1. Accessibility and spatial interaction: an introduction

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1.1 THE CONTEXT: SPATIAL INTERACTION AND ACCESSIBILITY ANALYSIS

Spatial interaction refers to economic or demographic flows between different locations, generally through a transport infrastructure. It implies a complementarity between two places engaged in a supply–demand relationship which is subject to certain costs, such as cost of transport or transaction costs.

Spatial interaction models (SIMs), stemming from their analogy with Newton's law of gravity, are especially suited to study the spatial interaction between pairs of locations, where space is measured in the form of cost–utility function (at the aggregate or disaggregate level).

SIMs have a long history and have been used in a wide variety of contexts. Wilson (1970) gave SIMs theoretical strength by deriving them using the entropy maximization approach. Nijkamp (1975) offered an economic framework by deriving SIMs from a cost-minimization approach and, finally, Anas (1983) demonstrated the formal equivalence between SIMs and logit models and microeconomic theory. All in all, SIMs in all their forms (unconstrained, singly constrained and doubly constrained) can be interpreted in macroeconomic and microeconomic terms, where a key behavioural element is provided by the cost function parameter (for a review, see Reggiani, 2014).

The accessibility function can be directly derived from SIMs and it therefore contains SIM behavioural cost components. Its analytical formulation is consistent with the accessibility concept and equation provided by Hansen (1959), the first author to apply a gravity-type model to the study of accessibility, defining it as 'potential of opportunity for interaction' (p. 73). In other words, accessibility of a given place is related to the importance of the opportunities available for interaction, as well as with the distance needed to reach those opportunities. Since then, accessibility analyses have addressed the issue of spatial interaction, while increasing the level of complexity: (1) by including other factors in addition to distance or the weight of places (van Wee et al., 2001); and (2) by using more detailed data and calibrating the models in a way that correctly represents the deterrence of distance, that is, the effort needed to overcome the distance between locations (Baradaran and Ramjerdi, 2001; Martínez and Viegas, 2013; Reggiani et al., 2011). Sensitiveness to cost–distance factor is known in accessibility studies as distance decay and it differs with factors such as individual perceptions, type of transport infrastructure or spatial characteristics of places under analysis. Doubly constrained or unconstrained SIMs are commonly used to estimate different types of distance decay.

There is no doubt that spatial interaction is related to accessibility, since improved accessibility will increase the spatial interaction between places. However this relation is often asymmetric, since some places take more advantage than others of better accessibility. Accessibility improvements can emerge from transport infrastructure developments or from land use changes, that is, increased number of jobs in a certain location. Accessibility indicators are able to capture changes in both components (transport infrastructure and land use) and for this reason their performance has been recognized in the framework of sustainability policy, in light of best practice planning and decision-making processes where evaluation methods, such as cost–benefit analysis, multi-criteria analysis and risk analysis, can embed accessibility results.

Given their spatial nature, accessibility indicators are very sensitive to the spatial unit of analysis (what is known as the modifiable area unit problem, MAUP). The MAUP will influence the goodness of fit of the calibration process (with spatial interaction data) and determine the role of self-potential. 'Self-potential' refers to the intra-zonal level of spatial interaction, which can be significant and even outweigh interaction between zones, especially in the most urbanized locations (Frost and Spence, 1995). The difficulty of estimating self-potentials or self-interactions in accessibility studies due to lack of data on transport networks within zones is widely acknowledged. This issue, which particularly affects gravity-type accessibility indicators, can be minimized by using smaller zones and new techniques to improve computational performance. Nowadays new sources of data are available that better represent intra-zonal and inter-zonal spatial interactions. This is true of data from location-sharing devices that report information with high spatial and temporal detail. The use of this data is a promising way of improving our understanding of mobility patterns and paves the way towards a stronger theoretical analysis of accessibility indicators, with reference to their dynamic framework.

Accessibility varies in space, since it is related to economic activity variables such as population, income, employment, and so on, and to the distance or cost and time of reaching these activities. In short, accessibility can be interpreted as the spatial arrangement of economic opportunities. Accessibility can be high around metropolitan areas and decreases as we move away from urban agglomerations. Accessibility also decreases whenever there is a barrier, as in the case of national borders. Several studies have found that national borders exert a negative influence on issues such as trade flows. Another source of variation in accessibility patterns is related to social groups: for example, young people are able to move faster and more easily than elderly people. Aspects such as the barrier effect (such as national borders) and the mobility patterns of different social groups can be included in accessibility analysis as methodological improvements.

Accessibility is associated with higher productivity levels, as regions with high accessibility benefit from lower transport costs and agglomeration economies. Accessibility also concerns patent output, regional economic growth, new firm formation, labour and export performance of regions.

