Spatial Econometrics in RSUE: Retrospect and Prospect*

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1 Introduction

Spatial econometrics featured prominently in the early years of the journal *Regional and Urban Economics*. In the very first issue, the second article by Walter Fisher (Fisher 1971) dealt with "Econometric Estimation with Spatial Dependence." It constitutes one of the first papers in the applied economic literature addressing the topic of spatial autocorrelation and its implication for estimation in linear regression models. In the following years, articles covering spatial econometric topics remained a frequent appearance in the journal, with a significant increase after 2000. This largely parallels the dissemination of the field in other economics journals (Anselin et al. 2004). Curiously, this contrasts with a marked absence of the much broader and interdisciplinary subject of *spatial data analysis* and related applications of geographic information systems. Apparently, Wallsten (2001) is the only paper in 35 years of *RSUE* that mentions "geographic information systems" in its title.

In this brief note, I formulate some remarks on spatial econometrics and how it relates to *RSUE*. It may be useful to provide some context and to start by considering the past. Therefore, I will first briefly comment on the evolution of spatial econometrics and how it relates to publications in the first 35 volumes of

*Some of the main ideas on the evolution of spatial econometrics as a field contained in this paper were earlier expressed in the Inaugural Arthur Getis Lecture in Spatial Analysis, San Diego State University, Oct. 2005, and in an address on "Spatial Econometrics: Past, Present and Future," part of a special session honoring Keith Ord at the 102nd Annual Meeting of the Association of American Geographers, Chicago, IL, March 2006.

RSUE, complementing the review provided by Minerva and Ottaviano (2007). This is followed by some speculations about future directions.

2 Looking Back

Spatial econometrics has its origins in the early 1970s, when Jean Paelinck used the term to refer to methodological aspects associated with incorporating dependence in cross-sectional multiregional econometric models. Initially, the development and application of spatial econometrics was mostly driven by the interests of regional scientists and applied economists in Europe, and several of the early classics appeared in *RSUE*. In part stimulated by advances in theory (social and spatial interaction) and technology (geographic information systems), the interest in spatial analysis in economics and other social sciences has seen tremendous growth in recent years (Goodchild et al. 2000). This culminated in the formal establishment in May 2006 of an international "Spatial Econometrics Association" at the Fifth Workshop on Spatial Econometrics and Statistics in Rome, Italy.

This increased interest in spatial problems in economics has coincided with a broadening of the publication outlets, and several recent theoretical advances have appeared in mainstream econometric journals, such as the *Journal of Econometrics* and *Econometrica*. Similarly, applications are no longer primarily targeted at regional science journals, but the leading field journals in economics have shown a dramatic increase in published spatial papers as well (for a recent overview, see Anselin et al. 2004).

In reviewing the evolution of the field since the early 1970s, I suggest a general classification into three distinct periods: the "preconditions for growth" (early 1970s to late 1980s), the "take off" (1990s), and "steady state" (post 2000). Each of these is characterized by a change in the focus of interest, an evolution of the disciplinary mix of sholars involved in the field, and a diversification of publication outlets.

The first stage was characterized by an interest in residual spatial autocorrelation, model specification (spatial lag and spatial error models), and basic estimation in linear spatial regression models (maximum likelihood and instrumental variables). *RSUE* contained seven articles that explicitly addressed these topics during the period 1971-1990 (see Table 1). Together with the quantitative geography journals *Geographical Analysis* and *Environment and Planning A*, it constituted the main outlet for this type of research. Interestingly, there was both a disciplinary and geographical split among the main contributors, consisting mostly of regional economists in the Netherlands on the one hand, and quantitative geographers/regional scientists in the UK and US on the other. The articles published in *RSUE* primarily represent the Dutch contingent.

By the early 1990s, several compilations had appeared and the field had been given a clearer and more formal definition, for example, as outlined in Anselin (1988). During the 1990s, the field also matured. Interest started to center on more rigorous formal proofs of the properties of estimators and test

statistics (e.g., specialized laws of large numbers and central limit theorems were developed), new approaches were introduced (e.g., LM statistics, GMM estimation, Bayesian techniques), panel data and discrete choice models were considered, more attention was paid to computational aspects, and accessible software had become available. Spatial problems also began to attract the attention of mainstream theoretical econometricians (such as Bera, Case, Conley, Kelejian, Pinkse, Prucha, Slade, among others) and papers started to appear in the leading econometric and field journals.

