those fields in that it takes a more general approach to the role of space in social phenomena, addressing policy issues at various level of scale —national, sub-national, regional, county, city, and local communities.

There was something of a hiatus in the development of regional science during the 1970s and 1980s when it came under attack from critics questioning its relevance and its over-reliance on abstract theory.

However, as discussed in a recent review by Stimson (2015), from the 1990s regional science has undergone a remarkable renewed impetus, which has been spurred by a number of factors, including:

— economist Paul Krugman's (1991) work on international trade, who along with others, called on economists to pay greater attention to economic geography and to renew their interest in regional science (for example, Fujita, Krugman and Venable, 1999);
— the emergence of the *new economic geography* initiated by Romer (1986) and Lucas (1988), which has evolved into what is known as *endogenous growth theory*;

— the *unification of Europe*, especially through the EU's policy emphasis on regional development and its substantial funding of research investigating regional inequalities;
— the rise of *globalisation* and its unequal distributional impacts, along with the massive increase in *urbanisation* and *rise of mega-cities* —especially in Asia— were to drive further renewed interest in regional analysis; and
— from within North America, the *decline of the «rust belt»* and *the rise of the «sun-belt»* and the associated inter-regional migration streams which spurred a renewed interest in regional modelling to investigate the role of amenity factors in migration and regional development.

2.2. Limitations and critiques

It is true that over time there has been a tendency for regional science to be dominated by economists with their inherent focus on developing theories and models - often abstract and as well as complex. Largely regional scientists have applied models using *aggregates* to investigate human behaviour and regional issues, and they have tended to take an optimisation approach to investigating location decisions. This has led to the development of a rich and wide array of models and analytic processes for investigating regional development and performance (see Boyce, *et al.,* 1991; Nijkamp and Mills, 2000), as well as methodological innovations in explicitly dealing with the issues encountered in the analysis of spatial data, such as the modifiable area unit- problem (MAUP) and spatial autocorrelation in spatial econometric modelling (Klassen and Paelinck, 1979; Anselin, 1988).

But the emphasis on theory and models and their inherent degree of abstractness and mathematical and statistical complexity has been something of a catalyst in engendering critiques from time-to-time and calls questioning the relevance of regional science research.

Extreme critiques of regional science occurred in the 1970s, led by Marxist and later post-modernist geographers (see, for example, Harvey, 1973; Barnes, 1976, 2003; Johnston, 1996), and also from planners. Those critics —who tended to be from outside the regional science community— argued that regional scientists lacked social and political commitment and advocacy, and claiming regional science was trapped in what the critics saw as a discredited positivist paradigm. Sayer (1976) suggested that regional science should shift from a model-based approach to one based on political economy. Critics charged that regional scientists were seeking to provide «universal truths rather than particular ones» (Polese, 1995: p. 314).

From within the regional science community, there was a particularly significant critique from the famous Swedish geographer, Torsten Hagerstrand, when he delivered the 1970 Regional Science Association's Presidential Address titled *What about people in regional science?* (Hagerstrand, 1970). He suggested that during the 1960s there had evolved a considerable difference between a preference for North American regional scientists to focus on theory, and a preference for European regional scientists to «remain closer to issues of application» (p. 7). Hagerstrand (1970: p. 7) said:

> «... we in Europe seemed to have been looking at regional science primarily as one of the possible instruments to guide policy and planning».

He proposed that regional scientists should:

> «... take a closer look at a problem which is coming more and more at the forefront in discussions among planners, politicians and street demonstrators, namely the fate of the individual human being in an increasingly complicated environment or, if one prefers, questions as to the quality of life» (p. 7).

He noted that «the problem is a practical one and, therefore, for the builder of theoretical models, a "hard nut to crack"» (p. 7).

Quoting Isard and Reiner's (1966) statement that «models of human behaviour over space have been almost entirely related to mass probabilistic behaviour», Hagerstrand (1970) noted that the models regional scientists tended to use depended on «large aggregates», often being presented:

> «... without explicit statements about the assumed social organisation and technology that exist at the micro-level from which the individual tries to handle his situation» (p. 8).

Hagerstrand used migration to illustrate the importance of investigating the «fundamental links between the micro-situation of the individual and the large scale aggregate outcome» (pp. 8-9). He referred to what he called a «twilight zone» for exploration between biography and aggregate statistics, that being:

> «... an area where the fundamental notion is that people retain their identity over time, where the life of the individual is his foremost project, and where aggregate behaviour cannot escape these facts» (p. 8).

He urged regional scientists to:

> «... eliminate imprecise thought processes which conceptually drive us into handling people as we handle money or goods once we commence the process of aggregation» (p. 9).

Hagerstrand (1970: pp. 8-9) also advocated the need for regional scientists to:

> «... better understand what it means for a location to have not only space coordinates but also time coordinates».

He emphasised that *time* becomes «critically important» when it:

> «... comes to fitting people and things together for functioning in socio-economic systems, whether these undergo long-term changes, or rest in something which could be defined as a steady state» (p. 10).

