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Multi-scale issues in cross-border comparative analysis

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ABSTRACT

Cross-border studies have recently received increasing attention in many disciplines, stimulated by globalisation, international trade and migration. In this paper, we take the analysis of the determinants of educational attainment on both sides of the international border between Northern Ireland and the Republic of Ireland to demonstrate how the impacts of the changing areal units and extent on social processes can be examined through spatial statistical analysis. A statistical model is constructed to relate the proportion of people with a post-secondary degree in a small area to a series of socio-economic characteristics of that area. We utilise both a traditional 'global' regression model and the local technique of Geographically Weighted Regression (GWR). Both models are calibrated on various cross-border data sets. The results also highlight the multi-scalar effects of the Modifiable Areal Unit Problem (MAUP) which are partially relevant in cross-border statistical analysis. They also demonstrate the potential of GWR to highlight cross-border differences in social processes.

1. Introduction

Within Europe most countries share a land border with at least one other country. There are more than 70 cross-border regions in Europe today, operating under names such as 'Euroregions', 'Euregios' or 'Working Communities' (Perkmann, 2003; Chen, 2004). Globalisation and regional integration processes have stimulated a number of cross-border studies within various academic fields (Paasi, 1999). Breitung (2002) summarises five approaches to geographical border study: political, physical, socioeconomic, functional and psychological. The political approach looks at the legal setup, mutual agreements, and the political geography of countries. The physical approach assesses a border regime by the mapping of land-use and physical features. The socioeconomic approach investigates different living standards and job opportunities with socioeconomic data from both sides of the border and with the narratives of residents and migrants. The psychological approach looks at territories of groups of people with different identities, experiences, and cultural influences by using interviews and mental maps. The functional approach explores institutional and personal trans-border links and the flows of people, goods, information, and money across borders, all of which suggest that processes across international borders are becoming more harmonised. Among the five approaches, the socioeconomic approach is characterised by the use of quantitative data and/or quantitative analytical methods, which will be the focus of this paper.

International borders are interesting for understanding and comparing the spatial processes operating within and between countries because they highlight potential differences in socio-economic processes caused by the different institutional, political, social and economic frameworks within different countries (e.g. Kuemmerle et al., 2006; Moreno et al., 2005; Lara-Valencia et al., 2008; Ceccato and Haining, 2004; Prokkola, 2011). There is an increasing number of geographical information system (GIS) applications for cross-border studies – mapping spatial distribution (Moreno et al., 2005), analysing spatial patterns (Decloly and Grasland, 1993; Ceccato and Haining, 2004), modelling spatial processes (Garrett and Marsh, 2002) and simulating spatial behaviour (Westlund and Bygvrå, 2002). However, the scale issue in cross border studies have not received sufficient attention.

The border between the Republic of Ireland and Northern Ireland (the latter being part of the United Kingdom) provides perhaps the best study region in Europe for examining the effect of an international border on socio-economic processes and for examining the statistical problems created by using the different definitions of spatial units on either side of the border. Both countries were part of the United Kingdom until 1926 and both have much in common despite the presence of an international border for the past 80 years. Indeed, the border, until recently very tightly controlled, is now virtually invisible. Consequently, the two countries have much in common, including the way most census data are defined, but have had 80 years in which to grow apart. It is therefore interesting to examine whether differences in social

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processes exist on either side of the border and whether such differences can be identified easily.

A major challenge for cross-border comparative analysis is that often the reporting units for data will be different on either side of the border. A research question here is then: "do observed differences in statistical analyses on either side of an international border result from data on either side being drawn from incompatible spatial units?" Consequently, cross-border comparative analysis involves a special type of multi-scale issue.

As well as having an ideal set of data at several areal units, this project takes advantage of recent developments in Geographic Information Systems (GISs) and spatial statistics to explore the multi-scale effects on cross-border comparative analysis and further improve our understanding of the Modifiable Areal Unit Problem (MAUP) (Fotheringham, 1998; Fotheringham and Wong, 1991; Nelson, 2001; Openshaw and Clarke, 1996; Swift et al., 2008). After this introduction, section 2 will discuss the methodology related to multi-scale modelling, which includes the multi-scale concept and two possible modelling techniques (global and local regression analysis). In section 3, a brief introduction is given to the study area, followed by the details of the spatial units used for the purpose of two countries. section 4 will describe detailed multi-scale analysis using educational attainment modelling as an example. A statistical model is constructed to relate the proportion of people with a post-secondary degree in a small area to a series of socio-economic characteristics of that area. Based on a defined multi-scale framework, global and local models are calibrated. The paper ends with some general conclusions about cross-border comparative analysis and the MAUP issue.

