Handbook of Regional Science

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Handbook of Regional Science

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About the Editors

Manfred M. Fischer is Emeritus Professor of Economic Geography at Vienna University of Economics and Business and Adjunct Professor at the Chinese Academy of Sciences. He was Co-founder of the prominent interdisciplinary journal *Geographical Systems* (Gordon & Breach) and is now Editor-in-Chief of its successor, the *Journal of Geographical Systems* (Springer). Professor Fischer also co-founded the Springer book series Advances in Spatial Science and served for 8 years as Chair of the IGU Commission on Mathematical Models. In this role he was responsible for organizing several of the Commission's highly successful international meetings around the world, including symposia in Shanghai and Beijing (1990). For more than 40 years he has consistently made significant contributions to regional science in general, and spatial data analysis, geocomputation, and spatial econometrics in particular. Professor Fischer has published widely, both books and articles, in dozens of distinct academic journals. Recently, his monograph on Metropolitan Innovation Systems has been translated into Chinese (Shanghai People's Publishing House, 2006). On account of his scholarly achievements, he has been named a Fellow of the Regional Science Association International, the Royal Dutch Academy of Sciences, the Austrian Academy of Sciences, and the International Academy of Sciences for Europe and Asia. Moreover, Professor Fischer has received the highest accolades of the RSAI: the Jean Paelinck Award 2015 for outstanding scholarly achievements in the field of Regional Science Methods, and the Founder's Medal 2016 that is awarded every 4 years for significant lifetime contributions.

Peter Nijkamp is Professor of Regional and Urban Economics and Economic Geography at VU University and affiliated to the Jheronimus Academy of Data Science (JADS); 's-Hertogenbosch (the Netherlands); the Royal Institute of Technology (KTH), Stockholm (Sweden); and A. Mickiewicz University, Poznan (Poland). He serves on the editorial/advisory boards of more than 30 journals. According to the RePec list, Professor Nijkamp is one of the top 30 most well-known economists in the world. His main research interests cover quantitative plan evaluation, regional and urban modelling, multicriteria analysis, transport systems analysis, mathematical systems modelling, technological innovation, entrepreneurship, environmental and resource management, and sustainable development. In the

past years, he has focused his research in particular on new quantitative methods for policy analysis as well as on spatial-behavioral analysis of economic agents. Professor Nijkamp has broad expertise in the area of public policy, services planning, infrastructure management, and environmental protection. In all these fields he has published many books and numerous articles.

Professor Nijkamp has been a visiting professor in many universities all over the world. He is Past President of the European Regional Science Association and of the Regional Science Association International. Professor Nijkamp is also Fellow of the Royal Netherlands Academy of Sciences and its former Vice President. From 2002 to 2009, he served as President of the Governing Board of the Netherlands Research Council (NWO). In addition, he is Past President of the European Heads of Research Councils (EUROHORCs). Professor Nijkamp is also Fellow of the Academia Europaea and member of many international scientific organizations. He has acted regularly as advisor to (inter)national bodies and (local and national) governments. In 1996, he was awarded the most prestigious scientific prize in the Netherlands, the Spinoza Award.

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Regional Science in Perspective: Editorial Introduction

Prologue

This *Handbook of Regional Science*, with 110 chapters and more than 2,300 pages, offers a representative and kaleidoscopic overview of the field of contemporaneous regional science. Its great diversity is also mirrored in the disciplinary composition of the 170 contributing authors who appear to have their roots in different disciplines, such as (regional and urban) economics, economic and social geography, architecture and planning, political science and public administration, demography and sociology, mathematics, statistics and econometrics, ecology and environmental science, and so forth. It is noteworthy that the search for a uniform and generally accepted scientific paradigm in regional science, in terms of theory or methodology, would be in vain. Each of the constituent disciplines in regional science brings in its own disciplinary theoretical, conceptual, or methodological framework.

Of course, such scientific approaches may sometimes be overlapping. The added value of regional science as a "portfolio" discipline is its bridging principle: combining different, but compatible – though often complementary – approaches in one research domain enhances our insights into the interdependent complexity of the space-economy. Regional science is not an archipelago consisting of different and disconnected islands. The integrating nature of regional science does not rest on one common scientific constellation, but on a joint use of appropriate research frames that enhance our understanding of spatial processes and structures, interdependencies, and governance issues on regions and cities on our planet. After a discussion of the aims and scope of this Handbook, we will briefly sketch the organization and the key substance of the eleven sections and the 110 constituent chapters of this multi-volume opus. In the final section of this introductory chapter we will attempt to identify some formal textual commonalities in the different chapters of this Handbook by seeking for various substantive concepts and terms commonly used across the chapters.

Aims and Scope

The *Handbook of Regional Science* is a multi-volume reference work providing state-of-the-art knowledge on regional science, composed by renowned scientists in the field. It is part of the prestigious "Springer Reference Library" that appears not

only in book format but also online as fully searchable and hyperlinked eReferences on SpringerLink. An important feature of Springer References is that they represent mainly work of tertiary literature, containing digested and established knowledge presented in an accessible format. The level of each chapter is such that not only a graduate student or a postdoc researcher but also a more advanced regional scientist can benefit from a chapter that does not belong to his or her area of expertise. Each chapter is also a stand-alone entity that covers a particular topic without assuming that the reader will need to read another part of the same topic elsewhere in the reference work.

This reference work addresses theory, methodology, application, and policy in one opus and is intended to serve the academic needs of graduate students as well as junior and senior scientists in regional science and related fields, with an interest in studying social science phenomena and processes that have an explicit spatial dimension. The work is specifically intended to function as an instructional guide for students and established scholars in regional science for ease of use and regular literature access, when needed.

Structure of the Handbook

The material in this Handbook has been chosen to provide a systematic state-of-the-art presentation of the diversity of current and emergent research topics, theories and models, methods and techniques, not available elsewhere, despite many excellent journals and book publications. The international group of authors was selected for their knowledge of a subject area and their ability to communicate basic information in their subject area succinctly and accessibly.

This second edition of the *Handbook of Regional Science* has changed considerably since the first edition in 2014, which is most evident by the addition of two new sections, one on the history of regional science and one on regional policy. Most chapters have been updated to incorporate new developments, while others have been rewritten by different authors with fresh perspectives on the material concerned. There are approximately 30 new chapters, written by leading scholars in the field covering topics such as knowledge spillovers, R&D collaboration networks, regional policy assessments, big data issues, dynamic modeling approaches, web-based tools for exploratory spatial data analysis, fuzzy modeling, multivariate spatial process models, endogeneity in spatial models and heterogeneous spatial autoregressive models, among others. These additions reflect largely developments that have come to the fore or gained importance since the first edition.