He proceeded to suggest that his famous *time-space prism* framework might serve as a basis for investigating the dynamics of complex interactions between the individual (and households) and their operational functional environment, advocating *simulation* as a modelling methodology.

As discussed by Stimson (2015), during the 1980s and 1990s and into the 2000s, critiques of regional science by regional scientists continued, being directed especially towards what many regarded to be an over-emphasis on a set of standard models and the minor and often «inconsequential tweaking of assumptions to produce results of little meaning» (Bolton, 2004: p. 359).

Those critiques included, for example, the following:

- Richardson (1988) raised questions about the reliance in the urban models on the assumptions of a monocentric city, while the reality was that complex urban areas are clearly polycentric;
- Bolton and Jensen (1995: p. 140) suggested regional science theory and its models had *not* moved far enough in analysing what they referred to as «the ordinary business of life as it is affected by the places where people live, work and consume»;
- Breheny (1984) Rodwin (1987) claimed regional science was «the least reflexive of disciplines», condemning the «deep ignorance among regional scientists of the nature of practical policy making and implementation» (Bolton, 1984);
- Bailly, Coffey and Gibson (1996: p. 153) called for regional scientists to «look a new ways to answer questions raised by our social, economic and political institutions»:
- Clarke and Madden (2001: pp. 1-2) noted there was «very little new» to suggest that the discipline was becoming more people-focused in its modelling, despite the lapse of two decades from Hagerstrand's 1970 plea; and
- Markusen (2005) argued there was a proliferation of research and publications in regional science that came from the so-called the «new left» in Europe —but also from research in North America— that had spurred a plethora of new concepts in investigating the phenomena of uneven regional development and of industrial restructuring (including concepts such as, flexible specialisation, new industrial spaces, industry clusters; re-agglomeration, networking and co-operative competition, social capital, world cities; sustainability, etc.) that were fuzzy concepts lacking clarity and difficult to operationalise.

2.3. Challenges: the big issues for regional science to address

It has also been commonplace for regional scientist to write about the contemporary challenges for regional science research.

For example, at the beginning of the 1990s Boyce, *et al.* (1991 p. 5) identified these five *big societal issues* for regional scientists to address:

- the ageing process;
- environmental questions, including urban sustainability;
- emerging new technologies;
- the new emerging policy map of Europe; and
- infrastructure policy.

A decade later, Nijkamp and Mills (2000) suggested regional science research should deal with these three *profound societal issues*:

— demographic change with its impacts on ageing, labour markets, housing and infrastructure and services;
— social changes, including segregation, emancipation, labour force participation, household composition; and
— economic transitions and industry restructuring.

To those one might have added the implications of technological change.

More recently Nijkamp and Ratajczak (2015: p. 24) have provided a timely reminder that regional science will be «marked by many uncertainties on the dynamics of the space economy», *uncertainties* that are related to:

— global population dynamics, including the urban-rural divide;
— the future of urbanisation;
— the complimentary interface between physical material and virtual digital spatial interaction; and
— the complexity of governance systems.

Nijkamp (2015: p. 4) has suggested a *broad analytical framework* for regional science is needed that involves the following:

— a shift from tangible spatial interactions to intangible cognitive interwovenness;
— the reinterpretation of the scientific and mental map of the space economy, through the awareness of fast and slow spatial dynamic processes, including the emergence of catastrophe, chaos and resilience theory, and evolutionary geography; and
— an increasing recognition of interdependent micro-meso-macro processes in complex spatial systems that have led to advanced innovative studies on spatial statistics and econometrics.

Mulligan (2014: pp. 18-46) has listed 14 *topics or themes for future research* in regional science chosen «especially to encourage new or younger scholars to the field» (p. 4). They are:

— *behaviour and heterogeneity*, especially focusing on non-optimal outcomes and solutions in decision-making;
— *environmental issues*, including quality-of-life, hazards research and climate change;
— *global urbanization*, including the evolution of national city-size distributions, urban primacy and mega-cities;
— *happiness*, including its implications for public policy;
— *housing and land use*, including housing markets, market constraints and regulations;
— *metropolitan sorting*, including the provision of public goods and taxing, inner city revival and suburbanisation;

- *neighbourhood change*, including turnover and cyclical change and neighbourhood effects;
- *networks*, including transport and business and social networks, contiguity effects, feedback effects, and within and between city networks;
- *non-metropolitan living*, including micro-politan and sub-metropolitan growth;
- *post-event growth and development*, including regional growth and development following traumatic event, natural hazards management, and terrorist threats;
- *regional creativity*, including innovation, entrepreneurship, and the creative milieu, and the endogeneity problem;
- *regional decline*, including demographic and economic structural transition, and the role of intangible factors;
- *regional specialisation* and diversity; and
- *resource inequality*, including the associated health and social issues, and informal and shadow activities.