It should be noted that, given the increasing relevance of accessibility issues, mostly in this globalized space-economy, a great number of review studies have been published that also show the potential and role of this tool for best practice and planning (see, among others, in the last decade: Becker et al., 2008; Dentinho et al., forthcoming; De Montis and Reggiani, 2012, 2013; Geurs and van Wee, 2004; Geurs et al., 2012; Gutiérrez et al., 2010; Levinson and Krizek, 2008). In this context, we aim to go beyond these accessibility analysis studies and to reflect on the specific issue of the link between spatial interaction and accessibility from the theoretical, methodological, empirical and policy analysis perspectives.

On the basis of the above, the rationale of this book is to present a collection of recent studies modelling and discussing spatial interaction by means of accessibility indicators. Table 1.1 summarizes the main characteristics of all the studies included in this book, focusing particularly on the applied measurement of accessibility.

The chapters have been organized in three parts: Part I deals with methods and data sources used to estimate spatial interaction through accessibility indicators. Part II is devoted to the social and spatial dimension of interaction. Finally, Part III of this book is dedicated to accessibility as a driver of spatial interaction, exploring the relationship between accessibility and regional economic performance.

Table 1.1 Overview of chapters included in this book

Chapter	Object	Accessibility measure	Attractiveness	Variable in the decay function	Form of the decay function	Spatial interaction data	Spatial units	Spatial context
J. Östh, A. Reggiani, G. Galiazzo (Ch. 2)	Estimation of distance decay parameters	Potential accessibility	Jobs	Cartesian distances	Power and exponential decay	Commuting flows	Municipalities	Sweden
D.P. McArthur, I. Thorsen, J. Ubøe (Ch. 3)	Impacts of accessibility to labour markets, measured in terms of distributions of employment and population	Weighted-average distance	Number of jobs, adjusted for the competition for jobs	Generalized transport costs	Logistic function	Hypothetical data on migration flows	Zones	Simulation
T.W. Nicolai, K. Nagel (Ch. 4)	Influence of spatial resolution, congestion and transport mode on accessibility outcomes	Logsum indicator	–	Travel time	Exponential decay	Home–work–home commuting plans	Origins: cells of different sizes and zones centroids; Destinations: network nodes	City of Zurich

L.A. Schintler, R. Kulkarni, K. Haynes, R. Stough (Ch. 5)	Spatial and temporal variations in the mobility patterns of individuals	Indicators based on the bipartite network modelling and mobility sheds	Counties that share common visitors	–	–	Brightkite location-sharing services data	Counties	Lower 48 states in the US
A. De Montis, S. Caschili, D. Trogu (Ch. 6)	Spatial dependence of accessibility in US counties	Potential accessibility	Number of commuters	Travel cost	Exponential and power decay	Commuting flows	Counties	US
M.H. Salas-Olmedo, A. Condeço-Melhorado, J. Gutiérrez (Ch. 7)	Border effects in the European Union	Potential accessibility	Gross domestic product	Travel time	Power decay	Trade flows	Countries	EU
V. Ribeiro, P. Remoaldo, J. Gutiérrez (Ch. 8)	Access of elderly people to bus stops	Accumulated opportunities	Bus stations	Travel time	–	Observed travel patterns of elderly people	Parishes	City of Braga (Portugal)

Table 1.1 (continued)

Chapter	Object	Accessibility measure	Attractiveness	Variable in the decay function	Form of the decay function	Spatial interaction data	Spatial units	Spatial context
P. Arbués, M. Mayor, J. Baños (Ch. 9)	Productivity impacts of road infrastructure	Potential accessibility	Population	Mean travel distance	–	–	Provinces	Spain
A. Holl (Ch. 10)	Location characteristics and corporate productivity	Potential accessibility	Population	Travel time	–	–	Municipalities	Spain
U. Gråsjö, C. Karlsson (Ch. 11)	Review chapter	Potential accessibility	Innovation (e.g. research and development, patents), population, gross regional product, etc	Proximity	–	Various	Municipalities, functional regions	Sweden

1.2 ADVANCES IN MODELLING ACCESSIBILITY AND SPATIAL INTERACTION

Part I presents novel methodologies used to calibrate accessibility with spatial interaction data, as well as advances regarding the dynamic interaction between transport and land use. It also reflects on the role of the unit of analysis in estimating accessibility and finally presents an analysis of mobility and accessibility patterns based on new sources of data, such as those from Global Positioning System (GPS)-equipped devices.