The reference work now contains 110 chapters and is subdivided into eleven sections that range from the history of regional science over regional housing and labor markets to spatial analysis and geocomputation, and finally to spatial statistics as well as spatial econometrics. The sections are categorized as follows, with the section editors along with the responsible editor-in-chief (EiC) given in parentheses:

- History of Regional Science (Peter Batey; EiC: PN)
- Location and Interaction (Piet Rietveld[†], Manfred M. Fischer; EiC: MMF)
- Regional Housing and Labor Markets (Alessandra Faggian, Marco Modica; EiC: MMF)
- Regional Economic Growth (Jacques Poot; EiC: PN)
- Innovation and Regional Economic Development (Roberta Capello; EiC: MMF)
- Regional Policy (Juan Cuadrado-Roura; EiC: PN)
- New Economic Geography, Evolutionary Economic Geography, and Regional Dynamics (Karima Kourtit, Andrés Rodríguez-Pose; EiC: PN)
- Environmental and Natural Resources (Amitrajeet Batabayal; EiC: MMF)
- Spatial Analysis and Geocomputation (Paul Longley, Manfred M. Fischer; EiC: MMF)
- Spatial Statistics (Peter Congdon; EiC: MMF)
- Spatial Econometrics (James LeSage; EiC: MMF)

The various sections in this Handbook will now concisely be introduced.

History of Regional Science

Regional science has over the past half a century turned into a broad multi-disciplinary orientation on regional and urban issues, combining – and being a complement to – urban and regional economics, social and economic geography, transportation science, environmental science, political science, and planning theory. Regional science has also developed a powerful scientific toolbox that is nowadays being used in many disciplines all over the world.

Regional science as a broadly recognized scientific domain has been brought to fruition only over the last 60 years. This does not imply that there was no interest in spatial issues in earlier times. On the contrary, already the grandfather of economics, Adam Smith, analyzed the relationship between location and trade, by emphasizing the importance of accessibility and spatial connectivity. And many other classical scholars, for example, Ricardo, Malthus, Quesnay and several others, have addressed – often implicitly – important issues of the space-economy. Of course, there is also a range of recognized predecessors of regional science, in particular, von Thünen, Weber, Palander, Predöhl, Christaller and Lösch. But the real history of regional science started with the seminal contributions of Walter Isard, who laid the foundation for a rigorous analytically oriented regional science since the mid-1950s. The framework developed by him had a theoretical foundation, a strong methodological orientation, and a strong emphasis on applied modeling of real-world phenomena and processes, seen from a multidisciplinary perspective.

It is noteworthy that Isard did not only provide original contributions to regional science in a strict sense, but also to ecological science, transportation science, and even conflict management. His approach is a perfect example of the

multidisciplinary nature of regional science. This trans-disciplinary character is also the key feature of the present multi-volume reference work. Contributors of the various chapters originate from several disciplines which all together make up the constituents of regional science. These chapters follow the strict methodological requirements imposed in the early genesis of regional science, in which quantitative analysis and multidisciplinary approach are key features.

The first section in the revised and updated version of the Handbook is a new section on the History of Regional Science and consists of eight chapters. As mentioned above, regional science has a respectable history which is so broad in scope and nature that it is not well possible to provide a comprehensive record of all achievements. And therefore, this section offers a selection of highlights in regional science thinking from its rich history. The chapters provide a broad coverage of themes that include the history of regional science concepts, methods, models, theories, and fields of application.

The opening chapter written by Peter Batey examines the evolving relationship between regional science methods and planning since the mid-1950s. In the early days of regional science, spatial planning was seen as a valid outlet for much of the analytical work carried out by regional scientists, but over the years a gap has emerged. The author argues that regional science may make an important contribution to planning analysis in an open-minded inter-disciplinary dialogue and in a concerted effort to make models and methods more user-friendly. Next, there is a comprehensive account by Michael Lahr and João Pedro Ferreira on shift-share analysis, one of the most durable regional science methods. This approach has become a popular analytical and forecasting tool, including time and space dimensions. The authors point out the need for a theoretical foundation and for methodological linkages with regression and input-output analysis. In a subsequent chapter, written by Gordon Mulligan and John Carruthers, the concept of city size distribution, a focal point of regional science interest, is discussed, addressing the evolution of thought in the area of theory, empirical testing, and policy formation in different time periods. The study of dynamic equilibria in spatial systems of cities in relation to economies of scale and transportation costs appears to provide also interesting liaisons with the new economic geography treated in a later section of this Handbook.

Location theory is one of the established cornerstones of regional science to be treated directly and indirectly in other sections of this reference work. In the chapter that follows, Roberta Capello offers a description of classical location theories and re-examines important constituents of locational analysis. She extends the economic logic of location theory towards communication costs and the "death of distance" notion. Folke Snickars discusses then another important element of location theory, namely, market area analysis and the existence of competing firms. After an exposition of earlier theoretical contributions, the author presents a series of behavioral models on location games between sellers and customers, using a cellular automata framework as the basis for simulating equilibrium states of seller-customer systems. In the subsequent chapter, Johannes Broecker focuses then on another major analytical strand in the regional science literature, namely, spatial interaction models. He shows how the derivation of such models has evolved from a variety of

methodological perspectives (ranging from social physics to microeconomic general spatial equilibrium). Finally, he also argues that the rich and systemic scope of spatial interaction models has also favored its use in policy evaluation.

The two final chapters in this History section address two important analytical foci in regional science in relation to planning and decision-making. First, Graham Clarke zooms in on current regional science methods in business and commerce. The author explores three different scales – macro, meso, and micro – and then moves on by focusing on various applications at each of these scale levels (ranging from gravity analysis to microsimulation). The final chapter in this section is provided by Kieran Donaghy, who returns to the links between regional science and planning by offering a survey of contributions made by regional scientists that support spatial planners and urban designers to engage in collective decision-making and design, leading to collective action and effective planning efforts by addressing real-world concerns and practicable approaches.

Location and Interaction

Spatial interdependencies between locations have always been at the heart of regional science research. Such interdependencies are clearly related to transport flows and mobility patterns, but go also much further. The section on Location and Interaction provides an overview of spatial interaction concepts, models, and accompanying methodologies. There are eleven chapters in this section.

The first chapter, written by Kenneth Button, focuses attention on the ways in which travel behavior and demand are analyzed within the framework of regional science. While the main methods of modeling travel behavior and demand are outlined and critiqued, specific attention is given to the practical aspects of applying travel behavior and demand analysis to subjects such as regional development, infrastructure investment, and congestion analysis. In the next chapter, Harvey Miller discusses activity-based analysis as an approach to understanding transportation, communication, urban and related social and physical systems using individual actions in space and time as the basis, along with corresponding methodologies.