2.4. Methodological issues

There are always important *methodological issues* for regional science to address.

For example, Nijkamp and Ratajczak (2015: pp. 16-17) have specifically posed six on-going *conceptual and methodological questions* for the attention of regional scientists:

- What is a relevant spatial scale of analysis in regional science?
- Should the focus be on geographic entities —such as cities, regions, industrial complexes— or on the behaviour of economic / social objects in a geographic space?
- What is the relationship between space and time vis-à-vis spatial movements and interactions?
- If spatial phenomena are linked —as suggested in Tobler's Law (Tobler, 1970) what are the essential spatial connectivity principles?
- If a geographic space acts as a barrier or an opportunity, what are the implications for exploratory analysis?
- How are concepts from networks and complexity related to regional dynamics?

And Nijkamp and Ratajczak (2015) have also suggested there is scope for regional science to embrace data-driven models.

Regional science might also benefit through *borrowing research methodologies from other disciplines* that are rarely used by regional scientists. That might include, for example:

- using qualitative comparative analysis (QCA) techniques that are widely used in social science research by sociologists, and related techniques such

as: multi-value QCA (MVQCA); fuzzy sets; and the most similar, different outcome/most different, similar outcome (MSDO/MDSO) linked technique (see Rihoux, 2006); and
— the use of quasi-experimentalist methods to derive causal statements with respect to the effectiveness of regional policy instruments (see Mitze, 2014).

Finally, recently Aroca, Haynes and Stimson (2015) have identified four *research methodological and empirical challenges* for demonstrating the *policy relevance* of regional science:

— innovation in using I-O and spatial econometric analysis and simulation to investigate regional disparities focusing on the evaluation of the relationships between concentration/primacy/agglomeration vs dispersal, efficiency, and in regional economic growth and inter-regional equity in the formulation of policy to address uneven development;
— moving from a non-spatial to a spatial framework for evaluation analysis by integrating the independent methodologies of spatial econometrics (SE) and computable general equilibrium (CGE) modelling to create a SECGC modelling approach for analysing the impacts of infrastructure investments in a hierarchical regional scale context to test whether impacts differ when comparing estimations with and without consideration of spatial dependence in CGE (for example, Chen and Haynes, 2015);
— making use of «big data»; and
— integrating micro-data or unit record with spatial objective data and performing spatial microsimulation modelling in urban and regional analysis.

Finally, there is as yet unfulfilled scope for regional science to make greater use of computational agent-based modelling (ABM) integrated with GIS (see Hellenstall, Crooke, See and Batty, 2012), particularly for examining urban issues and how cities operate, including testing theories and hypotheses about urban change based on the individual behaviour of agents (as discussed by Crooks, 2006).

3. Focusing on four specific methodological issues

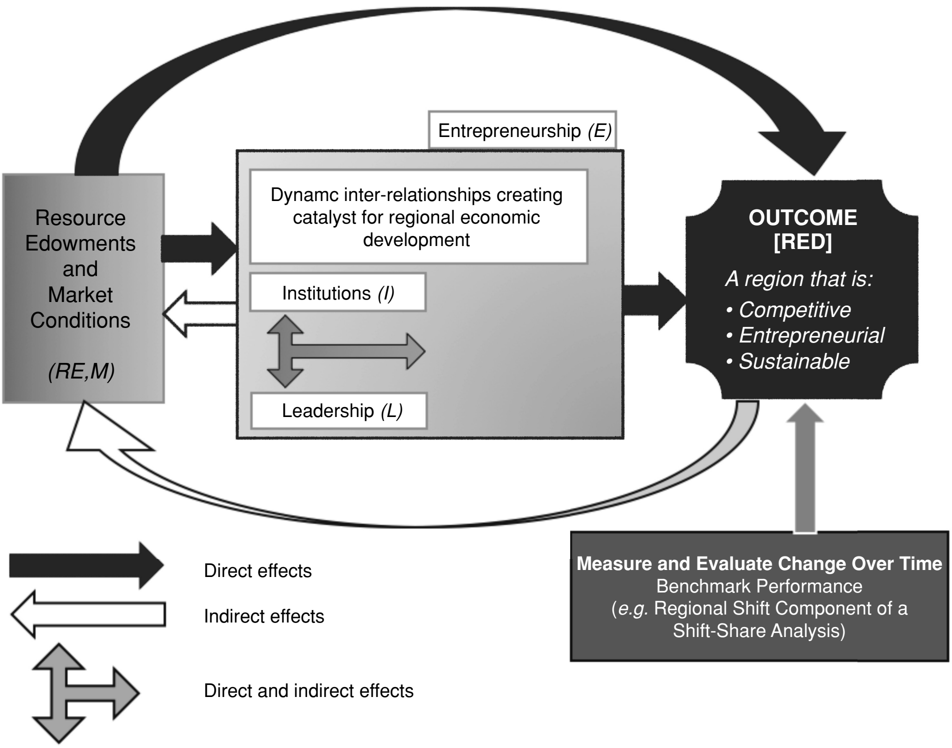
I now turn to explicitly address four number of methodological issues which I believe are important for regional scientists to give greater consider.