In the beginning of the decade (1992), *RSUE* published the first special issue of a journal totally devoted to spatial econometrics, but the remainder of the 1990s was rather sparse in terms of the representation of the field in the journal, with only two more articles (see Table 2). In contrast, by the end of the decade, important theoretical contributions had also appeared in the *Journal of Econometrics* and the *International Economic Review*, and spatial techniques had become so prevalent in real estate economics that a special issue of the *Journal of Real Estate Finance and Economics* was devoted to the topic (Pace et al. 1998). For whatever reason, very little of this work found its way into *RSUE* at the time.

After around 2000, there was a seaside change, with a tremendous increase in the number of both theoretical and applied papers dealing with spatial econometrics. Several journal special issues were devoted to the topic and articles appeared in all the major econometric and field journals (for a more detailed review, see Anselin et al. 2004). While no longer the sole (or primary) outlet, *RSUE* published a respectable share of these, with four methodological articles and nine applied papers in the first five volumes of the 21st century (Table 3). By this point in time, spatial econometrics is commonly used in empirical work in real estate economics, environmental economics, public economics, as well as in regional economics. Only a fraction of this is represented in *RSUE*, with the most conspicuously absent topic arguably being the spatial econometric analysis of economic growth convergence, a major thread in empirical spatial econometrics in regional economics (e.g., Rey 2004).

The increased adoption of spatial econometrics in the mainstream had some less fortuitous consequences for *RSUE*. As the topic has become more accepted among theoreticians, articles tend to get published in the flagship theoretical econometric journals, and much less so in the regional science or applied journals. Similarly, solid empirical spatial econometric work tends to appear more in the leading field journals in economics, rather than in the more interdisciplinary regional science outlets. The empirical spatial econometric articles in *RSUE* tend to be there because of the substantive focus of the journal, in urban economics and micro analysis. Rather than being targeted to *RSUE* because of the spatial methodology, which might have been the case in the past, such papers now employ spatial econometrics as an accepted tool. In earlier days, this might not have been the case.

3 Looking Forward

The charge for this note was to speculate how the nature of the journal and its constituent fields will change over the next twenty years. Thinking back on where we were twenty years *ago*, this may be hazardous at best.

Twenty years ago, it would have been hard to imagine that one day the internet would become the dominant medium to disseminate new scholarly ideas, that wireless communication would be ubiquitous and digital libraries commonplace, that electronic publishing would rival print media, videoconferencing would defy distance decay, and video podcast would become a way to distribute course materials.

Twenty years ago, very few scholars involved in spatial econometrics foresaw the ready availability of desktop GIS and the reliance on computing power to carry out statistical inference. Nowadays, empirical work involving the analysis of data sets containing hundreds of thousands (millions) of observations is becoming commonplace. Contrast this with the original "classic" Irish county data set in Cliff and Ord (1981), containing all of 26 observations. Even well into the 1990s, very few spatial econometric analyses dealt with more than 100 observations. Therefore, simple extrapolation to the future is not likely to be reliable, but since the charge was to "speculate," one can think of a number of directions where major change is to be expected.

In terms of spatial econometrics, each of the four driving forces of theory, data, methods and computation are bound to undergo fundamental change, even in the medium term, with consequences for scholarly publishing in general, and *RSUE* in particular.

Theoretical advances in social and spatial interaction, interdisciplinary work on social and spatial networks, and the related interest in agent based models are expected to create a growing demand for spatial econometric methods that allow calibration of complex (space-time) interactions. A greater reliance on computational approaches is likely, since many challenges remain to obtain analytical results and to prove formal properties. This will require advances in algorithms to deal with the cross-sectional dependence in a way that also allows parallelization.

Data availability will drive the demand for more sophisticated spatial econometric methods as well. The presence of sensors of various kinds, recording in real time both activity and the location of the activity will generate massive georeferenced data sets which cannot be handled with today's methodology. Initiatives to create realistic synthetic public micro data that include meaningful measures of non-spatial as well as spatial behavior are likely to bear fruit in the near future. New paradigms may need to be developed to analyze these, relaxing our familiar assumptions about distributions and functional forms, and combining insights from economic theory, statistics, data mining and computer science.

Computing itself is undergoing continual change, with a move from a desktop paradigm to web services, and computation becoming a "utility" untied from the monitor-keyboard combination. Scientific computing, such as that required

to analyze massive data sets will require further development of collaborative environments to exploit distributed (grid) computing. Such cyberinfrastructure (e-science) is still in its infancy for spatial social science, but several promising initiatives suggest that a similar path will be followed, as in the "hard" sciences. For spatial econometrics in particular, where there is strong complementarity between the need for formal proofs, the implementation of efficient algorithms and the application to large data sets, such cyberenvironments may be very effective in advancing the frontier of the field. A move towards a greater collaboratorive approach may also fundamentally change the way spatial econometric research is carried out and the manner in which new findings are disseminated.