In the next chapter, Richard Medina and Nigel Waters offer a concise review of social network analysis and elucidate how social network analytics can be and is used to influence and to understand the spatial manifestations of economic and political activity across regions in continuous and network space. The major social networks now extant are described, and their current activities are discussed, including the topics of micro-targeting, transparency, privacy, proprietary algorithms, and "fake news" and its synonyms such as post-truth. Policy implications to influence and govern these activities, such as taxation and regulation, are reviewed.

The relationship between urban development and transport is not simple, but complex and closely linked to urban processes, such as macroeconomic development, inter-regional migration, demography, household formation, and technological innovation. In his chapter, Michael Wegener discusses one segment of this complex relationship by focusing on integrated models of urban land use and

transport. Such models explicitly model the two-way interaction between land use and transport to forecast the likely impacts of land use and transportation policies for decision support in urban planning. In a subsequent chapter, David Boyce presents one approach to the construction of models of urban travel choices and implicitly location choices. Beginning with the simple route choice problem faced by vehicle operators in a congested urban road network, exogenous constants are relaxed and replaced with additional assumptions and fewer constants, leading toward a more general forecasting method.

Anna Nagurney next presents some of the major advances in modeling supply chains and transportation networks. Moreover, the author discusses how the concepts of system-optimization and user-optimization have underpinned transportation network models, and how they have evolved to enable the formulation of supply chain network problems operating under centralized or decentralized, that is, competitive, decision-making behavior. The chapter highlights some of the principal methodologies, including variational inequality theory, that have enabled the development of advanced transportation network equilibrium models as well as supply chain network equilibrium models.

Similar in spirit is the chapter on computable models of dynamic spatial oligopoly, written by Terry Friesz and Amir Meimand. The chapter begins with the basic definition of Nash equilibrium and the formulation of static spatial and network oligopoly as variational inequalities and then moves to dynamic network oligopoly models. The authors show that the differential Nash game describing competitive network oligopoly can be formulated as a differential variational inequality involving both control and state variables. In the subsequent chapter, Aura Reggiani reflects on complexity theory and models able to map out the complex interconnected spatial networks, from both a conceptual and applied perspective.

Johannes Broecker and Timo Mitze then introduce the theory of labor and capital movements between regions or countries. Movements of other mobile production factors, in particular knowledge, are not dealt with. The chapter explains the basic factor mobility model assuming perfect competition and full factor price flexibility, with particular emphasis given to the welfare results. After studying factor mobility in a static framework, the analysis is extended to a dynamic framework. The chapter also studies factor mobility in the new economic geography and briefly points to the role of the public sector for the analysis of factor mobility.

Inter-regional trade – representing the transfer of goods between individuals across regional borders – is a research topic that has been largely neglected by trade analysts. A dearth of data has limited formal exploration of inter-regional trade, but the current magnitudes of data volumes stimulate that greater attention be directed to this form of connectivity between economies. The chapter, written by Geoffrey Hewings and Jan Oosterhaven, starts with a brief review of the theory and tests of international trade and its link to new economic geography and then moves on to examine some alternative approaches to the measurement of trade, especially the role of intra-industry as opposed to inter-industry trade, vertical specialization, trade overlap, and spatial product cycles. The final chapter in this section, written by

the same authors, shifts the focus on inter-regional input-output models that have played a major continuous role in the history of regional science.

Regional Housing and Labor Markets

Housing and labor market research has been a focal point of attention in the history of regional science, and has generated important contributions to economic theorizing and analysis. The section on Regional Housing and Labor Markets is composed of nine chapters.

The first chapter, written by Dionysia Lambiri and Antonios Rovolis, offers a comprehensive review of the fundamental concepts and key analytical tools relevant for real estate and housing market research. While the definition and description of regional housing markets are complicated, the nature and causes of residential mobility are somewhat more clearly understood. In a subsequent chapter, David Brasington examines the state of the literature on residential mobility and house price hedonics. This chapter discusses the theoretical framework, looks at the empirical approaches to test theory, and considers briefly the factors influencing mobility and home prices. Whereas the theory behind second-stage demand regressions stemming from house price dynamics continues to receive some attention, the theory behind residential mobility and first-stage home price hedonics seems to be relatively stable. It is noteworthy that the empirical side of housing markets has received much more exploration in recent decades.

Subsequently, Michael Greenwood discusses the role of economic opportunities in the study of migration. From the earliest years of internal migration as a recognized field of study, scholars in many social science disciplines believed that such economic factors are key determinants of migration. During the 1980s and beyond, the availability of microdata that reflects personal employment status and household income has prompted numerous advances in our understanding of various migration phenomena and also has helped to clear up dilemmas regarding earlier studies that used aggregate data.

Search behavior is an important issue in the realm of housing and labor market research, including residential mobility and location decisions as well as job-choice problems. In her chapter, Alessandra Faggian outlines the standard model of search in a labor market context along with various extensions. In the subsequent chapter, Jan Rouwendal discusses the relations between housing and labor markets, with a specific focus on the role of commuting. Next, Stephan Goetz reviews labor supply, demand, and equilibrium topics with the goal of showing how they determine labor market outcomes across geographic space. Labor supply curves are based on utility-maximizing choices between working and leisure, subject to a budget constraint, whereas labor demand curves are derived from the firm's production function assuming profit-maximizing behavior. The author examines the challenges of defining and empirically delimiting labor market areas from historical perspectives and using statistical cluster analysis with commuting data serving as a key tool.

Over long periods of human history, labor market equilibrium involved movements from low-wage areas to high-wage areas, a form of arbitrage under the implicit view that wage differentials corresponded to utility differentials, as Philip Graves argues in his chapter on labor market theories and models. This "labor economics" view may likely be viable as long as movement and information costs are high, and under this view, the movements would be expected to cause wage convergence over space. But given recent failures to observe convergence in wage rates, the author suggests that an alternative view – assuming a utility equilibrium over space – might better predict and explain the labor market equilibrium. In this view the question whether the spatial equilibrium in labor markets involves convergence or divergence becomes an analytically complicated issue.

The long-term persistence of pronounced unemployment differentials between regions represents one of the most crucial issues confronting regional theory and policy. The chapter by Francesca Mameli, Vassilis Tselios, and Andrés Rodríguez-Pose reviews the theoretical and empirical literature on regional employment and unemployment research, with a focus on the causes of regional disparities in unemployment rates and on potential explanations. Finally, Laurent Gobillon and Harris Selod focus the attention to the literature on the spatial mismatch hypothesis – originally developed by the economist John Kain with an initial and exclusive focus on African-American poor in inner cities, a hypothesis that relates unemployment and poverty to the structure of cities.

Regional Economic Growth

Our understanding of regional economic growth has improved enormously in the past decades. Much of the existing work on regional growth has consisted of efforts to understand how factors beyond capital accumulation and technological change can affect regional development. The very broad conception of regional growth processes is reflected in the section on Regional Economic Growth.