3.1. Measuring and modelling regional endogenous growth

Despite the copious literature on *new growth theory* (often referred to as *regional endogenous growth or development theory*), as pointed out by Stimson, Stough and Salazar (2009) there is no agreed way to measure it, and nor is there a widely used operational model framework for investigating those endogenous factors or processes that might explain variations in regional economic performance.

Much has been written on the roles of factors such as human capital, entrepreneurship, institutions and leadership —which are endogenous to the region— in regional economic development. It is often difficult to develop explicit measures of such factors to then use as variables in spatial econometric models to investigate regional endogenous growth. Stimson, *et al.* (2009) have proposed such as model framework (see Figure 1) which has been operationalized in investigations of regional endogenous growth performance of cities across both US (Stimson, Stough, Shyy and Song, 2014) and regions across Australia (Stimson, Mitchell, Rhode and Shyy, 2011; Aroca, Stimson and Stough, 2014). But there are significant deficiencies concerning how to measure factors such as leadership and institution, and such modelling attempts are constrained to use inadequate proxy variables. However, Stimson, *et al.* (2009) have proposed a simple way to measure regional growth performance that is readily computed using widely available regional economic data, namely the change over time in regional employment derived through a *shift-share analysis* in which the *differential (or regional) shift component*, standardised by size of the regional labour market, is taken to be a measure of regional endogenous employment change performance over a specified period of time.

Figure 1. A framework for modelling regional endogenous development



Source: After Stimson, Stough and Salazar (2005).

The model (as developed initially by Stimson, Stough and Salazar in 2005) proposed that:

RED = f [(RE, M) mediated by (L, I, E)]

where:

RED represents regional endogenous development;
RE represents regional resource endowments and market conditions;
L represents leadership;
I represents institutions; and
E represents entrepreneurship.

Operationalizing such a modelling approach raises the question of using alternatives to the standard spatial econometric regression models that regional scientists tend to employ. The structural equation modelling approach that has been used by Aroca, *et al.* (2014) might be more appropriate as it enables one to test hypotheses about the *intervening* or *mediating* roles of factors like institutions, leadership and entrepreneurship in accounting for spatial differentiation in regional economic performance.

There remains, however, a dearth of empirical testing of model frameworks investigating variations in regional endogenous economic growth performance and what might be the explanatory power of factors and processes that are claimed to be within-region in nature (as against exogenous to the region) in accounting for such variations in regional growth performance. This remains a gap in regional science research, and it presents a challenge, in particular to compile regional database of operational variables that are measures of factors such as institutions, leadership, and entrepreneurship. Overcoming this deficiency will require considerable innovation by public agencies that generate spatial statistics as well as by regional science researchers.

3.2. Limitations of *de jure* regions and the need for a functional basis to regional demarcation as the spatial framework used in spatial econometric modelling

Most spatial econometric analysis and modelling investigating the causes of differentiation in regional economic performance across a space economy employs secondary data analysis of official data aggregated into *de jure* regions that are typically administrative areas, such as counties or local authorities.

The demarcation of the boundaries of such *de jure* regions is thus artificial, they being artefacts of administrative convenience or serving a political purpose. They certainly do *not* reflect a *functional economic* basis. As a result we encounter the *modifiable areal unit problem* (MAUP) and the need to account for *spatial autocorrelation*. As discussed by Stimson, *et al.* (2011: p. 132), a whole set of methodological issues arise, such as:

— the analysis of complex high dimensional non-experimental data is inherently difficult;

— the problem of collinearity;
— which variables are likely to have a positive, negative or no association with the dependent variable being used in the model?;
— is a spatial model such as the spatial autoregressive model or spatial error model more appropriate than the traditional OLS linear regression model?; and
— the problem of causation versus ecological association.

A comprehensive literature has evolved in regional science to deal with these issues (see, for example, Cliff and Ord, 1973; Openshaw, 1983; Anselin, 1998a, b; Fotheringham, Charlton,nd Brunsdon, 1998; Fotheringham and Wong, 1991; Anselin, 1995; Getis and Griffith, 2002; Anselin, Syabri and Kho, 2006; Anselin and Getis, 2008). That includes using spatially weighted regression methods and global and local indicators of spatial association, such as the Moran's *I* and Anselin's LISA software package *GeoDa* (Anselin, 2005).

If we were to use a regional demarcation that is functionally-based for spatial econometric analysis and modelling of regional economic performance we should overcome such problems associated with the MAUP and spatial autocorrelation that are inherent in using a *de jure* spatial framework. This has been demonstrated by work in Australia by Mitchell and Watts (2007), Stimson *et al.* (2011) and Stimson, Mitchell, Flanagan, Baum and Shyy (2016) which used the Intramax method (after Masser and Brown 1975) to develop a new functional national geography in which census journey-to-work data is used to generate *functional economic regions* (FERs) that sought to:

— regionalise the nation into meaningful labour market regions; and
— eliminate the spatial autocorrelation problem.