It is hard to imagine that the nature of scientific publishing will remain imune to these trends. Already, changing preferences in favor of electronic media rather than the traditional paper copy has altered the pace and scope of dissemination. Journals such as *RSUE* will have to address the influence of extensive facilities provided by future cyberinfrastructures for spatial social science and spatial econometrics, consisting of integrated resources, including working papers, data and software programs as well as multimedia presentations. Such infrastructures could turn out to be competitors or collaborators of the scholarly publishing industry. One issue seems clear: academic publishing as we know it today is not likely to survive in the same form for the next twenty years.

Spatial econometrics likely will continue to be an active discipline, given the remaining theoretical and computational challenges and the many indications of growing (not lessening) demand for methods that take into account the complexities of space and time. Time will tell whether this also will coincide with a continued (or greater) representation of the findings of the field in *RSUE*, whatever form the latter may take twenty years from now.

Table 1: Spatial Econometrics in RSUE – 1971 to 1990

Reference	Title
Fisher (1971)	Econometric estimation with spatial dependence
Hordijk (1974)	Spatial correlation in the disturbances of a linear interregional model
Bartels and Hordijk (1977)	On the power of the generalized Moran contiguity coefficient for spatial autocorrelation among regression disturbances
Steinnes (1980)	Aggregation, gerrymandering, and spatial econometrics
Blommestein (1983)	Specification and estimation of spatial econometric models: a discussion of alternative strategies for spatial economic modeling
Blommestein (1985)	Elimination of circular routes in spatial dynamic regression equations
Anselin (1990)	Some robust approaches to testing and estimation in spatial econometrics

Table 2: Spatial Econometrics in RSUE – the 1990s

Reference	Title
Vol. 22 (3)	Special Issue – Space and Applied Econometrics
Anselin (1992)	Space and applied econometrics: introduction
Kelejian and Robinson (1992)	Spatial autocorrelation: a new computationally simple test with an application to per capita county police expenditures
Nass and Garfinkle (1992)	Localized autocorrelation diagnostic statistics (LADS) for spatial models
Griffith (1992)	A spatially adjusted N-way ANOVA model
Bolduc et al. (1992)	Spatial autoregressive error components in travel flow models
Barringer and Smith (1992)	Experiments with central-limit properties of spatial samples from locally covariant random fields
Florax and Folmer (1992)	Specification and estimation of spatial linear regression models: Monte Carlo evaluation of pre-test estimators
Dubin (1992)	Spatial autocorrelation and neighborhood quality
Can (1992)	Specification and estimation of hedonic housing price models
Heikkila and Kantiotou (1992)	Calculating fiscal impacts where spatial effects are present
Case (1992)	Neighborhood influence and technological change
Anselin and Hudak (1992)	Spatial econometrics in practice: a review of software options
Anselin et al. (1996)	Simple diagnostic tests for spatial dependence
Kelejian and Robinson (1998)	A suggested test for spatial autocorrelation and/or heteroskedasticity and corresponding Monte Carlo results

Table 3: Spatial Econometrics in RSUE – Post 2000

Reference	Title
Methods	
Kelejian and Prucha (2002)	2SLS and OLS in a spatial autoregressive model with equal spatial weights
Saavedra (2003)	Tests for spatial lag dependence based on method of moments estimation
Florax et al. (2003)	Specification searches in spatial econometrics: the relevance of Hendry's methodology
Anselin and Moreno (2003)	Properties of tests for spatial error components
Applications	
Bivand and Szymanski (2000)	Modeling the spatial impact of the introduction of compulsory competitive tendering
Buettner (2001)	Local business taxation and competition for capital: the choice of the tax rate
Garrett and Marsh (2002)	The revenue impacts of cross-border lottery shopping in the presence of spatial autocorrelation
Mobley (2003)	Estimating hospital market pricing: an equilibrium approach using spatial econometrics
Brasington and Hite (2005)	Demand for environmental quality: a spatial hedonic analysis
Cohen and Paul (2005)	Agglomeration economies and industry location decisions: the impacts of spatial and industrial spillovers
Babcock et al. (2005)	Wage spillovers in public sector contract negotiations: the importance of social comparisons
Egger et al. (2005)	Commodity taxation in a linear world: a spatial panel data approach
Brown and Rork (2005)	Copycat gaming: a spatial analysis of state lottery structure

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