The opening chapter by Maria Abreu surveys the neoclassical model of growth and discusses its key features, predictions, and limitations. In the late 1980s and 1990s new models of endogenous growth questioned the neoclassical emphasis on capital accumulation as the main engine of regional growth, emphasizing instead the Schumpeterian idea that growth is primarily driven by innovations that are often themselves the result of profit-motivated research activities. Zoltan Acs and Mark Sanders review then endogenous growth theory and regional extensions, while Steven Bond-Smith and Philip McCann describe how the new economic geography and growth literature incorporates space into the standard Grossman and Helpman product variety model of endogenous growth. Next, the chapter by William Cochrane and Jacques Poot turns to a range of alternative perspectives, broadly referred to as demand-driven theories and models that have their origin in Keynesian economics.

Julie LeGallo and Bernard Fingleton proceed to provide a survey and synthesis of econometric tools to study regional economic growth and convergence. An important aspect of this chapter is the diversity of approaches that have been developed to

link regional growth theory to data. The authors focus on two main strands of growth empirics: the regression approach, where predictions from formal neoclassical and other growth theories have been tested using cross-sectional and panel data, and the distribution approach, which typically examines the entire distribution of output per capita across regions. The chapter illustrates that regional growth empirics has stimulated the development of new spatial econometric tools to address the specific data implications of various growth theories.

The section continues to examine a range of growth mechanisms. Some of these have to do with the role of human capital in economic growth. The work on human capital has greatly expanded our understanding of the nature, role, and mechanics of regional economic growth and development. The chapter by Carlotta Mellander and Richard Florida surveys this line of research that can be divided into two main thrusts: studies that focus on and measure human capital in terms of educational attainment and those that measure skills via occupations. Other mechanisms fall outside the domain of the neoclassical model and are related to issues of political and economic institutions, and social capital, for example. Hans Westlund and Johan Larsson then discuss the role of local social capital in regional economic growth, while Annekatrin Niebuhr and Cornelius Peters consider the economic effects of population diversity, with special emphasis on the impact of diversity on regional productivity and growth.

Infrastructure is an integral factor supporting regional growth. The chapter by Arthur Grimes outlines two models for analyzing the relationship between infrastructure and regional growth. The first model adopts a standard spatial equilibrium approach and shows that the effect of new infrastructure on regional activity depends on its direct impacts on local productivity, local amenities, and the price of non-traded goods. The second model treats a major infrastructure investment as a real option that gives private sector developers the option, but not the obligation, for further development.

The attention being given to well-being as a possible complement to the conventional measures of economic growth constitutes one of the notable turning points in our measurement of progress. The chapter by Philip Morrison focuses on the relationship between regional economic growth and well-being and discusses the conceptual and empirical challenges which subjective measures of well-being pose for regional science.

In spite of the ongoing efforts that several countries made into promoting a more balanced economic development within their territory, economic growth theory and even empirical evidence do not come to a unanimous conclusion on the efficiency of policy intervention. The final section of the section, written by Sandy Dall'erba and Irving Llamosas-Rosas, discusses the various strands of the theoretical literature, analyzes the results of empirical estimations in Europe and the USA, and provides recommendations for future research in this field.

Innovation and Regional Economic Development

Innovation is a dynamic process bringing about creative destruction and shifting the locus of innovation across industries and among locations. Thus, innovation is

fundamental to economic growth and variations in economic development across space. The section on Innovation and Regional Economic Development contains nine chapters.

The first chapter, written by Edward Malecki, addresses the geography of innovation and reviews what we know from the work of economists as well as geographers. It begins with the simple world as grasped by patent data and models based on those data. Second, it examines what we know about innovation as a dynamic and complex – even messy – process. Third, this dynamic, complex messiness is seen in the location of innovation and of innovative capability: the geography of innovation at the global scale, which is itself the outcome of several distinct flows and forces. Finally, the chapter discusses briefly the degree to which policy can influence the geography of innovation.

In the subsequent chapter, Philip Cooke surveys the theoretical and empirical research into regional innovation systems, a concept increasingly being applied in the world of policy analysis and practice. The chapter begins by addressing the debate on regional governance, learning, and policy contexts and proceeds to discuss the three-phase evolution of the regional systems of innovation perspective. Each of the phase changes is shown to denote important new ways of thinking about regional innovation and evolution. The most recent phase-change represents the engagement of regional innovation systems, as a core subfield of evolutionary economic geography, with key concepts in the complexity sciences.

The idea of innovation within regional innovation systems recognizes the importance of feedbacks and interactions that are crucial to innovation. In the next chapter, Emmanouil Tranos, highlights the importance of networks in the innovation process, while Thomas Scherngell reviews the literature on the geography of R&D collaboration networks that has developed largely in Europe, accompanied by significant efforts to support such networks by public funding. In a subsequent chapter, Börje Johansson presents a theoretical framework in which lasting differences in firm performance are related to persisting differences in firms' innovation and adoption behavior.

In recent years, the research focus has shifted from innovation and technology to the broader issues of knowledge and innovative capability. In line with this shift, Frank van Oort and Jan Lambooy focus attention on current theories and empirical research on cities and the knowledge economy, while Charlie Karlsson and Urban Gråsjö study knowledge spillovers and knowledge externalities as drivers of regional economic development. Hereby knowledge spillovers represent the transfer of knowledge from one agent to another one working on similar topics, which results in economic gains. Maryann Feldman and Scott Langford move on to review how network theory and social network analysis have been applied to address questions developed within the field of knowledge spillovers. The authors illustrate the potential of this research to illuminate the channels and mechanisms, especially those related to geography and the geographic concentration of innovation.

The final chapter, written by Michaela Trippl and Edward Bergman, reviews the literature on industrial districts, innovative milieus, and industrial clusters that have enriched our knowledge about endogenous factors and processes driving regional

development and the role of the region as an important level of economic coordination. This class of stylized development concepts that emerged in the 1970s endeavors to account for successful regional adaptations to changes in the global economic environment. Each of these concepts grew out of specific inquiries into the causes of economic success in the midst of general decline by building upon the early ideas of Alfred Marshall in several ways. Neo-Marshallian districts found in Italy highlight the importance of small firms supported by strong family and local ties, while the innovative milieu concept places great emphasis on the network structure of institutions to diffuse externally sourced innovations to the local economy. Clusters have become far more general in scope, fruitful in theoretical insights, and robust in applications, informing the work of both academics and policy-makers around the world.