In using that functional-based regional geography to analyse variations in spatial patterns of regional endogenous employment growth/decline in Australia, Stimson *et al.* (2011) showed that their FER national spatial framework seemed to have overcome the spatial autocorrelation issues that were encountered in an earlier analyses by Stimson, Robson and Shyy (2009) in which a *de jure* regional framework of local government authorities was used.

A functional-based regional geography for analysing and modelling regional economic performance also has the advantage of using spatial units that have real meaning as regional labour markets which we know are not confined to, nor defined by, *de jure* administrative areas and their boundaries. As spatial econometric analysis and modelling typically seeks to find explanation for the spatial variation in an aspect of regional employment, conducting such investigations within a functional economic regions spatial framework is much more meaningful.

3.3. Making greater use of unit record (micro) data and integrating with spatial data

Regional scientists have often made use of *micro (individual level) data* —especially data relating to the firm— in investigating economic and demographic issues such as business and industry operations, entrepreneurship, household dynamics, and income distribution.

Often access to such data is restricted and securitised, and in the US it has been facilitated through secure laboratories initiated by the Census Bureau, with the data being confidentialized (see Davis and Holly, 2006). Those data are provided as Public Use Microdata Samples, as well as national survey datasets, such as the US Census Bureau's Current Population Survey (CPS), the American Housing Survey (AHS), and the Survey of Income and program Participation (SIPP). It is also common for microdata to be longitudinal in nature.

Davis and Holly (2006: p. 280) have noted that facilities like the Research Data Centers (RDCs) —which have been established in the US by the Census Bureau in collaboration with research institutions across the nation— provide a secure environment enabling researchers to apply for accessing and interrogating such micro-data. They make the point that:

> «... essential to regional science research is the availability of detailed geographic identification within analytical data sets» (Davis and Hollly, 2006; p, 294).

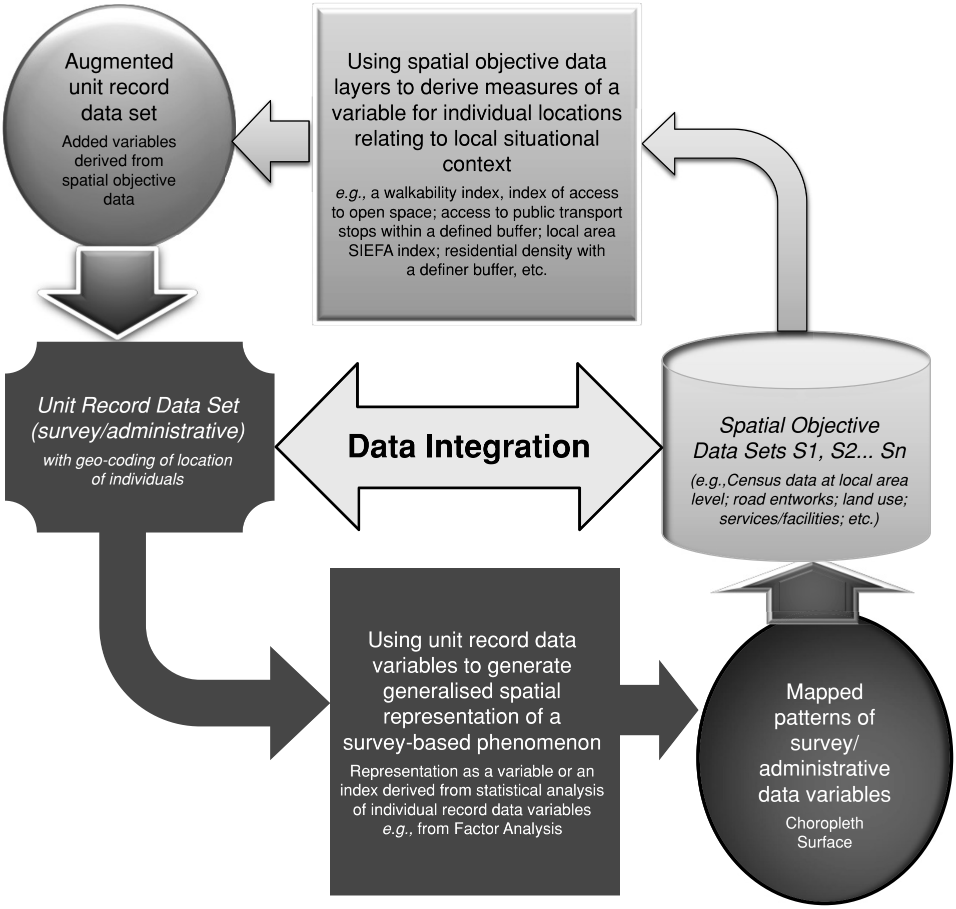
But they lament that the RDCs are an «underutilized resource by the regional science community» (p. 294).

