Chapter 7
Spatial Econometrics: Outline

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7.1 Introduction

- Spatial econometrics has a relatively short history compared to the emergence of econometrics as a discipline in 1930. If the term 'spatial econometrics' was introduced by Jean Paelinck at the annual meeting of the Dutch Statistical Association, Tilburg, May 1974, see Paelinck and Klaassen (1979, p. vii), it was only really at the end of the 1970s that spatial econometrics began to take hold. The late 1970s seem to be a turning point, as Anselin (2010) points out. Not only with the publication of Paelinck and Klaassen (1979)'s book, considered to be the first comprehensive attempt at outlining the field of spatial econometrics and its distinct methodology, but also with those of Bartels and Ketellapper (1979) and Bennett (1979) and some important articles Hordijk and Paelinck (1976), Hordijk (1979), Hordijk and Nijkamp (1977, 1978) among others.
- Initially, the development and application of spatial econometrics was mostly driven by the interests of regional scientists and applied economists in Europe.
- Context: challenges linked to the spread of microcomputing, the development of the New Economic Geography (1990s), and more recently Quantitative Spatial Economics and the revolution of big data since the beginning of this new century.

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- In 2006, creation of the Spatial Econometrics Association (SEA) to promote, disseminate and encourage the development of theoretical tools and empirical applications in spatial econometrics[1].
- Publication of several textbooks (Arbia (2006, 2014), LeSage and Pace (2009), Anselin and Rey (2014), Elhorst (2014), Kelejian and Piras (2017), Lee (2024) since the two traditional textbooks, Paelinck and Klaassen (1979) and Anselin (1988). The 1990s marked the real expansion of articles in the field. Anselin, Florax and Rey (2004, p. 1) underlined that "a tremendous growth in the number of publications in which spatial econometric techniques are applied, not only within regional science and economic geography, but also increasingly in the leading journals of economics, sociology and political science". Arbia (2011) provides an overview of publications after the creation of the SEA over the period 2007-2011. He counted that 237 articles had been published in econometric journal (47), in regional science journals (146) and in other journals (44). Those figures confirm the growing interest in spatial panels in the spatial econometrics literature since the turn of the century.
- From the 1990s, increasing volumes of geo-referenced data and progress in geographic information systems, technical advances, software developments and spatial econometrics takes place in social science.

7.2 Spatial Econometrics, Spatial Statistics and Standard Econometrics: A Clarification

- Definitions and scopes.
- Spatial effects: spatial dependence (local interaction of individuals or from unobserved characteristics) and spatial (observable/unobservable) heterogeneity (specific approach is necessary).
- Spatial econometrics deals with models specific to economics.

7.3 Early Stages of Spatial Econometrics (Mid 1970s to Late 1980s)

- Early stages of development of spatial econometrics were characterized by an interest on testing for residual spatial autocorrelation (Primarly using Moran's I), the model specification (spatial lag and spatial error models), basic estimation in linear spatial regression models (maximum likelihood and instrumental variables), model discrimination and specification testing, as well as some initial work on space-time models (Anselin (2007, p. 452, 2010, p. 11)).

[1] Article 2 of its statutes stipulated that: 'The purpose of the Association is to promote the development of the theoretical instruments and practical applications of spatial econometrics – including spatial statistics and spatial data analysis. Spatial econometrics should be regarded in abroad sense and inclusive of the developments of statistic models and instruments to analyze externalities, interactions, etc. in different areas such as, without limitation, economics, geography and regional sciences. The mission of the Association is to disseminate and encourage knowledge and good practice among universities and research institutions and in the community in general, becoming a reference point for operators in the field'.

Topics:

- Origins of the field: quantitative revolution in geography (Berry and Marble (1968), Curry (1970), Gould (1970), Tobler (1970)) and operational models which incorporate spatial effects in regional science and regional and urban economics (Granger (1969, 1974), Fisher (1971), Paelinck and Nijkamp (1975), Hordijk and Paelinck (1976)).
- In the 1980s, considerable attention was paid to model discrimination and specification tests of spatial models, also on space-time modelling and the spatial seemingly unrelated regression model.
- In the late 1980s, emergence of many publications, specialist meetings and major ressources that stimulated the development and promotion of spatial analytical methodology.

Lessons:

- Dominant Maximum Likelihood paradigm (Maximum Likelihood approach, first introduced by Ord (1975)).
- Beginning of other approaches such as instrumental variables and Bayesian methods.
- Geographical split of contributors. In continental Europe, interest comes primarily from researchers in the Netherlands, who are almost all trained in economics and econometrics. In the U.S., there is a small group of mathematical social network analysts, economists are mostly absent.