Regional Policy

Unbalanced, unequal, and problematic development possibilities among different regions have – over several decades – prompted the need for an active involvement of governments in regional development. The existence of regional income disparities, depopulation, and abandonment of rural areas, decisions on new infrastructures, or closure of old industries have driven public bodies to put in place dedicated policies that are generally included under the generic umbrella of "regional policies." One of the salient features of such policies was that the implementation of regional development programs, including measures to reduce unemployment or to favor balanced growth, was often undertaken by governments without seeking for theoretical foundations and with a very limited conceptual or methodological basis.

The awareness of this weak basis for regional interventions has fortunately prompted the design of solid policy strategies, thanks to the progress in regional analysis and novel research on the effectiveness of policies, empirical models, and instruments applied, such as growth poles, economic zones, technology parks, or tax incentives to attract investment. Economists, geographers, and spatial planners have increasingly been involved in a critical examination of many such approaches and instruments and the results achieved, the failures, and the effectiveness of actions undertaken in relation to the objectives pursued, etc. This has clearly stimulated a significant development in regional policy studies, particularly in regional science.

The topic of regional policy presents important aspects worthy of study. Some of these have been treated directly or indirectly in other sections of this Handbook. The objective of the present section on Regional Policy is to provide new reflections on key questions in regional development, such as the justification for and focus of regional policy, while also including an analysis of experiences of policies applied in specific cases. Below is a short summary of the content of the chapters included in this section that consists of seven chapters.

The chapter by Carlos Azzoni and Eduardo Haddad offers a systematic set of ideas on the need of regional policies, their justification, and their design as well as possible methods for assessment. They highlight that any regional policy has

sectoral and national consequences, while they also address the question whether public authorities should engage in explicit (place-based) regional policies or, rather, in (people-based) sectoral or social policies. Next, in their chapter, Gilles Duranton and Anthony Venables revisit the genesis of regional policies. They highlight that many development policies, such as infrastructure and local economic development schemes, are place-based and establish a rationale for effective policies and a framework for analyzing such effects by assessing their social value.

Clearly, a solid analysis of regional policies cannot be conducted without considering a differentiation into relevant spatial levels of intervention. In this context, José-Enrique Garcilazo and Joaquim Oliveira Martins point out that the idea of policies aimed at territories characterized by political-administrative borders should address a division into three levels: large metropolitan areas, rural/intermediate regions close to cities, and remote rural regions. They point at the dominance of large metropolitan areas, particularly supported by the emerging strong tertiarization, and they argue that a balance in spatial-economic space has to be found, linked also to the place-based principle.

Subsequent chapters analyze the features of regional policies related to specific cases. Juan Cuadrado-Roura tracks the development of European Regional Policy (ERP), currently integrated into the broader concept of Cohesion Policy. The main contribution of his chapter is an assessment of the ERP's positive outcomes, as well as its defects and failures, which provide valuable policy lessons. Clearly, within Europe, Eastern and Central countries present markedly different characteristics, partly due to historical circumstances and political developments in the post-WWII period. Grzegorz Gorzelak analyzes the territorial policies applied in these countries and focuses on the contradictions between sectoral and regional policies. He assesses the changes from their integration in the EU and the benefits of the ERP.

One of the instruments used in several countries in Asia, Europe and Latin-America has been the creation of "Special Economic Zones" (SEZs). In his chapter, Cristopher Hartwell reviews the key features of these zones, which have notable mutual differences, despite their common aims to create artificial, well-delimited areas with advantages and benefits that make them more attractive to investment and to generate employment. The author ponders some key questions, including whether SEZs are a substitute for organically generated institutions of growth, including networks/clusters and agglomerations. Finally, rural areas deserve special attention. In a synthetic chapter, André Torre and Frédéric Wallet provide a systematic inventory of the various instruments used for so-called "rural development policies," underscoring the diversity of instruments and the multiplicity of policy objectives. They observe clearly a move from a top-down approach towards a decentralized design process in regional policy for rural areas.

New Economic Geography, Evolutionary Economic Geography, and Regional Dynamics

Over the past years several new strands of thinking in the field of geography – and the spatial sciences, in general – have exerted a fundamental impact on the theory,

methodology, application, and policy analysis in regional science and have also entered "mainstream" regional science. There is clearly not a single or unambiguous paradigm that has become a dominant approach to new modes of regional science thinking. On the contrary, a methodological pluriformity has emerged, as is witnessed by spatial complexity analysis, models of self-organizing systems, spatial resilience analysis, or models of adaptive behavior and control. All such – often dynamic – approaches have gradually acquired a solid position in the modern regional science literature and, therefore, deserve a position in an up-to-date *Handbook of Regional Science*. The rather long title of the present section, namely, New Economic Geography, Evolutionary Economic Geography, and Regional Dynamics, testifies the broad coverage of new approaches that have entered the regional science domain in recent decades. This section made up by thirteen chapters mirrors the heterogeneity in new regional science developments, in tandem with novel approaches elsewhere.

The first chapter, written by Philip McCann, is devoted to various schools of thought on economic geography, in particular the new economic geography, evolutionary geography, and urban science. It reviews some major thematic anchor points for the development of urban and regional research, including the role of institutions for spatial development. Next, Carl Gaigné and Jacques-Francois Thisse revisit the new economic geography from the perspective of a unifying framework, based on spatial locational decisions of firms and households at both macro- and micro-spatial levels, while accounting for urban morphology, quality of life, social and skill composition, and spatial sectoral specialization. Another contribution to a thorough reflection on the new economic geography is provided by Steven Brakman, Harry Garretsen, and Charles van Marrewijk, who interpret the evolution of the new economic geography mainly from developments in international trade theory. They offer a critical account of the empirical testability of new economic geography models, a situation which also hampers their use in regional and urban policy.

Another new perspective, in relation to relational and evolutionary economic geography, is provided by Harald Bathelt and Pengfei Li. The authors investigate how these two new approaches can complement each other so as to obtain meaningful applications in economic geography. Particular attention is paid to cluster dynamics and relational-evolutionary approaches, leading to a tripolar framework of context, network, and action. In a similar vein, Ron Martin addresses path dependence in a spatial economic and evolutionary perspective. The author proposes a novel developmental-evolutionary model of path dependence including lock-in cases in a dynamic space-economy.

New geographic perspectives regard agglomeration advantages as a fundamental principle. Gilles Duranton offers in this context a critical review of agglomerations and job dynamics, against the background of the functionality of cities and the dynamic interactions between cities, jobs, and firms. Particular attention is given to the position of cities in developing countries. The subsequent chapter, by Riccardo Crescenzi, investigates the connection between economic geography theory and technological dynamics. His chapter explains the relationship between specialization

and diversification patterns, institutional-relational factors, and proximity on the one hand and territorial innovation profiles on the other hand.