Through the use of GIS technologies it is now easy to facilitate the *integration* of individual unit record (micro) data —including survey-based and administrative data— with other data that is spatially situated and is available from other data sources. This is important as it enables statistical and econometric analysis and modelling to be undertaken free of the strictures of the MAUP and without having to address the issue of spatial autocorrelation, and it avoids the issue of the ecological fallacy that are encountered when using spatially aggregated data. That is particularly important in being able to better inform policy development and for the evaluation of the outcomes of program implementation (see Heckman, 2001 for a discussion of micro-data and public policy).

That *integrative capability* and what it enables is illustrated in the framework shown in Figure 2. It is, of course, dependent on the unit record data file having a *geocoded location* for the individual embedded in the dataset. It enables, for example:

— survey-based individual unit record data to be enhanced/supplemented through the addition of non-survey information by adding variables that relate to the spatial situational setting of the individual, which may then be used as explanatory or intervening variables in modelling relationships between an individual behavioural outcome measure and individual characteristics and the situational setting attributes; and
— the use of *spatial micro-simulation* methods to derive *synthetic measures* of variables for spatial units that are derived from the unit record (micro) data to portray the spatial patterns of a behavioural phenomenon.

Figure 2. Framework for integrating unit record (micro) data and spatial objective data



Source: The author.

O'Donoghue, Morrissey and Lennon (2014) have provided a review of spatial micro-simulation as it has been applied to the investigation of issues relating to demography, welfare, health, regional development, and transport planning, agri-environmental analysis, crisis planning, and land use planning. That includes a review of methodological approaches.

Building on the pioneering work of Hagerstrand (1957, 1967), in which he used micro-analytic tools to simulate first the patterns of internal migration in central Sweden and later the spatial diffusion of innovation, Clarke, Keys and Williams (1979) developed a representational and methodological framework for interacting labour and housing systems, and then researchers in the Department of Geography at the University of Leeds in the UK (see Clarke, Keys and Williams, 1980; Clarke, 1996) investigated the possibility of using spatial micro-simulation to analyse socio-economic and a wide range of public policies issues including transport, housing expenditures and finance. Other early work also included the Harvard Urban development Model (Kain and Apgar, 1985) and a suite of models were developed by Birkin and Clarke (1988). More recently Tanton and Edwards (2013) have provided a detailed overview of methodological issues.

Certainly spatial microsimulation has become a mainstream analytical tool among social scientists for modelling a wide range of behavioural phenomena in a policy context (see Clarke, 1996; Birkin and Clarke, 2012). That is illustrated by the impressive range of modelling applications by the Leeds group and by the National Centre for Social and Economic Modelling (NATSEM) at the University of Canberra in Australia (as discussed in Donaghue *et al.,* 2014), where both a static and dynamic approach is being taken.

There is an opportunity for regional science research to make much greater use of microsimulation modelling that incorporated a spatial dimension enabling a «place-based» analysis to be incorporated in «people-focused» analyses (see O'Donaghue *et al.,* 2014, referring to Miller, 2007). There is a need for greater effort to generate spatially representative data to undertake such modelling, in particular to inform policy and to better understand behavioural change. This is particularly so as the contemporary advances in spatial microsimulation methodologies are overcoming early criticisms of the deficiencies *vis-a-vis* model validation.

Two examples of research in Australia integrating survey (micro) data with spatial objective data in urban and regional analysis are:

1. The work of researchers at NATSEM in which spatial microsimulation modelling is used to investigate a range of national social and economic policy-related issues in which national sample survey data are used in a microsimulation model to generate from survey data sets of synthetic spatial data (such as estimates of levels of poverty) to appraise the likely spatial impacts of policy changes (such as increasing the single pension rate) on households across local areas within the framework of the national census geography (see Tanton, Vidyattama, McNamara, Vu, and Harding, 2009; Harding and Tanton, 2014).
2. The work of researchers at the University of Queensland (McCrea, Shyy and Stimson, 2006; Chhetri, Stimson and Western, 2006: Chhetri, Stimson, Akbar and Western, 2007; Chhetri and Stimson, 2014) to investigate aspects of human behaviour in which survey data collected for a quality of urban life study in the Brisbane-South East Queensland region in Australia is integrated with spatial objective data to model the relationships between the subjective assessment of quality of urban life and a range of personal demographic and socio-economic characteristics and urban locational and environmental context attributes. That research also illustrates how that type of integrative modelling can be used to derive —from Principal Components Analysis (PCA) of the survey data— a set of broad dimensions that summarise

perceived attributes of local areas that have influenced people's decision to choose where they live, and to then produce maps showing the simulated patterns of those residential attributes across the metro-region.

3.4. The challenge of «big data»

We are living in what Anderson (2008) has called the «petabyte age» in which the proliferation and spread of rapidly emerging new digital technologies are producing massive streams of data —including data in real time and space— that are referred to as *«big data»*.