In Chapter 2, John Östh, Aura Reggiani and Giacomo Galiazzo highlight the importance of correctly estimating distance decay in accessibility analysis. The authors explore two commonly used distance decay functions – the exponential and the power function – and compare three different methods to estimate the distance decay parameter. In particular, the authors adopt two SIMs – the unconstrained and the doubly constrained SIMs – to calibrate spatial commuting flows between Swedish municipalities. The third method used to estimate the distance decay parameter is the half-life model embedded in SIMs, which is a new approach in such estimation studies. The main advantage of this method is the reduced amount of data required to estimate the distance decay parameter. The authors also reflect on how distances between places are specified, testing mean and median distance values as a way of determining the sensitiveness of distance decay methods to the size of geographical units (MAUP). Based on different distance decay estimates, the authors calculate several accessibility indicators for the spatial context of Sweden over a 15-year period, concluding that the accessibility model least sensitive to the MAUP is that which is calculated with the power function. The half-life model can be used as an alternative to the exponential function when flow data is missing, since similar accessibility patterns emerged from these two models.

Changes in transport infrastructure will reduce distance-related costs and this will have a positive impact on interaction between places. On the other hand, a change in the size of places motivated by an increase in the number of jobs, for example, will also increase interaction by attracting and generating new flows of people, goods and immaterial flows to that place due to the development of new residential areas and (re)location of firms. In most cases, a change in one factor cannot be dissociated from the others; thus, a change in infrastructure will lead to a change in size. Chapter 3 of this book deals with the complex interaction that could arise when transport networks are expanded or improved. David Philip McArthur, Inge Thorson and Jan Ubøe use a spatial general equilibrium model to estimate the impact of changing accessibility to a series of places as a result of a new bridge. Impacts are measured in terms of population, employment and migrations (of people and relocation of firms), with particular focus on urban and rural dimensions. They show that although accessibility may be improved in the short run due to reduced transport costs, in the long run population and jobs located in rural areas may fall. Some rural zones close to the central city may also register a decrease in terms of employment and an increase in population, reflecting a change from a rural to a suburban zone.

In Chapter 4, Thomas Nicolai and Kai Nagel analyse the influence of spatial disaggregation in accessibility computations, as well as the effect of considering congestion and different transport modes over accessibility levels. The authors use a logsum indicator to measure location accessibility, which accounts for the number and distribution of opportunities and the transport infrastructure. They use the city of Zurich as a case study, and couple a land use model (UrbanSim) with a transport model (MATSim), to perform a traffic simulation to estimate congested travel times for different transport modes (car, bicycle and walking). Regarding the spatial resolution of origin locations, the authors compare two approaches: zone-based and cell-based. For the zone-based approach, the centroid represents the origin location, while for the cell-based approach the location is represented by points that in turn depend on the size of the cell. Opportunities, meanwhile, are aggregated on the nearest node on the road network. The effect of spatial resolution is evaluated in terms of quality of the results and computational performance. The authors recommend the use of the cell-based approach, since it removes the controversial assumption, taken by the zone-based approach, of homogeneous accessibility within zones. Furthermore the cell-based approach showed similar computational efforts compared to the zone-based approach and yielded more meaningful results. However there is a disutility in improving spatial resolution in the cell-based approach, since at certain levels of high resolution the computational performance does not compensate in terms of improved quality of results. Apart from spatial resolution considerations, the authors conclude that the effect of congestion clearly changes accessibility levels in Zurich. In terms of transport modes, they reach the interesting conclusion that during peak hours in the urban core, accessibility by bicycle is similar to accessibility by car. In contrast, accessibility when walking is clearly worse than the other modes.

Laurie A. Schintler, Rajendra Kulkarni, Kingsley Haynes and Roger Stough (Chapter 5) provide a novel contribution on how new sources of data can be used to analyse mobility and accessibility patterns. Specifically, they use data from location service devices in the USA between 2008 and 2010. They present a set of indicators that are able to characterize the degree of mobility of US counties, the strength of ties between counties and the centrality of counties within the network of locations. Their results showed that central counties also have a higher number of individuals using these location service devices and that densely populated regions tend to be highly mobile. Their study also looks at travel distance patterns (national or regional) of individuals at a certain location, showing that tourist destinations generally present a larger number of domestic trips than regional trips. Finally, they identify distinct mobility sheds in the US, defined as regions in which the same set of people are travelling, concluding that these communities are usually in close proximity in spatial terms.

1.3 THE SOCIAL AND SPATIAL DIMENSION OF ACCESSIBILITY

Part II comprises three chapters on spatial patterns on accessibility and interaction from different perspectives. In Chapter 6, Andrea De Montis, Simone Caschili and Daniele Trogu analyse the role of spatial dependence in the accessibility of US counties, considering the extent to which the accessibility of a county depends on the characteristics of neighbouring counties. Using autocorrelation analysis the authors address two fundamental questions: (1) whether counties with high accessibility positively influence adjacent counties; and (2) the spatial association between accessibility levels and other socio-economic variables (population and income per capita). To answer the first question, the authors perform a univariate spatial autocorrelation analysis with the Moran I and the Local Indicator of Spatial Autocorrelation (LISA). Results show a strong spatial dependence on the accessibility of US counties, meaning that counties with similar levels of accessibility tend to cluster together. Furthermore they show the distribution of clusters of high and low accessibility levels across the country. To answer the second question the authors used a bivariate autocorrelation analysis, concluding that high accessibility clusters are located in large metropolitan regions, while low accessibility clusters are located in central areas of the US characterized by lower population density. Similar patterns were found for the association between accessibility and income, but in this case the authors also found clusters with negative spatial autocorrelation. This occurs in regions with higher income and less accessibility than surrounding counties, or in regions with lower income and higher accessibility than adjacent pairs.