New and dynamic geographical perspectives prompt also new views on barriers to policy. In this context, Henry Overman addresses in particular data availability, limitations of spatial analysis, and spatial policy evaluation. Various new viewpoints on location analytics in the new geography are next highlighted by Alan Murray. In addition to issues like congestion, dispersion, concentration, market size, and production scale, geographic distance frictions remain a fundamental issue in the new economic geography. Spatial optimization, facility location and allocation, market areas, and spatial routing continue to be crucial components in spatial analysis, despite emerging uncertainty in space dynamics and the rise of big data issues.

The next portion of this section addresses in particular spatial dynamics and flow analysis. First, Martin Andersson and Johan Larsson focus the attention on spatial industrial dynamics in relation to entrepreneurship. Next to new firm formation, the authors argue that "high impact" entrepreneurship deserves more interest, especially from the perspective of spatial spillovers. It is also stressed that entrepreneurship is key in understanding spatial path dependence and lock-in situations. In a subsequent chapter, Bruce Newbold studies another spatial-dynamic phenomenon in the new geography, namely, migration. He shows that the study of inter-regional migration from the exclusive economic perspective of individual responses to utility-maximization by potential migrants hampers the validity of the new economic geography for migration analysis. Clearly, another field of study in the new geography concerns environmental and climate conditions in a local-global society.

In their chapter, Sandy Dall'erba and Zhenhua Chen address inter alia prominent environmental and climate impacts on agriculture and transportation. They propose to adopt a systemic, multi-hazard approach in climate impact assessment, which may also open the way to spatial dependency analysis and adaptation and mitigation strategies. Finally, the relationship between social capital and creativity is addressed by Charlie Karlsson and Hans Westlund, using the new economic geography as a foundation. After a critical review the authors propose a synthesis approach, in which an interactive knowledge producing sector is modeled in the framework of a multi-region system. In this way, a new perspective regarding social capital is offered on cumulative causation, regional disparities, and industrial specialization in a spatial knowledge and network economy.

Environmental and Natural Resources

Environmental and natural resources have been seen as major drivers of regional development since the early history of regional science. Its importance has not changed over the past decades, partly due to the awareness of the necessity of these resources for human survival and partly due to new emerging issues such as ecological sustainability, spatial resilience, or climate change. Space is a key dimension of the physical, ecological, and human processes that affect environmental quality and the health of natural resource stocks. Therefore, environmental and

natural resource economics has long wrestled with spatial elements of human behavior, biophysical systems, and policy design. The treatment of space by environmental economists has evolved in important ways over time, moving from simple distance measures to more complex models of spatial processes.

The opening chapter of the section on Environmental and Natural Resources, written by Amy Ando and Kathy Baylis, presents knowledge developed in several areas of research in spatial environmental and natural resource economics. First, the chapter discusses the role played by spatial heterogeneity in designing optimal land conservation policies and efficient incentive policies to control pollution. Second, it describes the role space plays in nonmarket valuation techniques, especially the hedonic and travel cost approaches that inherently use space as a means to identify values of nonmarket goods. Third, it explains a set of experimental empirical methods using spatial shocks to estimate the effects of pollution or environmental policy on a wide range of outcomes, such as human health, employment, firm location decisions, and deforestation. Finally, the chapter directs focus on spatial models of human behavior including locational sorting and the interaction of multiple agents in a land use/conservation setting.

The importance of uncertainty considerations in the design of environmental policies has long been recognized, and the literature dealing with this topic is vast. Uncertainty is present in nearly all aspects of natural resource and environmental management. The chapter, written by Yacov Tsur and Amon Zemel, reviews the various sources of uncertainty, the methodologies developed to account for them, and the implications for policy-makers. Natural resources and environmental issues frequently involve use of more than one agent. When this is the case, strategic considerations either over time, space, or under uncertainty arise and these considerations can be usefully studied with game-theoretic models, as illustrated in the chapter by Hassan Benchekroun and Ngo van Long. This chapter covers applications of game theory in environmental and resource economics with a particular emphasis on non-cooperative transboundary pollution and resource games.

In the subsequent chapter, John Loomis, Christopher Huber, and Leslie Richardson shift attention to valuing environmental and natural resources. Where market prices do not exist, economists can infer willingness-to-pay using revealed preferences methods or using a "simulated market" asking respondents to state their willingness to pay. These revealed preference and stated preference methods are based on the same utility-maximizing process economists use to estimate the demand for market goods. The next chapter, written by Philip Graves, describes the hedonic method as a means of valuing environmental quality improvements, with a focus on air pollution. The author stresses that this method requires very good, ideally perfect perceptions of environmental benefits along with good/perfect knowledge of how environmental quality varies over space. This assumption, however, appears to be highly suspect in many settings. Next, Gara Villalba Méndez and Laura Talens Peiró review materials balance models that rely on physical laws to provide information useful not only to value natural systems but also to determine the amount and the composition of waste produced by human induced processes.

The problem of global warming or climate change is the most serious environmental problem confronting humans and societies today. This problem has international, national, and regional dimensions, and the presence of fundamental uncertainty about future benefits and costs makes it difficult to design and implement policy today. The chapter, written by Daria Karetnikov and Matthias Ruth discusses regional impacts expected from climate change and reviews differences in risk and mitigation capacities across major regions. Then, Emily Talen presents a discussion of what is meant by sustainability first from the regional and then from the city level. Both scales have a long history in the planning domain, but the notion of a sustainable city is key to both realms and the main focus of her chapter. While there is widespread agreement on broad parameters and principles about urban and regional sustainability, there are entrenched debates over implementation. The impact of human population growth on the environment represents another major challenge in our time. The final chapter in this section, written by Jill Findeis and Shadayen Pervez, reviews the relevant literature on the interrelationships among population growth, economic development, and environmental impacts at the micro-, meso-, and macro-scales.

Spatial Analysis and Geocomputation

The history of spatial analysis is noteworthy for its genesis in a number of different fields emerging nearly simultaneously. Much of the development has been based on the types of data characteristics of the particular research being done in the respective fields. Geologists and climatologists, for example, tend to analyze continuous data. Economists and political scientists pay particular attention to time series data. Regional scientists, geographers, and sociologists are especially interested in point and area data. Transportation planners favor network data, while many environmentalists use remotely sensed spatial data. Geocomputation is often used as an umbrella term for approaches to the analysis of problems that specifically have a geographic focus, but – in contrast to conventional spatial analysis studies – typically rely on massive and high-dimensional data sets that require modern computational techniques as well as technical infrastructures with performance that scales well with massive data.

The section on Spatial Analysis and Geocomputation contains eleven chapters. The first chapter, written by Michael Goodchild and Paul Longley, reflects on the key characteristics of geographic information, the problems posed by large data volumes, the relevance of geographic scale, the remit of geographic simulation, and the key achievements of geographic information science. Next, Michael de Smith reviews techniques that are applied in geocomputation and discusses some of the key underlying principles and issues. Chris Brunsdon shifts attention to Bayesian spatial analysis, by outlining the key ideas, emphasizing the role of Markov Chain Monte Carlo approaches, and discussing techniques for three key types of spatial data: point data, point-based measurement data, and area data.