«Big data» is certainly a hot topic, and it has been the «source of much enthusiasm, hype and a fair amount of cynicism» (Rae and Singleton, 2015: p. 1). There is confusion over the definition of «big data» —it is a «fuzzy» concept. It requires substantial investment in storage, transfer and processing architecture, typically undertaken through public agencies and big business. It is characterized by the *5-Vs —volume*, *verity*, *velocity*, *variety*, and *value* (Aikat, 2013).

Rae and Singleton (2015: pp. 3-4) point out that:

> «... Huge volumes of data are generated within regions daily, such as through the use or management of public services (e.g. global positioning satellite (GPS) tracking of law enforcement officials and use of healthcare facilities), or captured from transport-related activities (e.g. road flow information gathered by networks of traffic cameras). Other data are also generated by the private sector, including transaction data associated with consumption or the use of social media, where content are georeferenced by mobile devices».

Miller and Goodchild (2014) tell how:

> «...a large portion of the flood [of "big data"] is from sensors and software that digitize and store a broad spectrum of social, economic, political, and environmental patterns and processes».

They also point out that much «big data» is being generated through massive simulations of complex systems. Miller and Goodchild tell how we are certainly moving from a «data scarce» to a «data rich» world, in which the most fundamental changes are not the volume of data *per se*, but the variety and the velocity at which we can capture georeferenced data.

Indeed Hilbert (2013) has also suggested that:

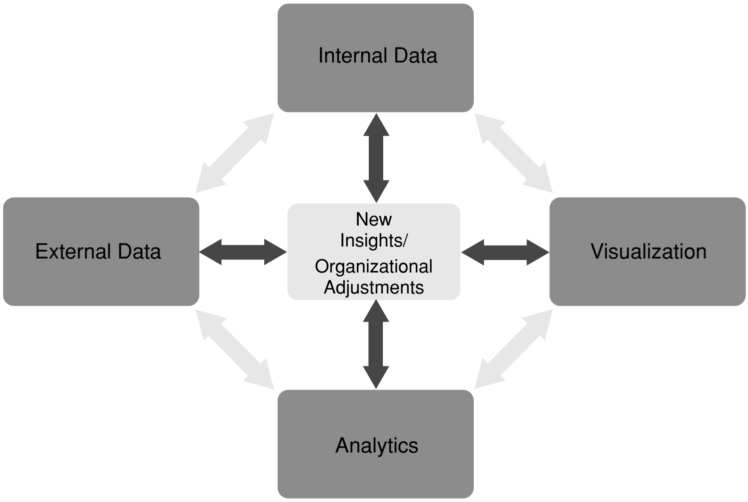
> «... the crux of the "Big Data" paradigm is actually not the increasingly large amount of data itself, but its analysis for intelligent decision-making» (p. 4).

Thus, he has proposed that *«big data analysis»* is a more fitting term to use as:

> «... the key feature of the paradigmatic change is that analytic treatment of data is systematically placed at the forefront of intelligent decision-making. The process can be seen as the natural next step in the evolution from the "Information Age" and 'Information Societies» to "Knowledge Societies": building on the digital infrastructure that led to vast increases in information, the current challenge consists in converting this digital information in to knowledge that informs intelligent decisions» (p. 4).

This is what Malvey, Shrowty and Akoner (2013) have referred to as the *transformative* potential of «big data», which they conceptualise as the «big data revolution» (see Figure 3).

Figure 3. The «big data» revolution



Source: Malvey, *et al.* (2013).

Of particular significance for regional science research is the *integrative* capability of «big data analytics», and this is its potential revolution. As discussed by Batty, Axhausen, Giannotti, Pozdnoukhov, Wachowicz, Ouzounsis and Portuglai (2012), the advances being made in data modelling capabilities using «big data» —such as data mining, large scale simulation models, and agent-based techniques— offer considerable potential to:

— enhance our understanding of the complexities of urban and regional systems; and
— assist in finding solutions to pressing problems.

Batty (2012: p. 102) has suggested that we are at the early stage of making the city *computable* through being able to seamlessly integrate diverse data from:

— sensors;
— hand held devices;
— electronic ticketing;
— in-car devices; and
— social media.

and subject it to sophisticated analytics in order to «make cities more efficient and more equitable». He points out how that is defining the «smart cities movement». As noted by the Centre for Applied Spatial Analysis (CASA 2012), it is all about:

> «... how computers, data, and analytics, which consist of models and predictions, are being embedded into cities»,

to help us make better sense of the complex urban world. That involves a focus on doing so through using advanced visualisation tools.

Important for regional science research is the challenge discussed by Violino (2014) to use «big data» and its associated information and communications technologies to:

> «... deliver sustainable economic development and a higher quality of life, while engaging citizens and effectively managing natural resources».