What aged well:

- The Weight Matrix (W): Despite criticism on the assumption of its 'exogenous' nature, the W matrix remains the standard for encoding spatial structure due to its transparency and flexibility.
- Moran's I: It has maintained its position as the 'gold standard' diagnostic tool for spatial correlation, especially with its local version (Anselin, 1995).

What aged not so well:

- Small sample ML. Emergence of large datasets, and often unrealistic normality assumption in the context of regional data favoured GM methods over ML.

7.4 Emergence of a Growing Interest in Spatial Econometrics (the 1990s)

- During the 1990s, 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 (Anselin (2007, p. 452).

Topics:

- Many new participants in the field (quantitative geographers, regional scientists, students, U.S. economists). Several mainstream econometricians begin to consider spatial problems (Bera, Durlauf, Kelejian, LeSage, Prucha, etc.).
- Increasing volumes of geo-referenced data and progress in geographic information systems.
- Spatial econometrics becomes significantly more rigorous. Formal derivations of the asymptotic properties of estimators and test statistics become standard, contrasting with a more informal approach during the previous stage.
- Research continues to be focused on issues of specification, estimation and testing.
- Social interactions (spillover effects and externalities) begin to come the foreground in the social science theory.
- Beginning of spatial effects to be considered in models of limited dependent variables.

Lessons:

- Geographically Weighted Regression (GWR): A limited adoption among econometricians. A similar ending for spatial filtering.
- Growing attention to small sample properties which completes more rigorous proofs of properties of estimators and test statistics.
- Instrumental variables or GMM approaches as estimation frameworks that avoid some of the challenges posed by Maximum Likelihood (impractical when the individual sample size is exceptionally large, explicit distributional assumptions which maybe difficult to satisfy).
- Generalization of Bayesian approaches (spatial statistics).
- During the 1990s, many software tools were developed, mostly in the noncommercial academic world (Anselin (2012)).
- Technical advances allow to take into account quite large data sets.
- Data availability and theoretical advances in social and spatial interaction, spatial networks drive the demand for more sophisticated spatial econometric methods.

What aged well:

- The emergence of S2SLS/GMM and their capacity to handle large data.
- Exploratory spatial data analysis (ESDA), local indicators of spatial autocorrelation, hot-spot analysis.

What aged not so well:

- GWR (overfitting, sampling issue, residual correlation).
- Spatial filtering (black-box, obscure spatial interpretation).

7.5 The 21st Century as a Turning Point to Reach the Mainstream

This period is a major turnaround, with a tremendous increase in the number of both theoretical and applied papers dealing with spatial econometrics, see Anselin, Florax

and Rey (2004), Arbia (2011), Baltagi (2011), Lee and Yu (2010, 2011, 2015). The previous stages laid the foundations for the full development of spatial econometrics. Then, in the 21st century we have reached a general acceptance of both spatial statistics and spatial econometrics as mainstream methodologies.

Topics:

- Beginning of the 2000s, quantitative spatial economics (quantitative models of economic geography, i.e., quantitative framework that connects closely to the observed data).
- Spatial panel econometrics (from static to dynamic models (Anselin (2001) and Anselin, Le Gallo and Jayet (2008) who divided these models into four categories)/methods, tests, cross-dependence methods and tests (distinction between weak and strong cross-dependence (Holly, Pesaran and Yamagata (2010, 2011), Chudik, Pesaran and Tosetti (2011)), multi-dimensional spatial panels (Le Gallo and Pirotte (2024)).
- Specialized models (frontier regression, quantile regression)
- Non-linear models (from cross-section to panel).
- Non-parametric approaches
- Large data sets, models, methods, and computational techniques.

Challenges:

- Interaction with artificial intelligence, machine learning techniques and networks.
- Multi-dimensional asymptotic theory and inference with high-dimensional data.
- Causal inference (Causal Inference and Interference: Rosenbaum and Rubin (1983), Hudgens and Halloran (2008). Spatial DiD: Delgado and Florax (2015), Chagas, Azzoni and Almeida (2016). Recent Developments: Serenini (2025).)
- Retain distinct identity? (e.g., vs network econometrics)

What aged well:

- Spatial panels and the intersection of time and space dimensions.
- Software evolution. From standalone software - Anselin's GAUSS-based SpaceStat (early 90's), later LeSage's MATLAB toolbox (late 90's), GeoDa (early 2000) - to integration within mainstream data science environments (Python, R, Stata). Open and free software (GeoDa, Python, and R).

What aged not so well:

- Overparametrization and lack of spatial interpretation.

7.6 Conclusion

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