Geovisualization and interaction technologies may give users a gateway into their data. In the next chapter Ross Maciejewski presents geovisualization as means for exploring spatial data with the aim to create new knowledge and provide new scientific insights. Geographical visualization is not purely about generating maps of data. It is also about generating tools and techniques for visually representing spatial and spatiotemporal data, and facilitating the exploration of this data for hypothesis generation and exploration. Closely related to this, Linda See addresses the topic of web-based tools for Exploratory Spatial Data Analysis (ESDA), a collection of tools and approaches for the statistical analysis of spatial and spatio-temporal data. The starting point of her chapter is a brief introduction to ESDA, followed by a historical overview of software tools that emerged from the mid-1990s onwards as the Internet was still evolving. The early web-based developments in ESDA are presented followed by the events that led to web-based mapping and web GIS. The author continues to describe the web-based tools that are currently available and reflects on future developments in data rich environments.

The field of spatiotemporal data mining emerged out of a need to create effective and efficient techniques in order to turn enormous amounts of data into meaningful information and knowledge. Tao Cheng and associates offer a state-of-the-art review of spatiotemporal data mining research with emphasis on three key areas: prediction, clustering/classification, and visualization. The Modifiable Areal Unit Problem (MAUP) is a serious analytical issue for analysts using spatial data, discussed by David Manley in the next chapter. The chapter provides an overview of the MAUP along with the two related aspects of the problem, the scale effect and the zonation effect, and details, moreover, the role of spatial autocorrelation in understanding the processes in the data that lead to statistical non-stationarity.

The next chapter, written by Clio Andris and David O'Sullivan, shifts attention to spatial network analysis. Spatial networks organize and structure human social, economic, and cultural systems. The analysis of network structure is rooted in mathematical graph theory, and spatial networks are a special type of graphs that are embedded on the Earth's surface. Thus, their analysis necessitates the fusion of graph theoretical and geographical concepts. Key concepts and definitions from graph theory are reviewed and used to develop a variety of graph structural measures. Particular emphasis is placed on three major concepts: high-level network structural features of centrality, cohesive subgraphs, and structural equivalence. With these metrics in mind, the authors describe considerations for their use within a spatial context. The chapter by Keith Clarke then moves on to cellular automata and agent-based models, two modeling approaches for spatial modeling that have enjoyed increasing popularity in recent years. For each type of model, the origins are explored, as are the key contributions and applications of the models and the software used.

The next chapter, written by Alison Heppenstall and Dianna Smith, provides a brief overview of spatial microsimulation, with a focus on the main algorithms that are typically employed. The final chapter in the section is on fuzzy modeling in spatial analysis by Yee Leung. Fuzzy set theory based on the notion of fuzzy sets provides a strict mathematical framework for fuzzy modeling in which imprecision

in the sense of vagueness can be precisely and rigorously analyzed. The author first outlines the basic definitions and operations of the theory and then moves to applications, with special reference to spatial classification and grouping as well as spatial optimization in a fuzzy environment.

Spatial Statistics

The roots of spatial statistics date back to Pearson and Fisher, but their modern manifestation is mainly due to Whittle, Moran, and Geary. From Cliff and Ord's books and papers of the late 1960s to the early 1980s comes the basic outline of what constitutes the key features of spatial statistics. The section on Spatial Statistics contains eleven chapters that mirror the diversity of statistical approaches, methods, and techniques used in regional science.

The first chapter, written by Peter Atkinson and Christopher Lloyd, provides an introduction to a set of geostatistical principles and techniques which can be applied to characterize or model spatial variation and use such sample models to optimize the mapping, simulation, and sampling of spatial properties. This chapter is focusing on the kinds of applications which may be of interest to regional scientists. When surveying a phenomenon characterized by spatial variation, it is necessary to find optimal sample locations in the study area. This problem is referred to spatial sampling and treated in the next chapter by Eric Delmelle. The chapter reviews fundamentals of spatial sampling and design. Their characteristics and merits under different situations are discussed, while a numerical example illustrates a modeling strategy to use covariate information in guiding the location of new samples.

The chapter, written by Jürgen Symanzik, on exploratory spatial data analysis, an extension of exploratory data analysis geared to dealing with the spatial aspects of data, provides an overview of methods, techniques, and software solutions. The next chapter, by Daniel Griffith and Yongwan Chun, directs attention to (eigenvector) spatial filtering, a spatial statistical methodology that enables spatial autocorrelation effects to be accounted for while preserving conventional statistical model specifications.

David Wheeler addresses Geographically Weighted Regression (GWR) that allows relationships in a regression model to vary over space. In contrast to traditional linear regression models, which have constant regression coefficients over space, regression coefficients are estimated locally at spatially referenced data points. The motivation for the introduction of GWR is the idea that a set of constant regression coefficients cannot adequately capture spatially varying relationships between covariates and an outcome variable. The author emphasizes that geographically weighted regression is a relatively simple and effective tool for spatial interpolation of an outcome variable, but a more problematic tool for inferring spatial processes in regression coefficients. The more complex approach of Bayesian spatially varying coefficient models has been demonstrated to better capture spatial non-stationarity in regression coefficients and is recommended as an alternative for inferential analysis.

The next chapter, written by Peter Congdon, offers a comprehensive account of Bayesian modeling of spatial data. Bayesian inference and applications have been a central element in recent developments in spatial statistics. This influence has rested on advances in computer-based estimations via Markov Chain Monte Carlo (MCMC) including recent developments to random walk MCMC approaches. Bayesian ideas have been particularly influential in spatial regression modeling, disease mapping, and analysis of point referenced spatial data. Starting with models for univariate spatial data, models can be extended to multivariate outcomes or to a space-time framework. Spatial models vary in how spatial dependence or correlation is represented, including neighborhood dependence in Markov field models, explicit spatial decay in point referenced spatial process models, and spatial lags or residual correlation effects in spatial autoregressive models. Bayesian implementation has been facilitated by a much improved computational environment centered on the R package.

In a subsequent chapter, Virgilio Gómez-Rubio, Roger Bivand, and Håvard Rue present integrated nested Laplace approximations as an alternative approach for fitting Bayesian hierarchical models in which the latent effects are a Gaussian Markov random field. Next, Robert Haining and Guangquan Li compare Bayesian and frequentist or likelihood-based approaches to inference and argue that Bayesian inference is more appropriate to an observational science, while Alan Gelfand presents multivariate spatial process models that focus on spatially referenced multivariate data in the form of vectors observed at a finite set of spatial locations. Such models need to capture both dependence among the components of the vectors as well as spatial dependence across the locations of the vectors. The chapter develops classes of models that provide the desired dependence. An example, using soil nutrient data from Costa Rica, is presented for illustration purposes.