2. Methodology

2.1. Multi-scale concepts

Scale can function as a sort of container in space or time for heterogeneous phenomena and processes, which has form and dynamics. Much of the difficulty in the treatment of 'scale' is the great variability in the interpretation and meaning of the term (Cheng and Masser, 2003). Issues such as absolute size, relative size, resolution, granularity, extent, and detail have to be defined. Marceau (1999) provides a comprehensive review of the scale issue in the social and natural sciences. Goodchild (2011) highlights the effects of spatial resolution on physical process models. In terms of spatial analysis, the scope of scale can be threefold: spatial, temporal, and decision-making (Agarwal et al., 2001).

2.1.1. Spatial scale

Spatial scale is linked with the terms "resolution" and "extent". A multi-resolution analysis principally explores the impacts of various definitions of spatial units which are utilised to test the sensitivity or stability of models. A multi-extent analysis principally explores the impacts of variation in the size of a study area on modelling. Numerous researches have explored the spatial multi-scale issue in terms of extent and resolution (Betts et al., 2006; Burnett and Blaschke, 2003; Kok and Veldkamp, 2001; Overmars et al., 2003; Pearson et al., 2004; Tate and Atkinson, 2001; Walsh and Crawford, 2001; Goodchild, 2011).

2.1.2. Temporal scale

Temporal scale is related to the terms "time step" and "duration". Time step is the smallest temporal unit of analysis in a model, while duration refers to the length of time that the model is applied (see an example by Dadvand et al., 2011).

2.1.3. Decision-making scale

Decision-making scale can be described in terms of: "agent" and "domain" (see an example by Wernz and Deshmukh (2012)). Agent refers to the human actor or actors in the model who are making decisions. The individual human is the smallest single decision-making agent; other agents can include a household, neighbourhood, county, state, province or nation. Domain, on the other hand, refers to the broadest social organisation incorporated in the model. While the agent captures the concept of who makes decisions, the domain describes the specific institutional and geographical context in which the agent acts. Institutionally, agents may overlap spatially.

In socio-economic spatial analysis, the three types of scale issues should be paid equal attention but this paper will focus on the spatial scale issue. Cross-border studies are generally involved in identifying distinguishable patterns and processes (Ps 1 and 2) between two sides of a border as shown in Fig. 1. To compare the cross-border patterns and processes, the effects of spatial resolution and extent on analytical results, need to be explored, or rather, a kind of sensitivity analysis should be conducted. These spatial analyses facilitate understanding of the multi-scalar features of the social processes under the study (Manley et al., 2006). Spatial resolution is frequently defined in terms of the areal units used to report data. In most cases, these are artificial units based on a hierarchy of administrative units. Due to different political and socio-economic systems, the spatial hierarchies between the two sides of an international border usually are defined and represented differently. Spatial extent is defined as the study area for specific spatial analysis or statistical models. In a cross-border study, it is interesting to examine if there is any significant difference in analytical results between the areas within the same distance to the border.

Spatial analysis based on these areal units and extents (see Fig. 1) should not ignore the MAUP issue. MAUP is a generalised term for several related problems in which the results of some type of analysis vary substantially when the areal units used in the analysis vary. Statistical information may be available for a series of different scales of areal units such as NUTS level 2 or 3 zones or there might be a variety of ways of aggregating smaller units into larger units so that the results of the analysis when using the larger zones depend on how those zones have been aggregated from the set of smaller zones (e.g. Taylor et al., 2003; Alvanides et al., 2001). A third type of modifiable areal problem occurs when the results of an analysis are sensitive to the definition of the spatial extent of the study region.

These MAUP issues have been well recognised in a wide range of disciplines, such as transport analysis (Viegas et al., 2009; Kwan and Weber, 2008), physical geography (Dark and Bram, 2007), mapping (Nakaya, 2000) and political geography (Johnston et al., 2006). Very diverse methods have been differently applied for examining or exploring the MAUP effect in a specific area, such as a multi-level model (Kwan and Weber, 2008). However, there

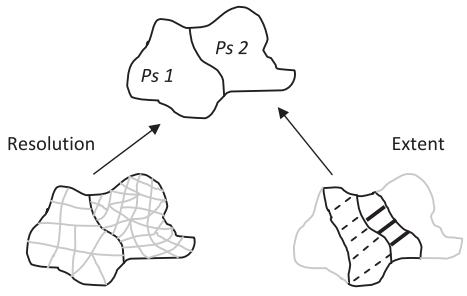

Fig. 1. Multi-scale issue in cross-border comparative analysis.