Rae and Singleton (2015) provide a discussion on using «big data» in regional science and regional studies, which is certainly in its infancy. They point to a number of important investments that have been occurring in:

— *«open data»* initiatives — particularly in the European Community through the Cohesion Policy Open Data platform, and through city initiatives such as London's DataStore and OpenData Paris; and

— «big data» infrastructures, such as the Administrative Data Research Network (ADRN), the Urban Big Data Centre (UBDC), and the Consumer Data Research Centre (CDRC) established through the Economic and Social Research Council (ESRC) the in the UK.

With respect to the CDRC, Lovelace, Birkin, Cross and Clarke (2015) provide an example of how collaboration between regional scientists and industry is using «big data» better understand patterns of regional retail flows in the UK through using datasets held by retail store chains that are derived from consumer loyalty cards.

Batty *et al.* (2012) have outlined how, in Europe, there has been collaborative research effort working towards developing and implementing a program of applications of «big data analytics». That is demonstrated through the *FutureICT* project to investigate a diverse range of issues including:

— housing booms and busts in large cities, linked to financial crises;

— impacts of changes in energy on urban transportation systems and mobility;

— the fracturing of transport networks due to short term problems related to urban conflict, weather and one-off events;

— the efficiencies produced by synthesising different urban data sets;

— the impact of climate change on cities in Europe, particularly sea level rise and rising temperatures on population location;

— the participation of citizens in the development of plans for smart cities of the future focussing on mobility, housing, better design and aesthetics (the city beautiful) and access to opportunities; and

— the impact of immigration phenomena in a global world.

A considerable literature has evolved on the nature of «big data» and «big data analytics». That includes what is called an «urban computing» approach which, interfaced with GIS, is claimed to be opening-up opportunities for:

— new theory development; and

— new and potentially better models for the quantitative assessment of different scenarios for urban development, to:

- inform policy and planning options for the management and delivery of public service;
- support increase stakeholder and community participation in decision-making; and
- improve the lives of ordinary people.

But while there is much enthusiasm and much hype about the potential to harness «big data» —including real-time data in a spatial framework— especially in research into strategies for «smart cities/regions» —there is also some scepticism, with many concerns being expressed about «big data» (see, for example, Kitchen, 2013; Ferguson, 2013; Burris, 2013; Akat, 2013; Goodchild, 2013); Marshall, 2014). For example, there are issues relating to:

— «big brother», privacy concerns, and citizen's rights;
— trust and ethical issues concerning its use;
— data quality and data representativeness and inclusion;
— the blind trust in imperfect algorithms; and
— state and corporate control and manipulation.

Promoters of the wonders of «big data» and «big data analytics» have been even suggesting that it represents the end of science as we know it, that it could even make the scientific method obsolete. This claim has come under considerable questioning, with Serras, Bosredon, Herranz and Batty (2014) suggesting that, even though we are getting massive amounts of «big data», it does not necessarily provide explanatory power about the «underlying decisions and behaviours of city users».

So where does this leave us? Importantly Rae and Singleton (2015: pp. 3-4) have reminded us that:

> «... The syntheses of data into information are hallmarks of both regional studies and regional science research».

That is what «big data» and «big data analytics» is supposed to be facilitating, providing us with the opportunity to capture, store and link temporally rich data within regions. Rae and Singleton (2015) «implore the regional studies and regional science communities to meet head on» (p. 4) this challenge. They urge regional scientists to «*think more, not less*, about big data», and develop successful «big data» examplars to demonstrate the:

> «... massive potential of big data for enlightening citizens and improving our understanding of critical urban and regional processes» (p. 4).

4. Conclusion

As an interdisciplinary field of enquiry, regional science has brought together researchers from a whole range of disciplines to undertake the development of theory and methods to investigate a wide range of social, economic and environmental issues within a spatial framework context, conducting those enquiries at a multitude of spatial scales, and using both data aggregated into those spatial frameworks along with also using micro-data. Inevitably during its relatively short history of a little more than 60 years, periodically regional science has had called into question its theories and methods. And it has had its relevance questioned, both from outside from within the regional science community. That has been helpful for the development of the regional science to ensure that regional scientists have continued to strive to demonstrate its applied relevance in informing the development of public policy for urban and regional development and planning, to evaluate policy and planning interventions, and to demonstrate applications in business (see, for example, Clarke and Madden, 2001; and the discussion by Stimson, 2015).

Throughout its history, periodically regional scientists have explicitly addressed the challenges regional science has had to confront towards this end of being relevant, identifying contemporary societal issues that might be informed through the application of regional science theory and methods. And regional scientists have pursued methodological innovation focused on explicitly improving approaches to integrating different types of data and for the analysing and modelling data that is embedded within a spatial framework in order to furnish improved understanding of urban and regional development and the behaviour of institutions, firms, and households and individuals within the context of space economies.

This chapter has provided a review of such challenges and issues that have been addressed in regional science and by regional scientists, focusing explicit attention on a number of contemporary methodological challenges that are worthy of greater attention.

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