María Henar Salas-Olmedo, Ana Condeço-Melhorado and Javier Gutiérrez (Chapter 7) reflect on the decrease of spatial interaction resulting from national borders. This is known as the border effect and has been measured in several studies using spatial interaction models and focusing on trade flows between countries. However the literature is unclear with regard to the magnitude of the border effect and it is argued that part of this controversy is due to how distances have been measured by previous authors. Following this rationale, the chapter makes two main contributions to the existing literature: (1) understanding the role of different distance metrics when measuring border effects; and (2) including border effects in the accessibility computation. Border effects are analysed for a set of European countries considering different distance metrics such as Euclidean distance, network distance, travel time and generalized transport costs. They found a higher preference in all countries for national rather than international trade. This is also true for all distance metrics; however, border effects increase with the complexity of the distance metric (higher when travel times and generalized transport costs are considered). Border effects are generally higher in peripheral countries and may reflect less competitiveness to trade in international markets. Finally, the authors introduce the border effect in the market potential indicator in order to capture not only the decrease of distance-related interaction, but also the effect of national borders on spatial interaction.

In Chapter 8, Vitor Ribeiro, Paula Remoaldo and Javier Gutiérrez analyse the accessibility of elderly people to public transport. They argue that urban characteristics such as street slope angle and the speed at which the elderly people walk should be included when modelling accessibility of the elderly, since this can greatly affect their ability to reach public transport. The authors analyse the accessibility of the elderly to bus stops in the municipality of Braga (Portugal) and compare different measurements, including slope angle and walking speed, concluding that the inclusion of street slope angle and walking speed provides better estimates of the accessibility to bus stops for this group. Based on these results, they argue that these factors should be considered in studies dealing with transport-related social exclusion and in the analysis of spatial inequalities.

1.4 ACCESSIBILITY AS A DRIVER OF SPATIAL INTERACTION

The first two chapters of Part III look at the relationship between accessibility and productivity. Pelayo Arbués, Matías Mayor and José Baños (Chapter 9) focus on measuring the output effect of road transportation infrastructure in Spanish provinces between 1997 and 2006. They estimate a production function using a panel of data from Spanish provinces in order to account for marginal productivity effects within a province and to document the existence of spillover effects outside the provincial boundaries through the use of spatial econometrics methodologies. Road infrastructure endowment indicators are measured in three different ways: using an accessibility measure, the traditional road stock indicators and a variable that attempts to adjust the stock indicator to the degree of utilization. The authors found strong evidence of the positive impact of better road accessibility on the domestic economy of a province. The results also showed that improved accessibility would increase the productivity of neighbouring areas even more than the spatial unit.

In Chapter 10, Adelheid Holl presents an empirical analysis of the relationship between location characteristics and productivity using data from Spanish firms. Both urban agglomeration and better transport accessibility can provide firms with access to denser and larger markets and this may help improve efficiency and increase productivity. The analysis distinguishes different location characteristics such as local population size, local population density and accessibility. The results show a significant positive productivity effect for all three location characteristics, particularly accessibility, and the author concludes that transport accessibility better captures the benefits of location.

The concluding chapter is a contribution from Urban Gråsjö and Charlie Karlsson and analyses the potential of accessibility in spatial economics. They look at different empirical studies conducted in a Swedish context where accessibility measures were used to explain patent output, regional economic growth, new firm formation and firm dynamics, the emergence of new export products and labour mobility. All studies reviewed show the positive impact of accessibility on market size and knowledge sources. Accessibility is considered a useful tool for spatial economic studies because: (1) it is related to economic theories such as spatial interaction and random choice; (2) it captures the spatial dependencies between locations and thus spillover effects; and (3) it gives a better representation of space-economy evolution by providing useful insights for policy-making.

This book aims to address a wide variety of issues and perspectives linked to the accessibility concept in order to outline its analytical fruitfulness – due to its transversal nature – as well as its performance in different empirical applications in light of specific policy strategies. Nevertheless, the potential of accessibility analysis has still not been fully exploited. In the near future new topics will certainly be addressed with novel approaches using accessibility tools. Certainly the impact of new sources of information, such as information and communication technologies (ICT), will be as significant for accessibility studies as geographic information systems (GIS) were several years ago in terms of offering advanced findings, mainly with reference to the complex dynamic interaction between accessibility and space-economy.

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