The chapter by Sergio Rey shifts attention to space-time data analysis. Particular emphasis is devoted to exploratory methods for space-time data focusing on the evolution of spatial patterns as well as on the identification of temporary dynamics that cluster in space. The final chapter in the section, written by Lance Waller, reviews methods to detect, evaluate, and interpret spatial space-time patterns within disease surveillance data.

Spatial Econometrics

Since Jean Paelinck and Leo Klaassen's description of the field in 1979 and Luc Anselin's influential book Spatial Econometrics, published in 1988, the field of spatial econometrics has blossomed to address the fact that regional data often exhibits dependence between observed outcomes of nearby regions as well as characteristics of regions used as explanatory variables in regional science relationships. Conventional regression models and associated estimation methods assume independence between observations, so spatial econometrics focuses on modifications needed for estimation and interpretation of regression models involving dependence in outcomes located at points in space.

The section on Spatial Econometrics is made up by eleven chapters. Separate chapters are devoted to alternative estimation approaches including a chapter by Kelley Pace on maximum likelihood estimation, another one by Jeffrey Mills and Olivier Parent on Bayesian MCMC estimation, and one by Ingmar Prucha on instrumental variables/method of moments estimation. The section contains chapters by Julie LeGallo on cross-section regression models and by Paul Elhorst on spatial panel models and common factors. In his chapter, Elhorst provides a survey of the literature on spatial panel data models and a motivation for use of common factors. Both static and dynamic as well as dynamic models with common factors are discussed. Next, a chapter, written by Xiaokun Wang, is focused on modeling situations involving binary or censored data outcomes, while another one, written by Christine Thomas-Agnan and James LeSage, considers modeling origin-destination flows.

The non-linear nature of spatial regression models requires special attention to interpretation of estimates from these models, a topic covered in the chapter on interpreting spatial econometric models by James LeSage and Kelley Pace. Next, a chapter on heterogenous coefficient spatial regression panel models, by Yao-Yu Chih and James LeSage, discusses use of the time dimension of the data in the presence of sample data covering long time spans to estimate coefficients for each region in a space-time panel setting. Since regional science theories often focus on interactions between regions or consumers/firms located in space, region-specific or consumer/firm-specific estimates open up new ways to more rigorously test our theoretical models as well as challenges for interpretation.

Another chapter focusing on endogeneity in spatial models, by Julie LeGallo and Bernard Fingleton, discusses issues that arise when explanatory variables exhibit simultaneity in models for spatially dependent data generating processes. There is a great deal of confusion regarding simultaneous interaction between regional/spatial outcomes in the dependent variable and endogenously determined explanatory variables, and this chapter clarifies issues and provides various suggestions and approaches needed to address this type of applied modeling situation.

A final chapter, entitled "Using Convex Combinations of Spatial Weights in Spatial Autoregressive Models," by Nicolas Debarsy and James LeSage, shows how spatial interaction can be broadened to include other types of interaction between regional outcomes captured in the dependent variable vector. There has been a great deal of dissatisfaction with exclusive use of spatial weight matrices as the basis for modeling interaction between regions, which ignores other types of possible interaction between regions, firms, or consumers located in space. For example, regions could interact based on economic or cultural connections, historical patterns of migration or trade flows, formal and informal supply chain or financial networks, etc. The authors show how to estimate models that combine multiple connectivity matrices by assigning scalar weights to form a convex combination of each type of connectivity. Estimates for the scalar weights that sum up to unity allow inferences regarding the relative importance of the various types of connectivity between regions.

A Content Cloud Analysis of the Handbook

A content cloud (also known as word cloud, text cloud, or tag cloud) is the result generated by an image-based tool that aims to present the most prominent words or terms in a text. The tool uses a web-based algorithm to extract the most essential or pertinent expressions in textual data and summarizes the essence of a text in visualized format. Usually, this presentation uses different font sizes and different colors so as to emphasize the differences between prominent text expressions, in terms of frequency and importance in the text. The content cloud generator usually decomposes a written text into component identifiers and then counts their frequency of appearance in the text concerned. This leads then to a hierarchical visual presentation of the degree of prominence of words or terms in textual data. Content cloud analysis has gained in the past decade quite some popularity as an electronic identification tool of core messages or trend expressions in a text, so that its essence can easily be grasped by the reader.

This multi-volume reference work covers a wide variety of concepts, methods, and research tools. Despite their diversity and variability in use, there is a wealth of concepts and terms that show up frequently in the various distinct chapters in this Handbook. The terms with the highest frequency of appearance through the entire reference work are summarized in the form of a content cloud generated by using a

Fig. 1 Content cloud of relevant terms in the *Handbook of Regional Science*

digital search algorithm. The multicolor visualization – indicating commonalities and frequencies of terms through color intensities and font sizes – offers a balanced representation of the main substance issues covered by this reference work.

Figure 1 presents the content cloud results from an unsupervised visualization exercise. This means that a priori no words or terms are imposed on the algorithm; it selects by way of auto-organization the most important and frequently occurring core words, as they appear in each of the 110 chapters, of course, after elimination of less relevant terms in this context, such as region, science, or space. It is easily seen that the figure provides an interesting hierarchy of concepts or words such as data, knowledge, economic, growth, development, social, firms, labor, market, capital, network, local, time, location, and so forth. It is noteworthy that many of these higher-order terms are also often appearing in modern regional science research and witness concepts like knowledge economy, data analytics and spatial econometrics, economic growth, regional development, social capital, innovation networks, knowledge spillovers, labor market, and the like. The findings from our content cloud analysis appear to match surprisingly well with contemporaneous regional science research issues, seen from a bird's eye view.

Closing Remarks

Regional science is a fascinating scientific domain characterized by a great vitality and innovativeness. Its multidisciplinary orientation and the active involvement of thousands of scholars with different backgrounds lead to a permanent evolution and creative adaptation to new spatial issues. Regional science is "work in progress," as is testified by this second edition of the *Handbook of Regional Science* which shows significant differences compared to its first edition published in 2014.

Let us conclude by hoping that the readers find the new, rewritten, and updated chapters informative and instructive. If readers believe that there are important omissions in the reference work or that the reference work could have benefited from a different structure, we do hope that they will share their thoughts on these and related matters with us. In particular we welcome suggestions and proposals for particular research topics that arguably have been neglected.

We would like to thank the members of the Springer Reference Editorial Team, in particular Barbara Fess, Esther Niederhammer, and Barbara Wolf, for their support initiating the project as well as in providing invaluable guidance throughout the process. And of course, we are deeply grateful to the Section Editors and the authors for their work. Without their valuable assistance no second edition would exist.

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